Plain of Plenty

Farming Practices, Food Production, and the Agricultural Potential of the Late Bronze Age (1600 – 1200 BCE) Argive Plain, Greece

Riia Elina Timonen

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Finally, I must thank all the cats I have had the pleasure of meeting, petting, and loving over the years - you have brought joy to my days, time and again.

Nederlandse samenvatting

De Argolis in het noordoosten van Peloponnesos, Griekenland, was een van de kerngebieden van de Myceense cultuur die de laatste eeuwen van de Bronstijd (*c.* 1600-1200 v. Chr.) in Griekenland omvat. Het gebied staat bekend om zijn opmerkelijke nederzettingsconcentratie, waarbij verschillende centrale plaatsen op korte afstand van elkaar lagen op een relatief kleine vlakte. Hoewel de centrale nederzettingen op de Argolis grondig zijn onderzocht, was niet goed bekend hoe het gebied in staat was deze centra en hun bewoners van voedsel te voorzien. Bovendien is de aard van de landbouw in het gebied nooit goed onderzocht.

In deze studie wordt onderzocht welke landbouwstrategieën de Myceense bevolking gebruikte om in hun levensonderhoud te voorzien, en hoe de landbow verknoopt was met de samenleving van de Argolis. In dit onderzoek wordt onderzocht hoe groot de bevolking kon zijn opbasis van het voedsel dat in dit gebied werd geproduceerd. Het onderzoek is onderdeel van het bredere SETinSTONE project. Dit project onderzoekt of de arbeidskosten van monumentale bouwprojecten die op het Myceense vasteland werden uitgevoerd, zoals de bouw van vestingmuren en uitgebreide graven, een uitputting van de werknemers- en milieubronnen veroorzaakte, wat mogelijk heeft bijgedragen aan de sociaal-politieke crisis - de ineenstorting van de Bronstijd - in ca. 1200 v. Chr.

Om de voedselproductie op de Argolis in de Late Bronstijd te bestuderen, is een model gemaakt van het lokale landbouwpotentieel. Het model bevat de reconstructie van de Myceense landbouwpraktijken in relatie tot de Myceense politieke organisatie: een complex, hiërarchisch systeem onder toezicht van paleisbesturen. De modellering beslaat uit een reeks berekeningen voor een schatting van het soort en de hoeveelheid voedsel die door de plaatselijke bevolking werd geconsumeerd, hun energieverbruik en de hoeveelheid land die nodig was voor het cultiveren van gewassen en het houden van dieren. De voor het model benodigde gegevens zijn gebaseerd gepubliceerde archeologische, geografische, en etnografische studies. Deze aanpak van het combineren van gegevens uit verschillende bronnen in een samenhangende analyse is essentieel voor het onderzoek van boerengemeenschappen uit de Bronstijd, waarvan de materiële resten schaars zijn.

De resultaten van dit proefschrift tonen aan dat de landbouw van de Myceense boeren duurzaam was en dat zij goed bestand waren tegen bedreigingen zoals droogte en plagen. De Argolis vlakte in de Late Bronstijd was ideaal voor landbouwgemeenschappen die streefden naar duurzaamheid zonder hoge productiviteit. Dit proefschrift bespreekt de bestaande schattingen van de ruimte die nodig is om één persoon in het Neolithicum en de Bronstijd van de Egeïsche Zee van voedsel te voorzien. Eerdere schattingen van deze 'bestaansruimte' hebben geen rekening gehouden met de ruimtelijke behoeften en arbeidsbehoeften van de veestapel. Zuivel- en vleesproductie kunnen echter een dramatische invloed hebben op het landbouwpotentieel.

Daarom draagt dit onderzoek bij aan een beter begrip van de landbouwpraktijken en het bestaanssysteem van de Myceense samenlevingen in de eeuwen vóór de ineenstorting van de Bronstijd. Het illustreert hoe de vorming van de Myceense elites een diepgaande invloed kan hebben gehad op de plaatselijke landbouwgemeenschappen en via hen op de gehele samenleving.

Curriculum vitae

Riia Timonen was born in Mikkeli, Finland in 1985. She attended upper secondary school at Mikkelin Yhteiskoulun lukio between 2001 and 2003. In 2005 she began her Bachelor's studies in Art and Culture Studies at the University of Jyväskylä, Finland, specializing in Classical Greek and Roman art, museology, and heritage studies. During her BA and MA studies, Riia participated in archaeological 3D-recording projects in Greece, organized by the Finnish Institute at Athens. She also completed a semester in Milan, Italy, where she studied Art History and Egyptology. She completed her MA studies in Art History at the University of Jyväskylä in 2012. Her MA thesis focused on the depictions of mythical bear in Finnish prehistoric and early historical art. After graduation, Riia participated in several archaeological excavation and geophysical survey projects in mainland Greece, Crete and Sicily, organized by the Finnish Institute at Athens, University of Helsinki, and the Institute for Mediterranean Studies (IMS-FORTH). In 2016, she was selected as a PhD Candidate in the SETinSTONE project at Leiden University, Faculty of Archaeology, headed by Prof.dr. Ann Brysbaert who was her initial supervisor. She completed her PhD under the supervision of Prof.dr. Bleda Düring and Dr. Amanda Henry. Riia investigated the food production potential of the Mycenaean Argive Plain, northeastern Peloponnese, Greece. Her dissertation, on which this book is based, presented a systematic study of the local agricultural practices and landscape resources, resulting in the estimation of the area's agricultural potential. During her PhD studies, Riia participated in excavation projects in central mainland Greece, took on various teaching and administrative tasks at the Faculty of Archaeology, and enjoyed being an active member of the PhD community. Riia is interested in studying rural lifeways in the Bronze Age Aegean, with a special focus on dietary and cultivation practices and tracing past agricultural activities in modern landscapes.

Chapter 1

Introduction

This monograph investigates the agricultural economy of the Mycenaean society of the Late Bronze Age (*c.* 1600-1200 BCE) Argive Plain, located in the north-eastern Peloponnese, Greece. The study consists of three main topics. Firstly, it offers a reconstruction of the local agricultural practices which formed the main subsistence strategy of the local population. Secondly, it performs an evaluation of the potential of the environment for food production through crop and animal husbandry. Thirdly, on the basis of a combination of environment and cultural aspects, it establishes an estimation of the population that could be sustainably fed. These three aspects will give new insights to the Late Bronze Age Argive Plain society, and the relationship it had with the environment.

The Late Bronze Age in southern mainland Greece and the Aegean islands has traditionally been referred to as the Mycenaean period (Maran and Wright 2020; Shelton 2012; Shermeldine *et al.* 2008). The Mycenaean period is known for its monumental sites, such as fortified settlements with walls of 'Cyclopean' masonry, burial architecture consisting of grave circles and beehive-shaped tholos tombs, and skilfully crafted gold and bronze items recovered in burial contexts (e.g. Crowley 2010; Hitchcock 2012; Laffineur 2012). The accomplishments of the Mycenaeans also include an early writing system called the Linear B script (e.g. Killen 1984; Nakassis 2013; Palaima 2012). These assemblages have triggered a long tradition of archaeological research dedicated to the deciphering and interpretation of the Linear B texts (from their first published translations by Bennett Jr. in 1953 to the most recent works by Judson 2020; Salgarella 2020; Zurbach 2020, and others), and understanding Mycenaean societal and political organization (e.g., the collective papers of Redistribution in the Aegean Bronze Age 2011, published in American Journal of Archaeology).

The Late Bronze Age Argive Plain has been associated with Homer's epic works, and considered as the place of origin for heroes such as king Atreus and his son Agamemnon (see Deger-Jalkotzy and Lemos [eds.] 2006; Gill 2008: 67). Inspired by epic tales, and the visible remains of the Bronze Age fortified settlements, the area became a popular destination for aristocratic travellers in the 18th and 19th centuries. Traveller's stories stimulated academic research interest in the area (e.g. Kotsonas 2020; Morris 2000). The first archaeological excavations were conducted in the Argive Plain as early as the latter half of the 19th century (Kotsonas 2020). Famous scholars such as Schliemann and Tsountas were first to work at the Late Bronze Age sites of Mycenae and Tiryns. In the early 20th century, their work was continued by scholars such as Wace and Pendlebury, representing the newly established British School at Athens (Muskett 2014: 41-48; Webster 2008: 20). Today, many foreign and local archaeological schools, universities, and cohorts continue to excavate at Argive Plain sites, their work representing the continuum of more than a century of scholarly interest in the area.

From the beginning, the work at the Late Bronze Age sites of the Argive Plain focused on recovering the riches that could connect the sites with the ancient legends of kings, gods, and adventurers. Over time, this interest developed into a focus on the political organization of the plain and its neighbouring regions. It is only in recent years that the focus of Mycenaean studies in general has shifted from the palatial centres and their elites towards the broader society and local political systems (Feuer 2011: 68; Lupack 1999; 2011; Nakassis 2013; 2015; Sjöberg 2004; Wright 2004). How Mycenaeans related with their environment and sustained themselves are topics much less investigated. The deciphered Linear B texts, and the archaeobotanical and zooarchaeological data collected from the Late Bronze Age sites have shed limited light on local agriculture. However, little is known about how agriculture operated. Furthermore, quality estimates of the sustainability of the local agricultural production are lacking. Research tradition has mostly focused on palatial activities and the elites, and farming systems remain poorly understood.

This study contributes to the study of the Late Bronze Age rural communities of mainland Greece by investigating how they practiced agriculture. In this study, the term rural refers mainly to the people and areas located outside more densely inhabited settlements with administrative functions, but without directly contrasting it with urban, as urbanization in the Aegean context is seen to have taken place later, from the Early Iron Age onwards, perhaps beginning as early as the post-Mycenaean period (de Polignac 2005; Haggis 2015; Lemos *et al.* 2009). Rural further refers to people who resided in communities whose main livelihood came from agriculture, and to areas where agricultural activities took place. The case study area, the Argive Plain, is a first-rate example of a region where previous research has almost exclusively focused on the activities of the local Mycenaean elite. Thus, the plain is recognized by many as one of the Mycenaean core areas (Bennet 2011: 157; Kilian 1988), and it is home to some of the most imposing Late Bronze Age settlements: Mycenae, Tiryns, and Midea. At the end of the Late Bronze Age, during the Mycenaean period, the Argive Plain was characterized by a unique settlement pattern, with several large settlements located within a few kilometres from each other. A few of these settlements, Mycenae, Tiryns and Midea, were fortified with defence walls, some of which were assembled from massive, unworked stone blocks so astonishing in size and appearance that they became commonly known as the Cyclopean style. Due to their walled character, these settlements are sometimes referred to as citadels, which points to their likely use as strongholds, places of potential refuge for the population living in their surroundings (Iakovidis 1983). In addition, they are often defined as Mycenaean palaces or palatial centres, inhabited by the local elites, administrative bodies, and specialist workers (see §2.2.1 and 3.4 in this volume).

The Argive Plain also included other large Late Bronze Age settlements such as Argos, Nafplion, and Argive Heraion, which were not walled and whose function and status has remained undefined due to the absence of evidence. The question of the relationship between the most notable settlements of the region has never quite been solved. Perhaps because of this, the land use of the plain has not been discussed in great detail, with the notable exception of John Bintliff, who conducted a detailed study of the area and its environment for his PhD dissertation (Bintliff 1977a). Archaeological investigations in the area, such as the Mycenaean Survey (Iakovidis *et al.* 2003), the Western Argolid Regional Project [1] (e.g. Caraher *et al.* 2017) and the geological studies of Zangger (e.g. 1993, 1994) have continued apace since Bintliff's dissertation, creating new data of the local environment. In addition, new methods such as Geographic Information Systems and remote sensing enable more careful analysis of the landscape and its changes (e.g. Bonnier *et al.* 2019; Galaty *et al.* 2014; Knitter *et al.* 2019; Pullen 2022). Such studies have created great potential for new investigations that can significantly expand the knowledge of Late Bronze Age subsistence strategies.

This study has three main aims. The first is to develop a comprehensive understanding of the agricultural practices in the Argive Plain area, specifically in the last centuries of the Late Bronze Age, in the Late Helladic III (1420/1410-1330/1315-1200/1190 BCE)[2] period, when the Mycenaean culture experienced a peak in wealth and power. The second aim is to estimate the potential of the region to sustain its populations. This analysis of the agricultural potential consists of a series of calculations of the crop productivity, environmental affordances, and food consumption. The calculations result in a number of people who could be sustained by the region and by the specific methods and knowledge that was available to produce food. The third, wider aim is to better understand the Mycenaean society as a whole and relate the agricultural practices to the social and political organization of the region. The societies in the Late Bronze Age Aegean region were in a state of transformation, from small subsistence communities towards larger state-like societies, with a more distinguished hierarchy. Most of the population consisted of non-elite members, farmers and simple workers, whose lifestyle likely resembled that of their ancestors. Therefore, Mycenaean societies cannot be understood only based on the newly established elite, even though their activities are much better recorded in the archaeological evidence. Studying the Late Bronze Age farming practices can help to place the emphasis on the non-elite. In addition, the establishment of the maximum size of the population that could be sustainable in a region enables more realistic observations of the potential of the local communities to adapt to major changes in their lives. In the Late Bronze Age, these could be sprouted for example by emerging elites and increasing social stratification, new foreign connections, and environmental changes.

Through these aims, this work touches upon a few key elements of the wider research tradition of the Bronze Age societies of the Eastern Mediterranean. Reconstructions of food production processes produce information on the environmental exploitation and resilience of the local population. These two themes, sustainability and resilience, have become increasingly important in recent archaeological research (specifically for Greece, see e.g. Lantzas 2016; Marston 2015; Timonen and Brysbaert 2021; Weiberg and Finné 2018), not least because they resonate with the pressing issues of our modern societies. In relation to the end of the Bronze Age, which is characterized by a major societal and political crisis, it is reasonable to ask whether Mycenaean communities were thriving in the given environmental conditions, cultural practices, and with the available technology, or if they were on their way to a subsistence crisis. A growing, developing

[1] Up to date, and to the best knowledge of the current author, the Western Argolid Regional Project has completed their survey in the Western fringes of the Argive Plain, but has not yet published their Bronze Age finds. Findings of other periods can be found for example in Erny and Caraher 2020, Gallimore *et al.* 2017 and Tetford *et al.* 2017 and 2018.

[2] This chronology is based on the presentation of Manning (2010: 23, Table 2.2). However, see section 2.1 of this book for further discussion about Helladic chronology. See also Friedrich *et al.* 2020, Manning 2014 and 2022, and Pearson *et al.* 2018 and 2022 for the most recent dating for the Thera eruption, which is the key determinant in the Aegean Bronze Age chronology.

population such as the Mycenaean population of the Argive Plain would ideally have reached a state of balance between its immediate needs and the available resources. By tracking down maximum population capacities through the analysis of food production, it is possible to see whether this was, in fact, the case. While the maximum capacity of the environment to sustain a population does not equal actual population numbers formulated by demographic methodologies, a comparison of these two approaches can shed light on regional sustainability, and potentially on its causality to population growth and decline (see Chapter 4 pp.50-54 for further discussion).

Moreover, by focusing specifically on the human-environment relationship, it is possible to get a better understanding of how much the resource availability was dependent on the increasing modification of the local landscape. This is particularly relevant in a context where the local economy was transforming from subsistence farming into gathering wealth through specialized agricultural production such as wool and oil. The study of the size of the population of the Late Helladic III Argive Plain can further help to examine its position in the wider Mediterranean network, which, at the time, was dominated by the prominent Near Eastern and Egyptian civilizations. Finally, determining the local population sizes helps to examine the development of Mycenaean monumental architecture. In the Argive Plain context, the end of the Late Bronze Age was a period of high activity in large-scale construction projects. Most of the massive Cyclopean fortification walls were constructed at this time. Simultaneously, large tholos and chamber tomb cemeteries were dug in hillslopes (Hitchcock 2012; Voutsaki 2012), and a road system characterized as 'Mycenaean highways' emerged on the eastern side of the plain (Brysbaert 2013; 2020; 2021; Hitchcock 2012; Janssen 2002; Lavery 1990; Voutsaki 2012). These projects required a substantial workforce and organizational skills (Brysbaert 2013). Whether these workforces and the resources used for the construction became depleted in this period, as suggested in earlier literature, is now being analyzed in great detail (Brysbaert 2020; 2021; Timonen and Brysbaert 2021). Most recently, these themes were investigated in 2016-2021 by the SETinSTONE project (ERC grant agreement no. 646667), to which this study contributes by examining the capacity of the Argive Plain to sustain its population.

One of the main research interests of the Argive Plain has been its Late Helladic III settlement pattern which, due to the aforementioned abundance of large, fortified settlements, is considered rather unique in the Late Bronze Age Aegean context (e.g. Shelmerdine 1997, 1999a). At the same time, the plain is lacking systematically collected evidence (i.e. survey data) of small rural sites which would prove the presence of agricultural communities and households (e.g. Wright 2004). This is one of the main reasons why Argive Plain agriculture or the agricultural labourers have not been examined intensively. The concept of agricultural potential can provide an alternative method to study regional subsistence strategies when there is a scarcity of settlement data (see section 4.2. in this book for more details). The process of formulating the agricultural potential examines the relation between the input and output efforts of food production. These consist, for example, of the available environmental conditions, species, and technology, and the basic subsistence needs per capita, household, and other units such as the local administrative elite. Due to a long history of research in the Argive Plain region, a vast amount of data is available from the local fortified settlements (see Chapter 3 with references). Besides rich material finds of ceramics and metals, excavations have yielded botanical, faunal, and skeletal data (see Chapter 5).

This study approaches the Argive Plain subsistence activities through a literature review of these and other published data sets. The data is divided into six groups based on geography and soils, climate, flora, fauna, material and agricultural objects (limited to storage and agricultural installations), and human remains. Through comparative, interdisciplinary analysis, it examines local agriculture as an integrated system of intensive farming and animal husbandry. These data sets are combined with published data from similar contexts in the Middle and Late Bronze Age mainland Greece. ArcGIS will be used to analyze and visualize the data obtained. Literature analysis is supplemented with observations made during site visits. More importantly, studies of recent farming communities following traditional (i.e., mostly pre-industrial, non-mechanized methods without extensive use of fertilizers) practices are used as analogies for agricultural practices in semi-arid environments. A great deal of research has been devoted to the examination of Linear B tablets found at various sites (e.g. Aranvantinos and Vasilogamvrou 2012; Nakassis 2013; Palaima 2012; Shelmerdine 2008b). However, due to their emphasis on elite activities, the information they include is only partially relevant to the topic of this monograph. Therefore, textual evidence will not be central to this study.

This monograph consists of eight chapters of which this introduction is the first. The second chapter provides an overview of the universal characteristics of the Late Bronze Age Aegean societies and the economic systems. Much of the evidence of the societal stratification, land and other ownership, and the regional and overseas flow of products derives from the Linear B records, and will be summarized. Third chapter introduces the reader to the Argive Plain in the LH III period, right before the end of the Bronze Age. The focus of the chapter is on determining the local settlement pattern, based on the scattered data available. The chapter also provides an overview of the recent excavations and surveys in the Argive Plain sites and its surroundings. Fourth discusses the methodological background for the reconstructions of early agricultural systems and introduces the analysis of the agricultural potential. The data collected for the analysis are presented in the fifth chapter, which is divided into six subchapters, each presenting one type of data. The reconstruction of the Late Bronze Age agricultural practices and the analysis of the agricultural potential of the Argive Plain are presented in the sixth chapter. Finally, the seventh chapter discusses the results in relation to the population estimates presented for the area and examines the yet unanswered questions concerning the subsistence strategies and land use organization of the Argive Plain. The conclusions are presented in the final chapter.

Chapter 2

Mycenaean society and economy

The ‘Mycenaean period’ covers a time of *c.* 400 years at the end of the Bronze Age (*c.* 1600-1200 BCE).[1] It is marked by the emergence of complex palatial hierarchy and administration which used a specific writing system, Linear B, to record its activities. Even though the societies examined in this book are mainly located in the southern mainland Greece and the Aegean, archaeological finds from Cyprus, Egypt, Levant, Hittite empire, southern Italy, Sicily and Andalusia bear witness to the extent of the Mycenaean trade exchange and influence. Late Helladic (henceforth LH) and Late Bronze Age (henceforth LBA) are the chronological terms often used side by side to describe the societies inhabiting the Aegean between *c.* 1600 and 1200 BCE. Alongside them, the term Mycenaean is still widely used to specifically indicate the southern mainland populations from other LBA Aegean societies, for example (the Minoan) Crete, the Cyclades, and northern Greece (e.g. Manning 2012; Shelmerdine 2008b).[2]

Like other Late Bronze Age Eastern Mediterranean civilisations, the Mycenaeans sustained themselves with crop cultivation and animal husbandry. At the same time, their political and economic organizations went through major changes, which may have changed the nature of the subsistence production. While agriculture is the main topic of this book, the following chapter gives an overview of some of the key characteristics of the Mycenaean societal, political, and economic structures as they appear in textual evidence. Understanding the organization of subsistence strategies, land use and ownership in a hierarchical society has relevance to the ways farming may have been practised and how the farmer communities can be reconstructed.

The extent of Mycenaean Greece and chronology

In mainland Greece, the Late Bronze Age is commonly defined through its own chronological system, the Helladic chronology, which is mainly based on pottery typologies (see Table 2.1 and Appendix 1). According to this chronology, the Mycenaean period extends from the Middle Helladic III/Late Helladic I (henceforth MH III/LH I) to the Late Helladic IIIC (henceforth LH IIIC) (Manning 2012: 13–14). In absolute chronology, the period begins *c.* 1600 BCE. Two competing systems for defining absolute chronology for the Mycenaean mainland exist. The Low Dating is based on similarities of the Greek ceramic types with Egypt and Mesopotamia. The High Dating is based on more recent results of radiocarbon dating, which has given more accurate results for the Early Helladic period but shows a larger error margin for the Middle and Late Helladic periods. Although there are yet unresolved issues with the accuracy of the High Dating for the beginning of the LH period, due to the thriving research interest towards improving it, it is preferred in this study.

The Mycenaean period thus began *c.* 1600 BCE, during the transition from the MH III to the LH I period, when notable political changes are observed in the Aegean. These include the gathering of wealth by elites, and

Table 2.1. Simplified chronological table of the Bronze Age in mainland Greece showing the relative chronological system and the two absolute dating systems commonly used to describe the period (adapted from Shelmerdine 2008a). This study mainly uses the relative dating system, but whenever relevant, the High Dating is referred to (see footnote 2).

Period	Abbreviation	Low Dating, BCE	High dating, BCE
Early Helladic	EH	3300-2000	3100-2100/2050
Middle Helladic	MH	2000-1600	2100/2050-1700/1675
Late Helladic I	LH I	1600-1500	1700/1675-1635/1600
Late Helladic IIA	LH IIA	1500-1430	1635/1600-1480/1470
Late Helladic IIB	LH IIB	1430-1390	1480/1470-1420/1410
Late Helladic IIIA1	LH IIIA1	1390-1370/1360	1420/1410-1390/1370
Late Helladic IIIA2	LH IIIA2	1370/1360-1300	1390/1370-1330/1315
Late Helladic IIIB	LH IIIB	1300-1200	1330/1315-1200/1190
Late Helladic IIIC	LH IIIC	1200-1100	1200/1190-1075/1050

[1] See Shelmerdine 2008a for further information about the dating of the Mycenaean period.
[2] All three terms are used in this study. Late Helladic (III) is preferred whenever it is possible to focus the discussion on the last centuries in the end of the Late Bronze Age in the mainland. However, it is often necessary to discuss more broadly about the LBA, since the evidence used in this study expands chronologically and geographically beyond the peak of the Mycenaean period (14th-13th centuries BCE, see Shelton 2012: 143-144). The term Mycenaean is especially useful when the discussion touches upon common cultural aspects of the mainland communities.

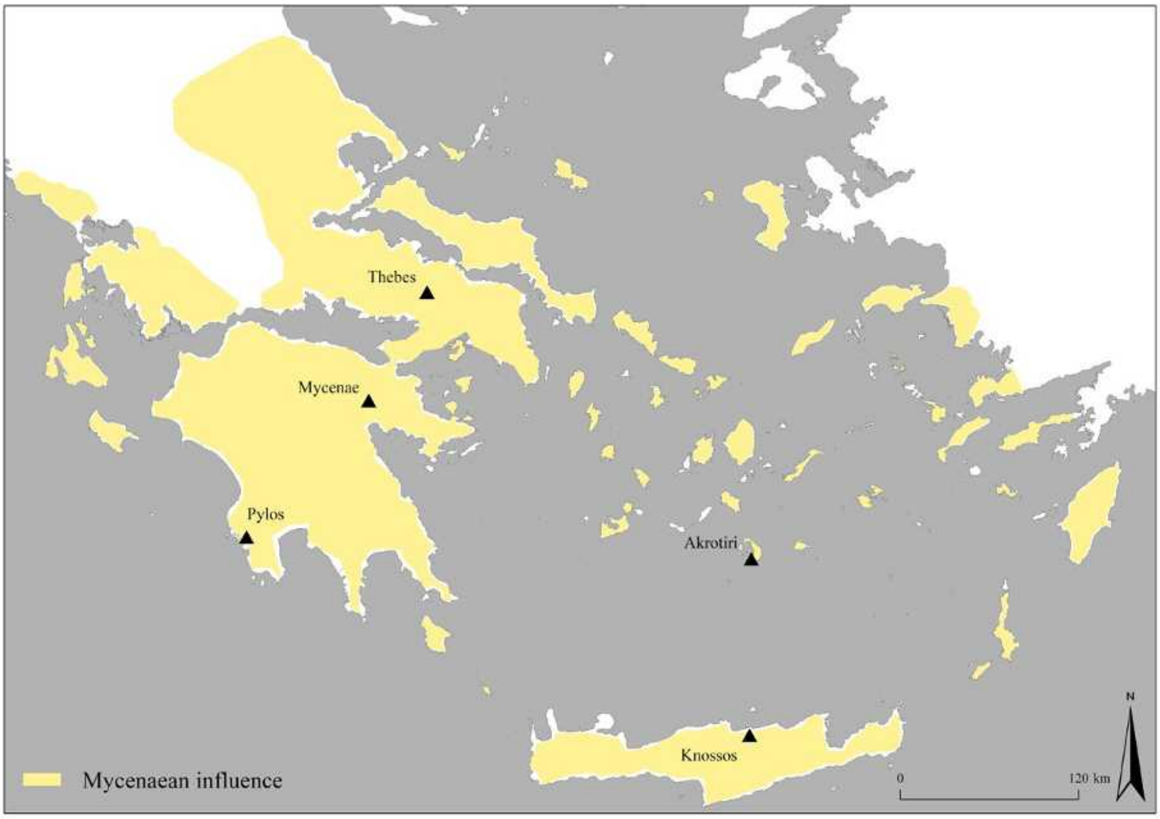

Figure 2.1. The extent of Mycenaean assemblages in the Aegean in the LH III period.

the construction of the first mainland 'palaces', large settlements with fortification walls, quarters for administrative and diplomatic purposes, and sophisticated infrastructures. The emergence of the new elite and the increasing control over the society is accompanied by more uniform material culture (Bennet 2013: 242-43; Shelton 2012: 139–40).

The LH IIIA period marks the beginning of the 'palatial period' for the Greek mainland. During this time, the Mycenaean culture was widespread over the Greek mainland and the Cycladic and Dodecanese islands (see Figure 2.1). The Peloponnese was one of the most important Mycenaean areas. On its western side, the palatial centre of Pylos, also referred to as the Palace of Nestor, controlled a large territory, covering most parts of modern Messenia (the palace was first excavated by Carl Blegen and the University of Cincinnati; see e.g. Blegen 1957; Blegen and Rawson [eds.] 1966. Since then, the site had been studied by the University of Cincinnati teams led by Jack Davis; see e.g. Davis 1997, 2022; Stocker and Davis 2004; Davis and Bennet 2017 for extensive project bibliography). On the northeastern side of the Peloponnese, there were various palatial centres of the Argive Plain. In the south, the palace of Ayios Vasileios oversaw the area of Laconia (Vasilogamvrou 2012; Voutsaki *et al.* 2018; Wiersma 2016; Wiersma *et al.* 2020). In addition, many Mycenaean sites, including the heavily fortified Teichos Dymaion in Achaea, have been recovered in the northern Peloponnese (e.g. Gazis 2017; Papadopoulos 1978; Tartaron *et al.* 2006).

Attica, on the southern mainland, underwent extensive 'Mycenaeanization' (e.g. Laffineur 2012; Papadimitriou *et al.* 2020). In Athens, remnants of large fortification walls and some small house structures remain underneath more recent architecture, suggesting the presence of a potential palace (Iakovidis 1962, 1983; Sioumpara 2018; Wright 1994). On the central mainland, Mycenaean culture centred around the palatial sites of Thebes, first excavated by Keramopoullos (Praktika Tes en Athenais Archaiologikes Etaireias [PAE] 1911, 1912, 1921, 1922, 1927, 1928, 1929; Dakouri-Hild 2001, 2005, 2012; Aravantinos and Kountouri 2014), and Dimini near modern Volos (Adrymi-Sismani 2004, 2014; Pantou 2010). A major fortified site of Gla was also located in Boeotia, southern central mainland (Iakovidis and Threpsiades 2001; Maggidis 2020). Most of the islands of the southern Aegean Sea had Mycenaean occupation, including notable settlements at Aegina, Euboia, Thera (Santorini), Milos, Naxos, and Paros (Berg 2019).

Whereas the southern mainland Greece withheld was where many of the Mycenaean heartlands were located, the northern mainland consisted of communities with more localized cultures. These communities, and their notable local centres such as Toumba Thessaloniki and Assiros Toumba, lacked similar centralized and hierarchical administrative structures to the Mycenaean centres in the south. Therefore, the northernmost areas of modern Greece have not been directly included in the Mycenaean core areas, although they adopted many aspects of the Mycenaean material culture during the Late Bronze Age (see e.g. Andreou 2012, 2020; Dickinson 2006: 26, fig. 2.1). Before the palatial period on the mainland, the emerging Mycenaean palatial elite was closely connected to the Minoan palaces on Crete (Bennet 2013: 235). From the LH I onwards, these formerly Minoan palaces transformed into Mycenaean ones when new Mycenaean(ized) elites took over (Bennet 2013: 243).

The palatial period in LH IIIA-B marks the peak of Mycenaean culture. Palatial buildings gained their form in the LH II/LH IIIA (see pp.25-30), as did most of the pronounced tholos tombs used by the elite (Hitchcock 2012: 202-205; Mee and Cavanagh 1990). By the LH IIIB, besides becoming spaces for administrative and diplomatic purposes, palatial centres included religious facilities such as the Cult Centre at Mycenae, as well as large artisans' quarters for the manufacturing of valuable objects, such as those made of precious metals and ivory. Animal sacrifices, feasting, ritual hunting, and processions were part of the spiritual and social practices of the Mycenaean elite (Boyd 2014; French 2002; Hamilakis 2003; Hamilakis and Konsolaki 2004; Hruby 2008; Palaima 2004; Walberg and Reese 2008). Outside the palaces, the Mycenaeans founded sanctuaries, which had a level of independence and power (French 2002: 47; Maran 2006: 78). Road networks and other infrastructure to expand and improve land use and connections were constructed in the LH IIIA and B (Brysbaert *et al.* 2020; Jansen 2002; Lavery 1990, 1995; Mamassis *et al.* 2015; Smith 1995). Mycenaean pottery in its homogenised form can be found across the Eastern Mediterranean (Shelton 2012: 145; van Wijngaarden 2002), while exotica and raw materials trade extended far across the Mediterranean to coastal western Asia and coastal Aeolia (e.g. Cline 1994; Dickinson 1994: 235, fig. 7.1, 196-206; French 2002: 48, fig. 15; van Wijngaarden 2002). Most of the records of the palatial centres, the Linear B texts (see below), date to the *c.* 100-year period of the LH IIIB (Driessen 2008; Nakassis 2013).

The Bronze Age collapse

The Mycenaean period ended around 1200 BCE, at the end of the LH IIIB2 period (Jung 2012: 172, table 13.1). Even before this final crisis, in *c.* LH IIIB1, many of the palatial centres had faced major destruction. Collapsed walls and buildings are visible in the Argive Plain citadels of Mycenae and Tiryns as well. During the LH IIIB2, some of these structures were rebuilt and other profound changes were implemented inside the fortified citadels, such as the construction of water installations and other infrastructure. Some of the fortification walls were also reinforced and extended (see §3.3). In LH IIIB2, many of the large palatial settlements were nevertheless destroyed, leaving behind collapsed buildings and signs of major fires (Deger-Jalkotzy 2008: 387-90). The citadels were not rebuilt, apart from a few exceptions, such as Tiryns (Maran 2009, 2015). In addition, Linear B stopped being used (Deger-Jalkotzy 2008: 390; Shelton 2012: 146). In the aftermath of the crisis, changes are visible in the burial types, which shift from communal chamber tombs to more modest single cist and pit inhumations (Maran 2015: 285; Pappi and Triantaphyllou 2007).

The Mycenaean period is followed by a population decrease and the abandonment of many of the key sites. However, this is not evident at every notable LBA settlement, as rebuilding and settling continued or even increased after the crisis years, for example at Tiryns (Maran 2006; 2009: 255-257, 2015: 283-286). Similar changes were seen not only in mainland Greece and the Aegean, but all around the Eastern Mediterranean (Shelton 2012: 146). This has been labelled 'the Bronze Age collapse' (e.g. de Menocal and Cook 2005; Middleton 2012; Weiss 1997; Wilkinson 1997) or, more recently, 'crisis' (e.g. Kaniewski *et al.* 2013; Knapp and Manning 2016; Maran 2009).

Many arguments have been presented as to what caused the LBA collapse. The crisis has been linked to a foreign invasion by the Sea Peoples, migratory groups of various nationalities attacking the coastal settlements of the Eastern Mediterranean from the sea. The Sea Peoples are described in the cuneiform texts of the LBA Ugarit and depicted in wall reliefs at Medinet Habu in Egypt (Kaniewski *et al.* 2011: 1). However, in the Aegean there is no tangible evidence of the destruction in the LBA citadels being caused by a foreign invasion (Deger-Jalkotzy 2008: 391). In recent years, rapid climate change and other rapid environmental catastrophes have been connected to the crisis (e.g. Drake 2012; Kaniewski *et al.* 2013, 2015; Moody and Watrous 2016; Tsonis *et al.* 2010a; Weiss 1997). A severe period of drought, lasting for years, might have caused a dramatic depletion of staple resources such as food, and resulted in societal unrest. So far, paleoclimatic studies have shown some signs of a brief period of unstable or drier climatic conditions during the LH III (see details in §5.2.2). However, the most high-definition dating available now places the event *c.* 50 years earlier than the Bronze

Age collapse (Finné *et al.* 2017). The scale of this dry period is unknown, and therefore rapid climate change cannot be confirmed as the trigger for the LBA crisis. The over-exploitation of resources and workforces by Mycenaean elites might also have contributed to the collapse. Nevertheless, the most recent estimates of the workforce and resources needed for the palatial construction projects in the Argive Plain do not indicate that large-scale construction activities would have threatened local subsistence (Brysbaert 2013, 2015; Timonen and Brysbaert 2021). Thus, to date, the exact reasons for the collapse remain unknown, although it seems likely that it occurred due to a number of changes in both political and environmental circumstances.

It has been further questioned whether 'collapse' or 'crises should be used at all to describe the end of the Bronze Age. In the Mycenaean context, material evidence demonstrates that in many places, settlements continued be at least partially inhabited in the sub-Mycenaean period, and the subsequent changes seem less dramatic as previously described. Rebuilding took place at many Mycenaean palatial sites, although on a smaller scale, and comprising housing areas instead of palatial quarters. While many sites were abandoned, some sites, such as Lefkandi on the island of Euboia, experienced growth in wealth and size after the collapse during the post-palatial period (Lemos 2006: 525). Trade in the Eastern Mediterranean continued (see e.g. Dickinson 2007 for Aegean and Eastern Mediterranean trade in the Early Iron Age). Thus, the collapse mainly applied to the political and economic structures related to the Mycenaean palaces and their elite. The subsistence activities of the non-elite likely remained fairly unchanged after the collapse.

Summary: The Mycenaean period in Greece

The Mycenaean era, spanning approximately 400 years during the Late Bronze Age primarily concerned societies in southern mainland Greece and the Aegean islands. Although its chronological span was relatively short, the period oversaw the spread of the Mycenaean culture widely across the Mediterranean. Mycenaeanization, the gradual spread and standardization of material culture, but likely also aspects of political, societal, and religious systems, spread throughout mainland Greece and the Aegean islands.

Recent discoveries for example in the Gulf of Volos, have exposed new Mycenaean 'core areas' (e.g. Karouzou 2020; Lis *et al.* 2023) with several central sites situated in close proximity to each other. Studies into the interactions of such sites with each other but also across the Mediterranean are constantly reshaping our understanding of the societal structures and settlement hierarchy of the Mycenaean cultural group. Even though current evidence seems to suggest that the northernmost areas of modern Greece were not strictly Mycenaeanized, future research has the potential to drastically change this picture.

This peak of the Mycenaean period in around 1200 BCE quickly ends in a population decline and site abandonment. The causes to this crisis that remains yet unsolved, and a great interest to anyone involved with Aegean archaeology. However, the main focus here is on farming communities responsible for sustaining the people inhabiting the Argive Plain during the Mycenaean peak in the LH IIIB. Thus, the present study is not trying to solve the Bronze Age collapse but examines the sustainability and livelihood of the population in the preceding period. Nevertheless, as this crisis could have been exacerbated by a climatic change causing food shortages and social unrest, it is of interest here to examine whether the severity of these issues was increased by underlying problems in resource availability.

Mycenaean society in Linear B textual evidence

From the overview of the LBA chronology and the spatial and material achievements of the people referred to as the Mycenaeans, this study moves on to examine the general characteristics and the stratification of the Mycenaean society in more detail. The second part of the following section discusses what Linear B records have revealed about the land use and ownership system in the LBA. This is relevant to the ways agriculture could be practised.

Societal organization

Mycenaean society was complex and stratified. The social stratification is most evident in Linear B texts, which list various titles and occupations held by individuals in Mycenaean administrations. Recent noteworthy studies on the tasks and importance of these individuals have been published by Nakassis (2013, 2015), Killen (1984, 1995, 2001), de Fidio (1999), and Palaima (1995, 2004), among others. Social stratification is also evident in a change in the burial styles and wealth, with more elaborate tholos and chamber tombs with more valuable burial items. These tombs were used for communal or family burials, and thus probably reflect the emergence of elite groups (Dabney and Wright 1990).

Many of the individuals mentioned in the Linear B texts worked as officials in the palatial administration (Nakassis 2013: 1-2). The head of such an administration was a ruler, the *wanax* (Lin. B: *wa-na-ka*), who had religious and ceremonial roles (Kilian 1988: 293; Shelmerdine 1999b: 19-21) and was the main supervisor of the economic activities of the palace. In Pylos, the *wanax* was also the biggest private landholder (Nakassis 2013: 7). Traditionally, the *wanax* has been considered a king (Hiller 1988; Kilian 1988), but in recent research he is regarded as a director, or the 'director' of the administration (Bennet 2001: 28; Shelmerdine 2008b: 128). Below the *wanax* were various bureaucrats, such as the *lāwāgetās* (*ra-wa-ke-ta*), 'the second man in command', the *hekwetai* (*e-qe-ta*) 'followers', and 'the collectors', who were only mentioned by their individual names. Each of the officials seem to have carried out a variety of tasks within the administration, and each of them either owned or possessed rights to agricultural land (Nakassis 2013: 7-8; Shelmerdine 2008b: 130-32). While the executive officers are mainly mentioned in the Linear B texts of Pylos and Knossos, references to the *wanax* are found in the texts and sealings of multiple Mycenaean locales (Shelmerdine 2008b: 129-31), suggesting that Mycenaean Greece might have had a somewhat standardized administrative system.

The LBA palatial centre of Pylos extended its control over a wide territory in modern-day Messenia by dividing it into sub-districts. Here, the region monitored by Pylos was divided into two provinces and sixteen districts. Each province had a governor, dāmokoros (*da-mo-ko-ro*), and each district had its own supervising administrator (Lupack 2011: 212; Nakassis 2013: 9). While some indications of territorial divisions or satellite settlements can be derived from the place names recorded in the Linear B texts found in Knossos and Thebes, evidence of the presence of similar district division as the one at Pylos has so far not been confirmed (Bennet 2011).

The palatial administration regularly hired special labourers, such as builders, herders, crafters, rowers and soldiers. These individuals were usually rewarded for their work either with food rations or land allocations (Nakassis 2015: 596-97). The palatial centre included workshops for skilled craftsmen who worked under a system called *ta-ra-si-ja*. The palace provided these workers raw materials, such as bronze, which they turned into finished products (Halstead 1992: 61; Nakassis 2015: 583).

The palace also had female workers. Most of them worked in the textile industry, often together with their children, and received a reimbursement from the palace in food rations (further discussion in §2.3 and §6.2). Female textile workers at Pylos (PY Aa-series), Knossos (e.g. KN Ak-series), and Mycenae (V- and Oe-series) all received food rations with a similar volume (*c.* 20 l of grain and 20 l of figs), suggesting that standardised industrial and ration systems were in use (see §6.2.1 for fig volumes, and Palmer 1992 for rations). Elsewhere, male workers at Mycenae[3] and female workers at Knossos received *c.* 1.2 litres of rations per day. Palaima (2008: 386–87) notes that this number is similar to the amounts received by Roman slaves (1.13-1.15 l/day). The female textile workers have been noted to represent lower status individuals of Mycenaean society, and their work has sometimes been categorized as slave labour. This is due to the type of payment (i.e., food) they received for their work efforts, and because many of them are described in the records as having a foreign ethnicity (Shelmerdine 2008b, 139). There is, however, no consensus whether slavery in the sense of forced labour existed in the Mycenaean society. Furthermore, at Pylos, men working as sword-makers and wall-makers (PY An 128 and PY Fn 1427) received similar food rations to the female textile workers (Gregersen 1997: 397-98). This could suggest that these food rations were paid to skilled workers. Other labourers, such as the Pylian unguent-boiler, *ko-ka-ro*, even received larger amounts of cereal and figs, estimated to have sustained him for five months (PY Fg 374) (Gregersen 1997: 397-98).

Not much is written on the people who lived and worked outside the palatial sites and the immediate supervision of their administrators. The Linear B texts indicate that the religious sector, including sanctuaries, had their own high officials, such as priests (*i-je-re-u*) and priestesses (*i-je-re-ja*). (Shelmerdine 2008b: 130-34). In Pylos, some members of the religious personnel received food rations from the palace (PY Fn-series). However, the volumes of these rations were so small that it could have not sustained them (Gregersen 1997: 399). It is possible that the religious personnel received their subsistence mainly from outside the palace.

Among the largest landowners and users in the Mycenaean society were the *damoi* (*da-mo*), who seem to have functioned outside the palatial administration. The term *damos* has been understood to mean two things: the political and geographical districts (e.g. 16 in the Pylian territory) controlled by the palace, or the people and their representatives occupying these districts (Lupack 2011: 212). Each *damos* district had local officials, who were also connected to the palatial authority (Lupack 2011: 212; Nakassis 2013, 9). It has been suggested that the people of the *damoi* had their own administrative boards, who were given the power to conduct legal negotiations on behalf of the people. (Lupack 2011: 12-15; Nakassis 2013: 171-72; Shelmerdine 2008b: 134). The Pylos Linear B records imply that the *damoi* controlled substantial amounts of land, which was likely used for subsistence agricultural production.

[3] In a Tablet (MY Au 658) from the West House in Mycenae, male workers received 'z 960' as a monthly payment, which equals to *c.* 0.64 litres of grain per day.

As demonstrated on pp.10-13, due to this control the *damoi* formed a strong social and economic power. However, the same *damoi* were likely also producing the specific goods that the palace collected as taxes. This means that they were not entirely independent entities, economically or politically.

Of agricultural workers, the Linear B tablets mention mainly herders, and some specialized employees performing agricultural tasks. The tablets of Pylos mention at least 154 different herders. Most of them were shepherds, likely managing the flocks of the palace (see also §5.5.1), but pig and cattle herders are referred to as well (Nakassis 2015: 592). One Tiryns tablet (Ef 2) mentions an 'oxherd' (*qo-u-ko-ro*), while elsewhere (TI Cb 4) they were recorded with their names (Brysbaert 2013: 61; Kajava 2011; see also §2.2.3 and 5.5.1 about oxen and plough teams). In addition, 'fig-overseers', *opisukoi* (*o-pi-su-ko*) are mentioned in a Pylos tablet (PY Jn 829), suggesting that at least there, figs were systematically cultivated and their production was part of the palatial economy. Perhaps this special title bore resemblance to the *sycophantae* ('fig-detectives'), a term from the Classical period indicating officers tasked with preventing the illegal export of figs from Attica,[4] or alternatively persons overseeing the preservation of figs offered to gods in times of famine (Berti 2009: 99-100; Loscalzo 2012: 32–33). Nevertheless, the presence of fig-overseers and the use of figs as payment rations by the palace means that the palatial administration was interested in their production in large quantities. Fig production is discussed further in §5.4.2.4.

Among other subsistence-related low status workers are beekeepers, hunters, net-makers, woodworkers, and (rarely) potters (see Shelmerdine 2008b: 142 for a list of specialized workers). These professions were likely recorded in the tablets only because the labourer had some economic interaction with the palatial administration. Many of these tasks were probably part of the work of farmers, who performed them when cultivation and animal husbandry needed less attention.

Farmers are not visible in the textual records. Since crop cultivation was the subsistence strategy of highest importance in the Mycenaean societies (indicated for example by the food rations paid in cereal, and by archaeobotanical remains of cereal species), it can be assumed that farmers were present in large numbers. Linear B records clearly attest that an individual could hold several simultaneous occupations and titles, and that many of the higher administrative officers held land allocations in return for their work efforts. 'Professional' farmers could have worked on this elite land as hired workers or sharecroppers, as Halstead (1999a) has suggested, or they could have owned their own plots for subsistence production. The administrative officers could have also been at least partially responsible for their own subsistence in the lands they owned if their responsibilities for the palace did not extend over the entire year (see further discussion in §2.3). The absence of farmers in the textual records suggests that the palace was not in direct interaction with them, or that perhaps they were so ubiquitous that there was no need to specifically mention them.

In the textual records, Mycenaean society appears as a complex organization of individuals possessing various professions. The elite consist of bureaucrats (often with a military function) working for the palace, supervising its economic activities. Despite the obvious hierarchy, led by the *wanax*, the palace did not seem to strictly control the activities of the people living in its territory (e.g. Lupack 1999, 2008). Below the palatial elite, many labourers with surprisingly specialised tasks worked for the palace, receiving distinct types of reimbursements depending on the type of 'contract' they had (e.g. Killen 1998; Nakassis 2013; Zurbach 2013). Outside the palatial centres, other settlements had their own administrative officials and specialised workers. In general, many had the right to own property and to make legal decisions without palatial intervention (Killen 1998; Nakassis 2013; Zurbach 2013; see also the following section 2.2.2). In this complex system, the farmers formed a large, but relatively independent group of workers, whose main task was to sustain themselves and, likely, the society by supplying some of their products, or their labour, to the palace. This taxation system is further explored on pp.15-16.

Landowners and users in textual evidence

Farmers practicing agriculture might be absent from the LBA textual evidence, but according to the Linear B texts, various individuals and groups were able to own land, or hold the rights to it. In fact, land seems to have been among the most valued possessions in Mycenaean society, and the recording of land management was one of the most important tasks of the (Pylian) administration (Zurbach 2008: 826). Landownership regulations would have had a major influence on the terms under which land could be cultivated, who was able to enjoy the profits, and how much could be produced on a piece of land. The best textual evidence of the landownership system in the Mycenaean society comes from the Linear B tablets recovered in Pylos.

[4] According to Athenaeus's (*c.* 1st-2nd *c.* AD) *Deipnosophistae (book III)* Sycophantae are mentioned in the History of Attica by Classical author Istros. Only this secondary fragment remains of the reference of Istors. However, *sycophantae* are mentioned by other Classical and later historical authors as well. More recently, the term became to mean someone dishonest and corrupted, using his (political) power for slandering (Berti 2009: 99-100).

More fragmentary evidence is available in the tablets of Knossos and Tiryns (Zurbach 2008: 826) The following section presents a brief overview of the Mycenaean land use system as it is currently understood. The topic is debated, however, and many contradicting perspectives on landownership issues exist.

A series of Linear B tablets from Pylos (the PY E-series) has recorded transactions related to landownership and use. This series includes three sets focussing specifically on landownership; the En/Eo, the Ep/Eb, and the Ea. (Lupack 2008: 55). These tablets were likely compiled for the use of the local palatial administration, who wanted an inventory of the lands (and individuals) from which they could collect taxes. This assumption is based on the notion that these texts only describe the identity of a landholder and the size of the holding, but not, for example, the location of the plot(s). Thus, the palatial administration was mainly interested in the target production of the various landholdings (Bennet 2008; Killen 1984; Lupack 2008: 53-57).

The Pylian territory was divided into two governmental areas, the Hither Province and the Further Province. *Pa-ki-ja-ne*, the sanctuary of Poseidon, was in the Hither Province, close to the palatial centre of Pylos. Various types of landholdings are associated with this sanctuary. The two main categories of land recorded in the Pylos texts are *ke-ke-me-na* and *ki-ti-me-na*. They seem to refer to communally owned land (*ke-ke-me-na*), and privately owned land (*ki-ti-me-na*) (Lupack 2008: 63; Uchitel 2007: 474; Ventris and Chadwick 1956: 233).

The *ke-ke-me-na* land was owned (or at least controlled autonomously) by the *damoi*, local village communities who held a position of power in the Pylian state and were able to act with partial independence from the palatial authority (Lupack 2008: 55-57; Zurbach 2020: 16-17). It is unclear whether all individuals belonging to the *damoi* owned land, or if only few individuals of this group were landowners (Bennett Jr. 1956: 133). In the latter case, the landowners could have been included in a group called *ko-to-no-o-ko*, which was likely a representative committee of the *damos*, 'the most prominent men' or 'a group of elders' (Deger-Jalkotzy 1983: 90–91; Lupack 2008: 55). The people of the *damoi*, nevertheless, are considered to represent the farmers of the Mycenaean society.

The status of the *ki-ti-me-na* land is less clear. The user rights to this type of land were mostly held by individuals called *te-re-ta* (*telestai*), who could hold various professions (Lupack 2008: 55–57; Uchitel 2007: 475–76). *Te-re-ta* were usually bound to provide services in exchange for the rights to the land. This has led some to suggest that *ki-ti-me-na* was given to them by the *wanax,* the Mycenaean 'ruler' who owned the land privately (Deger-Jalkotzy 1983: 102–3). Deger-Jalkotzy (1983: 102-3) argues that the *ki-ti-me-na* land expresses a change in the political system. The land was initially owned by the *damoi,* but along with the development of the palatial hierarchical system, some of the *damos*' land was claimed by the *wanax* to be privately owned. It was then given to the new officials *te-re-ta,* with the obligation to provide services to the palace. However, Lupack (2008: 69-72) has suggested that *te-re-ta* actually owed their service to the *damoi*. In this case, the *ki-ti-me-na* land was also owned by the *damoi*, although it was taxed by the palace (see pp. 15-16 about taxation). Lupack (2008: 72) further suggests that since it seems the responsibilities of the *te-re-ta* were often related to military services, they might have been responsible for the defence of the *damoi.*

Both types of land, *ke-ke-me-na* and *ki-ti-me-na*, could be owned or leased, although the exact types of these arrangements remain mostly unclear. Two common types of landholdings were *ko-to-na* and *o-na-to*. *Ko-to-na* have been interpreted as large estates, while *o-na-to* were small plots related to or intersected from these large estates (Bennett Jr. 1983; Lane 2012: 62; Uchitel 2007: 474). *Damoi* were usually the owners of the *ko-to-na*, while the small *o-na-ta* plots leased to various individuals. Part of the land was left unleased. According to Deger-Jalkotzy (1983: 97) this was private land, individually owned by families belonging to the *damos*. Bennett Jr. (1956: 118-21) notes that, while the ownership rights of the *ko-to-na* land were simple, the *o-na-to* land seemed to have conditional rights of use. *O-na-te-re* could hold rights to several plots of land simultaneously. These plots could belong to different estates (*ko-to-na*). Many (but not all) of the *o-na-te-re* held religious offices, and this group consisted of both males and females (Uchitel 2007: 478).

Although *damoi* seem to have been in control of much of the land recorded in the Linear B tablets, the palace was collecting taxes from these lands in the form of products, or as work contributions. Thus, *damoi* were, to some extent, subordinate to the palatial administration. It is possible that they owned the land but allowed the palace to collect taxes from it, and supervised tax collection themselves (Killen 1998; Lupack 2008). A famous Pylos fragment introduces an argument about a landholding between the *damos* and a priestess of the sanctuary *pa-ki-ja-ne*. The argument concerns *wo-ze-e* obligations imposed on the priestess. *Wo-ze-e* appears to have been a work obligation imposed on the holder of a specific type of land. Deger-Jalkotzy (1983: 98-100) suggested *wo-ze-e* referred to *corvée* labour (unpaid labour, usually requisitioned as personal services by landowners or other persons in power). This means that in return for the right to make profit out of land, its holder had to provide services to the state, for example in the military, or in construction projects initiated by the palace. The priestess of *pa-ki-ja-ne* appeals to the name of Poseidon and claims that she is freed from these obligations because she or her land possesses *e-to-ni-jo* (Deger-Jalkotzy 1983: 91). Lupack (2008: 66) suggests that the *damos* opposed the priestess' demand because if her land had *e-to-ni-jo*, the burden of taxes (or work obligation) imposed on that land would be divided amongst the remaining *damos* landowners, adding to the amount they had to contribute to the palace. This reference indicates that the palace was not needed as a mediator in the quarrels about landownership or usage rights (Deger-Jalkotzy 1983: 91). It seems that in this case the palace was not even in the position to interfere with a quarrel that concerned land owned by the *damos*. It also suggests that holding land most often included an obligation towards the landowner, either as labour services or turning over part of the profit - despite the profile of the holder.

In return for taking a share of the production or using the labour force, the palace may have offered the *damoi* and land leasers security and aid, for example in the form of military protection, or improved infrastructure such as roads and bridges. Halstead (1992: 69) has suggested the palace could have supported the people with emergency rations of food in case of harvest failures. Another way for the palace to compensate its people could have been related to animal power. Killen (1998) argued that the food (e.g. cereal and figs) needed to provide rations to palatial workers was grown on the *damos*' land, and that to secure production, the palace loaned oxen to the *damoi* to be used for ploughing. The ownership of oxen by the palace is attested in the Pylos and Knossos tablets. The Mycenaean palaces held them in great value, which is indicated by the recording of them by their names and special characteristics (Kajava 2011, although mostly in the Knossian context; e.g. Killen 2015; Palaima 1992). Shelmerdine (2008b: 134) suggests that the lending of oxen to the agriculturalists was an effective measure for creating a dependency relationship between the palace and the people. Such a convention indicated the birth of a new arrangement, in which the Mycenaean administrative elite took control over the older power structure represented by the *damoi*. Nevertheless, in some cases, the *damoi* also seem to have owned oxen (tablet PY An 830) and they were likely not fully dependent on the leasing of draft animals (ibid.). The use of oxen in agricultural tasks is not recorded in the Linear B texts, but show up for example in material culture where pairs of oxen and yokes, are depicted in Bronze Age miniature statuettes (§5.5.1).

Despite the obligations that came with leasing, land was held as an asset in the Mycenaean society. The owners or leasers of land were individuals with diverse backgrounds and skills. There were both male and female landowners, with various professions, from herding to religious offices (women landowners seem to have mostly held religious offices). Nakassis (2013: 124) lists over 130 individuals in the Pylos texts related to land use and/or ownership. A comparison of the different sets of tablets has confirmed that the same individuals are recorded in different tablets in relation to landholdings. This means that a single individual could hold several plots of land. In one case (PY Ae series) a landholder also owned animals, while others were assigned to watch over these animals (Nakassis 2013: 133). The texts also mention individuals who did not possess (or have rights to) plots of land (*a-ko-to-no*) (Nakassis 2013: 119), and in one case, a man was recorded to hold land as a compensation for manslaughter of a family member (Nakassis 2013: 129).

Two major questions remain unanswered: did the *damoi* own all land, and how was the land under the distinct types of ownership, holding, and leasing agreements used? The two provinces of Pylos were divided into 16 control areas, with their own administrative members appearing subordinate to the palace. Killen (1998) suggests that these districts were the *damoi*, local village communities and their governing officials, and that the vast majority of the Pylian land was owned by these communities. At the same time, he (ibid.) introduces four types of landowners belonging to the Mycenaean elite, the *wanax*, the *lawagetas*, three *telestai* and one individual named Wroikion. This indicates that besides *damoi*, individual members of the elite could also own land. Halstead (1999c: 38) has suggested that some two-thirds of the palatial workers in Pylos were supported by the palace through land allocations. Whether this land was, in fact, owned by the palace or handed to the workers in collaboration with the *damoi* remains unclear. It would seem logical, however, that for its private production the palace would have possessed land over which it did not have to negotiate with the local communities (Zurbach 2016). Zurbach (2013: 645) argues that the even distribution and rectangular shape of land plots, also familiar from the Linear B texts of Pylos and Knossos, refers to land distribution controlled by an authority at least in the Archaic context. This could also indicate that the Mycenaean palatial authority was responsible for the distribution of land, although it also strongly suggests the use of specific agricultural land preparation techniques (see below).

When it comes to the practical use of the land, Bennett Jr. (1956: 132) pointed out early on that land use is not recorded in the Linear B texts. It seems likely that most of the land was used for agricultural activities, however. In this way the land, whether it was leased by the *damos* or allocated by the palace, could have provided subsistence and potential wealth to its user. Furthermore, in Pylos (and to a lesser extent in Knossos, see Zurbach 2008: 832) land was measured in grain, GRA, usually combined with a reference to seed, pe-mo (spermo), and a crop type such as wheat (*120). This has been seen to mean that one unit of land equalled to the surface area, which could be sown with one unit of seed stock (Lupack 2008: 51; Palmer 1992: 481-86; Zurbach 2020: 20). Although this refers to the use of land for (cereal) cultivation purposes, land that was not sown with cereals (but used for tree crops, for example) was measured in a comparable way (Palmer 1992: 481-86). In two separate cases, the landholding area of an individual is marked as GRA 94. Uchitel (2007: 479) has suggested that this was a standard size of a landholding for an official of a specific rank. One of these references (PY Eq 213) lists an individual who owned five plots of land with a total area of 94 units of seed. In the same context presents the only appearance of the word 'field', *a-ro-u-ra*. The locations of these plots are unknown, but it is possible that they were in separate locations. Zurbach (2013: 645-646) has suggested that the orthogonal distribution of plots in the Knossos and Pylos tablets refers to the use of sole ard, which only broke the surface of the soil and, thus, created rectangular plots as a result of double ploughing in a crisscross pattern (in contrast to the plough which turned over the soil and did not require going back and forth to form the furrow).

Finally, no confirmed formula to translate the seed units into size units of land exist, but some suggestions have been made. A woman key-bearer (a high religious office), a major landholder in the *pa-ki-ja-ne* district, contributed 2 GRA to the palace. Nakassis suggested that this would amount to some 200 litres of seed (Nakassis 2013: 130). De Fidio (1977: 176) hypothesised that GRA 3 would equal approximately one hectare of land, thus, a piece of land that could be sowed with 150 litres of wheat seed. This is a little more than Nakassis' figure, which refers to 100 litres of seed sowed on 1 ha of land. Similarly, Chadwick (1973: 236-37) suggested that the ratio of seed could have been 100 litres to 1 ha. Due to these uncertainties, the volumes and plot sizes presented here cannot be directly extrapolated over the available agricultural land. If, however, GRA 3 equalled 1 hectare as suggested by de Fidio (based on comparisons with other seed-land ratios in the Eastern Mediterranean and Near East), the 'standard' major landholding of GRA 94 mentioned above would have amounted to a respectable 30 hectares of land, over ten times the size of a subsistence plot (Halstead 1995a) and a rather sufficient amount for a major landholder (see also Zurbach 2020).

Land use in the Argive Plain tablets

The Pylos E-series represents the most detailed record of the Mycenaean landownership system. However, it is difficult to estimate to what degree the Pylian system can be applied to other Mycenaean core areas, such as the Argive Plain. The Argive Plain tablets (from Mycenae, Tiryns, and Midea) are fragmentary, and they do not contain indications about territorial division into provinces or districts. It is possible that such an organization still existed and that the evidence has since been lost. However, there are many differences between the two regions, including a notable difference in size between the territories of Pylos and the Argive Plain. It is possible that the small size of the plain would have made division into provinces impractical. The considerable number of large settlements with palatial characteristics located close to each other further counters the idea of a district division controlled by one central settlement alone. Here it is assumed that the Argive Plain had a unique territorial division, meaning that the Argive Plain had at least three independent centres, Mycenae, Midea, and Tiryns, each in control of their own subsistence areas. This approach follows the suggestions of Galaty, Pullen, and their co-researchers (e.g. Galaty *et al.* 2015; Pullen 2010, 2013, 2022; to some extent also Kilian 1988: 297, fig. 3). A contradicting perspective, according to which Mycenae took the political and economic control of the Argive Plain and wider regions towards the Argolid peninsula and Corinth in the LH III, has been popular in the Bronze Age Aegean archaeology (e.g. Brysbaert and Vikatou 2022 in relation to the network of highways which begun from Mycenae; Maran 2006, 2009, 2015; Voutsaki 1995, 2010; Wright 1987, 2006). Political geography, and the approaches of this book regarding the Argive Plain palatial states are further discussed on pp.31-35 and 132-134.

However, there are a few similarities between the Argive Plain Linear B tablets and the Pylos and Knossos tablets concerning economy and land. Tablets recovered from Mycenae record the system of *ta-ra-si-ja*, in which the palace gave raw materials such as wool to its crafts personnel with the expectation of them working it into finished products in the palatial workshops. Similar organizations of labour have been recorded for example in Pylos. The Mycenae tablets further record the handing out of rations of grain and figs to its workers, again showing similarities to the records of Pylos and other Mycenaean palatial centres (e.g. Bennett Jr. 1953; Chadwick *et al.* 1962; Vermeule and Chadwick 1964). Similarities in one economic activity could suggest similarities in other areas of economic and political organization in these domains.

Although fragmentary, the Linear B tablets recovered at Tiryns are most informative about potential land use systems. Two tablets (TI Ef 2 and Ef 3) include land-related terminology that is similar to that of the Pylian E-series. For example, the fragments mention GRA 6 (grain), DA (land of *damoi*?), *pe-mo* (seed) and *ke-ke-me* (*ke-ke-me-na* land, i.e., the communal land owned and leased out by the *damoi*). One tablet (Ef 2) further records an individual described as a 'herdsman' or an 'oxherd'. He might be related to the landholdings mentioned, perhaps as the holder of rights to this land (Brysbaert 2013: 61; Godart and Olivier 1975: 44-46).

These few fragmentary lines seem to refer to a similar land categorization system as described in the Pylian texts, although it is not possible to say if this system was as complex as the one presented in the Pylos E-series. Furthermore, unlike the Pylos land use records, which were found in the storeroom of the palatial complex where all linear B records were kept, the Tiryns tablets were recovered in a secondary context. This could mean that they might not be as closely connected with palace activities (Zurbach 2008: 827). Nevertheless, if a similar categorization was used by the Argive Plain communities, it means that here *damoi* also controlled much of the cultivable land and leased it out to various parties - likely for subsistence purposes. The piece of land mentioned in the fragments, GRA 6, would equate to an average plot of a subsistence farmer, 2ha, if de Fidio's (1977: 176) estimate (presented on p. 13) is to be used. It could represent an allocation to the herdsman in return for his services as the tender for large working animals. However, with such fragmented information, this may be considered a working hypothesis only. The fact that the tablet was stored in Tiryns is important: firstly, it can be assumed that the piece of land was located somewhere close to the central settlement, within its 'control area'. Secondly, it seems to support the idea of independent control areas for each Argive Plain centre with an administrative system. If Linear B records are considered as evidence of such system, these would include Mycenae, Tiryns and Midea. This would mean that each of these areas was quite small, because the plain itself does not offer much potential for expansion. For Mycenae, however, an expansion in the north towards the Corinth plateau would have been a fair possibility, as is suggested by the network of Mycenaean highways, many of which (e.g. M1, M2, M3, and M6) lead from Mycenae towards Nemea and the Corinth plateau (e.g. Brysbaert *et al*. 2020, Brysbaert and Vikatou 2022; Lavery 1995).

Summary: Mycenaean land and society

What emerges from the textual fragments is a picture of a complex system of land use, ownership, and status. At the same time, distinct types of landownership and usage activities, such as potential conventions about inheriting land, are not recorded in the Linear B tablets, or the tablets holding the information have long since disappeared (Deger-Jalkotzy 1983: 90). In the LH IIIB, after many of the palaces had reached their peak in wealth and power quite rapidly, the landownership system was likely still in a phase of transition from *damos*-based land control to palatial elites and administration gaining more power over land. This could have led to disagreements between landholders, landowners, and other individuals with power. Bennett Jr. (1956: 133) argued that land leasing by local communities was a relatively new system, emerging on top of the private and communal land division. For example, in Pylos, the establishment of the sanctuary of *pa-ki-ja-ne* could have increased population, creating new subsistence pressure. This pushed the local landowners to develop a system of land leasing, which they would implement on those parts of the land which were not needed for their own sustenance. More recently, Zurbach (2008: 836-837) has also suggested that the different units and methods of measuring land in the Pylos, Knossos and Tiryns tablets (e.g. GRA versus DA/PA) are visible demonstrations of an evolution of property ownership and management system. According to him, however, the palatial control over land was diminishing and different units of private ownership were emerging.

While the palace was taking more control over the entire economy during the LH III, partially because it was able to provide services such as military security and infrastructure in return, the *damos* communities appear to have remained relatively self-sustained. Instead of single isolated farmsteads, the textual evidence seems to point towards communal work and decision making. Deger-Jalkotzy (1983: 91-95) described the land use economy as a 'communal self-government'. Rather than sharing the land amongst individual households, the people of the *damoi* worked their land collectively. The community exercised certain property rights as a group, guided by a decisive committee of elders. Deger-Jalkotzy (1983: 96) further suggests, that *ke-ke-me-na ko-to-na* land, the communal land owned by the *damoi*, was at least partially held by individual households within the *damos*. The palatial administration treated the *damoi* as collective units, types of corporations, recognizing their ownership rights while establishing a relationship based on returning services. On the contrary, Deger-Jalkotzy (1983: 101-102) argued that the *wanax* was still the ultimate owner of all property, and that he transferred the landownership rights downwards to the *damoi*. Lupack (2008: 67) suggests that, since the *damoi* paid taxes to the central government, they were ultimately subordinate to the system. However, *damoi* were able to manage their resources by themselves and govern their own people with respect to most daily issues. This indicates that they held a level of independence from palatial rule. This is also the preferred view in this study, although, as said above, the settlement hierarchy, and thus regional governing was likely different in the Argive Plain than in the Pylos territory.

Mycenaean economy

Centralization of power and resources in Mycenaean palatial centres, and the assumed redistribution of resources transformed into items of subsistence or exotic value in a highly controlled way have dominated our understanding of the LBA Greek economic system. Generally, centralization indicates the increasing control by the central power over the society, while economic centralization describes the control over the production, distribution and consumption of a variety of items.

Recent studies have argued that the Mycenaean economic system developed into a centralized system from the reciprocal relations which were characteristic of the preceding Middle Helladic communities (Galaty *et al.* 2016: 66-68; Nakassis *et al.* 2011: 181; Voutsaki 2016: 76-77). These relations were maintained by a system of gift and service exchange. In time, inequalities created by gift exchange developed into centralization of resources. In this scenario, the maintenance of the kinship relations transformed into conspicuous consumption, in which the emerging elite manifested their power and gained allies by displaying and distributing valuable materials and objects (Pullen 2016: 85; Voutsaki 2001: 205-207, 2016: 76-77). This facilitated the separation of elite from the rest, while beneficial partnerships transformed into dependency relationships (Galaty *et al.* 2016: 66; Voutsaki 2001: 205-207, 2010: 96, 2016: 75-76). Voutsaki (2016: 72) describes the process as 'eroded' reciprocity. According to her, the accumulation of wealth reflects a change from an egalitarian kinship to a stratified and individualistic societal organization.

The following section provides an overview of the main aspects of the Mycenaean economy as it appeared in the LH III period after completing the transformation described above. Understanding the key aspects of the local economic system is relevant to the study of the LBA agricultural practices, since it seems crops were produced in several economic sectors, and for multiple purposes beyond basic subsistence needs. While the LBA subsistence agriculture is discussed in pp.132-149, this section focuses on two other economic aspects: the so-called palatial production, and taxation.

Taxation

The shift of power in the direction of the emerging palaces appears to have been formalized in the development of a centralized tax system (Voutsaki 2001: 204-205). Mycenaean palaces supported themselves by collecting resources, services, and goods from the communities living in their surroundings. These transactions are recorded in the Linear B texts of Pylos and Knossos. 'Taxes' were collected in the form of portable commodities, such as olive oil, textiles, or raw materials such as hives, wood, or spices and herbs meant to be used in the palatial craft production (Halstead 1992: 59; 1999a: 319; Killen 1984). At least in Pylos, taxes were collected from both communal (*ke-ke-me-na*) and privately owned (*ki-ti-me-na*) lands (Killen 1998; Lupack 2008). The Pylian territory was divided into taxable districts, each of which were required to provide the same set of products. Regional specialisation to the manufacturing of specific products did not occur (Halstead 1992: 59). In Pylos, the amount of taxes likely varied according to the size and population of the region (Halstead 1999c: 36), but, as discussed previously (pp. 8-10), taxes could also mean services, such as individuals signed to military duties.

Since at least the three major sites of the Argive Plain, Mycenae, Midea and Tiryns, kept administrative records, does this mean each of them maintained their own tax systems? Neither taxation or the palatial production of staples (see next section) of the Argive Plain have been directly touched upon in recent literature. This is because there is not much evidence, textual or material, to argue for or against such systems. There is hardly any evidence of territorial division amongst the Argive plain settlements, nor are there references to regional administrations, or to settlements subordinate to one of the major centres of the plain. However, the Linear B tablets discovered at the House of the Oil Merchant at Mycenae do mention an extensive list of specific goods, such as herbs and spices, which could represent products collected as taxes (Bennett Jr. and Chadwick 1958: 107). Furthermore, the *ta-ra-si-ja* system recorded in the same tablets is related to the production of wool and leather textiles and metals, and as such could also suggest that at least some of the raw materials, for example hives, were collected as taxes. Many of these items may also have been part of the palatial direct production (as wool likely was) or imported through maritime trade (for example precious metals). Furthermore, the record of a herder together with a specific amount of land (6 GRA) in the Tiryns tablets (pp. 13-14) seems to resemble recordings in the Pylos E-series which have been interpreted as inventory records for taxation purposes. If so, the Tiryns fragment would be part of a palatial inventory that listed plots of which taxable products were expected. If Tiryns followed a similar taxation system as Pylos, it is likely that the other two centres, Mycenae and Midea, would have had their own systems in place too. Nevertheless, since there is only one piece of evidence, it would be unwise to draw any firm conclusions about the economic systems exerted by individual palaces of the Argive Plain. Thus, the current data cannot answer the questions of taxation in the LH III Argive Plain.

Palatial production

Besides acquiring products from outside producers, Mycenaean palaces executed direct production of certain goods, such as wool (for textiles), wheat, olive oil, and wine. This production was separated from the taxation system and more systematically monitored (Halstead 1999c: 36; Shelmerdine 1999b: 21). Halstead (1992: 60-61) suggests that this direct production was mainly agricultural and that it was located on lands close to the central authority or important sub-centres. This land could have belonged to one of the administrative officers, the *wanax*, or to the *damoi*, who allocated it for palatial use (Halstead 1999c: 39).

At the same time, the control over such items was sometimes ambiguous, as illustrated by the distribution and processing of wool. Linear B evidence from Knossos, Thebes, and Pylos suggests that wool collected for palatial use was used by the *ta-ra-si-ja* system, in which wool was given to specialized workers such as spinners, weavers, and finishers, who manufactured it into textiles. However, wool was also given to non-textile workers as a reimbursement of their services to the palace (Alberti 2012: 101-3; Rougemont 2014: 358-60; Varias Garcia 2012: 159). Nosch argues (2014: 395-96) that at least in Knossos, the amount of wool collected from the 100,000 sheep recorded in the Linear B texts was so high that the palace could not afford to support all the workers needed to manufacture it into textiles. Therefore, rather substantial amounts of the palatial wool could have been used as reimbursement. Wool was also sent away from the palatial centres to other settlements, sanctuaries, and individual households, perhaps to special workers residing in these places (Alberti 2012: 101-3; Rougemont 2014: 358-60; Varias Garcia 2012: 159). In conclusion, it seems that the raw materials and finished products, also described as palatial production, did not remain solely for the use of the palatial elites but were distributed more widely.

Part of the direct production was likely used to pay the palatial workers in food rations, although Halstead argues (1999c: 38) that only one third of the palatial workers received rations while the rest were paid in land allocations. In the Pylos tablets (Er-series), these landholders were required to contribute wheat or other agricultural products to 'Poseidon and others' (for example to the sanctuary of Poseidon, *pa-ki-ja-ne*). Killen suggests (2008) that these records describe a system in which the landholder was expected to give a share of the production (preferably wheat, but also other foodstuffs as an equivalent of wheat) to the central authority in exchange for the holding. The size of this contribution depended on the size of the plot.

As described in detail in this dissertation on pp.8-10, in many cases the nature of the landholding was linked to the products and services the holder provided to the palace. In exchange for the right to cultivate a plot of land, the individual had to accept the terms, for example the production targets, set to the lease by the palace (Shelmerdine 2008b: 130-34). If what Killen (2008) suggests is true, the palace received its sustenance through three channels: taxes in the form of special goods and services, direct production of bulk goods, and small streams of bulk goods from each land lease. Of these, the first two are firmly attested in the research tradition, while the status of the latter remains unclear. Furthermore, if land leasers contributed a share, this contribution could have been made towards any local authority, for example a *damos* or a sanctuary, not necessarily towards the palace.

Control over the availability of goods

Redistribution has been a vastly debated concept related to the Mycenaean palatial economic system, and thoroughly redefined and discussed in a set of recent papers introduced by Galaty and co-authors (2011;[5]). Redistribution refers to centralized collection of resources by a higher authority, and their distribution to the dependents, for example as finalized products of value, or as food rations. In the LBA Greek context the central authority is the palace, from which the products are redistributed back to segments of the community in a controlled way (Killen 2008).

The redistribution theory derives from the works of Polanyi and Finley, and Renfrew. According to Polanyi (1977: 51-52), in 'primitive' societies the economy was embedded in social relations. The organization of labour, land use, distribution of products etc. occurred through social interaction and relations, which functioned through kinship and gift exchange. From the 'primitive stage', the economy evolved towards the 'archaic stage',

[5] Several contributions in the Redistribution in Aegean Palatial Societies forum, published in the *American Journal of Archaeology* 2011, Vol. 112, No. 2 (April 2011).

in which redistribution is the main economic activity. This change entails the accumulation of products by elites, a central authority, and product redistribution. This system created and maintained social structures, such as the elite status. Polanyi (1977: 67-73) did not describe a central place as having had a significant role in the collection of products, but rather referred to the control of the movement of these products by the central authority.

Finley compared the economic model of Mycenaean society with that of Bronze Age Near Eastern examples, which were better documented in writing. According to him (1957: 134-35), the redistributive system was a massive operation that included the movement of personnel, activities, and materials, which were all organized and controlled by the palatial administration. This system of transactions was recorded in the Linear B texts. Elsewhere, he (1979: 63) refers to 'distributing the booty', created by wars and trade, which was first collected to a central storage from which it was distributed forward. In times when 'booty' was not available, relationships were maintained by gift giving, which included objects of value, but also services, rewards, prizes, fees and other types of payments (Finley 1979: 64-66). Finley, however, points out that exchange of essential products must have taken place between rural household outside the redistributive system, since they had no access to the trade of valuables (Finley 1979: 70).

Based on its political and economic system, Renfrew (1972) defined the Bronze Age Aegean as a chiefdom. Chiefdoms were redistributive, and they had a central administration that played a significant role in the economic, political and religious activities (Renfrew 1972: 363-65). The palatial centres of the Mycenaean and Minoan societies functioned as redistributive centres, where exchange of goods took place. Their import was organized through tax collection, and the redistribution by the palace mainly concerned foodstuffs (in some cases also raw materials such as bronze). For the collection of goods, each palace had large storage facilities in which they could store bulk products such as grain and oil (Renfrew 1972: 296–97).

Various reinterpretations of state formation and the redistributive system have since been presented. Killen (2008) saw redistribution mainly as a system in which the palace allocated raw materials to its craft workers. Craftsmen and women were dependent or semi-dependent on these commodities and/or the rations of foodstuffs given to them by the palace. Like Finley and Renfrew, he (Killen 2008) argued that large storage facilities of the palatial centres were used to store bulk goods such as cereals before redistribution. According to Bennet (2001: 25), the Mycenaean 'state' would only collect, store and redistribute staple crops. The more precious resources, such as valuable materials, would be 'mobilized' so the palace could participate in the Mediterranean trade. Thus, the movement of these resources would be supervised, but they would not be centrally collected or actively redistributed.

In the redistribution of products, according to these traditional models, the palace maintained tight control over the society, including the subsistence farming communities. Recent studies (e.g. Galaty *et al.* 2016; Lupack 2011; Nakassis *et al.* 2011; Pullen 2016; Voutsaki 2016) have, however, pointed out discrepancies and the absence of the redistribution and centralization models in the textual and material evidence of the mainland Mycenaean palaces. Such as the absence of large storage facilities in the mainland palatial sites (Privitera 2014). The palace controlled (i.e., recorded) only a very selective variety of materials production and distribution. For example, pottery production it is not mentioned at all in the texts but is present in substantial amounts in the material records (Thomas 2005: 539). Similarly, the absence of pulses in the textual evidence contrasts with their physical presence in LH III storage and household contexts (Halstead 1992; Valamoti *et al.* 2011). Therefore, the limited variety of items recorded by the palace does not credibly prove that all subsistence items were centrally collected and distributed. The redistributive system was not all-encompassing as previously suggested.

The idea that the palace would have had almost complete control over all levels of the society has come into question. Nakassis *et al.* (2011: 177) call the model 'inaccurate and misleading'. Instead, redistribution is now seen as one among a variety of exchange strategies (Earle 2011: 241–43; Nakassis *et al.* 2011: 177). Nakassis *et al.* (2011: 181) refer to parallel economies, which operated alongside each other. The ration system, which had palatial labourers receiving a share of cereal and other foodstuffs, formed one such economy, while land allotments given to other workers of the palace (likely with a higher status) formed another, and people living in the countryside belonged to yet another parallel economy. Earle (2011: 238-241) divides the BA Aegean economies into four sectors: the subsistence economy, the trading economy, the religious economy of sanctuaries, and the political economy of palaces. While the political economy has been at the centre of scholarly interest, the subsistence economy, practiced by the local farming communities, has received much less attention, and the relationship between the two remains poorly understood. Each economic sector seems to have had some autonomy, but they were also intertwined since, for example, the palatial economy relied on seasonal corvée labour and in return supported the subsistence economy with animal power, or infrastructure (pp. 8-10). There was no central control over the entire economy, only stricter control over some sectors of the economy. A similar conclusion has been presented, for example, by Voutsaki (2010, see in detail in pp. 31-35) in relation to the political and economic situation in the Argive Plain. Mycenae may have controlled the circulation of precious raw materials and objects, all the way from their acquisition through foreign trade to their final placement in burials with the deceased. However, even as such, this type of control only covered specific areas of the political and economic system of the area, and there was plenty of space for the autonomy for other functionaries.

For the palatial economy, the latest research prefers a decentralized model. In this system, the palace was involved in the final contributions of products, collected as taxes or produced on palatial land (Halstead 1992: 59; 1999c: 36). Instead of redistribution, scholars now use 'mobilization' to highlight that products are not really being redistributed and their movement is in one direction only, namely towards the palatial elite. Such mobilization of products was used by the elite to maintain and reproduce their power (Nakassis *et al.* 2011: 180). The evidence for the presence of elite-serving mobilization of products has been linked to a lack of substantial storage facilities in Mycenaean palaces (see pp. 82-84). It could also explain why the amount of land owned directly by the palaces appears to have been quite small (pp. 25-31), and probably could only serve the elite and their dependent workers (Nakassis *et al.* 2011: 180; Halstead 2011: 231).

Conclusion: Evidence of economic transactions

Much of the evidence available of the Mycenaean economy is textual, and therefore concerns the elite-economy, more specifically the transactions and resources that the Mycenaean palatial centres were interested in. While certain aspects of the Mycenaean economy, for example the use of specialist workers to make sophisticated products from allocated resources, or their payments in food products, seem to have been standardized between palaces located in the mainland an in Crete, local environmental and cultural characteristics notably shaped palatial economies. Therefore, models of Mycenaean economies from other regional contexts cannot be directly applied on other regions where evidence of transactions is scarce.

The current understanding of the Mycenaean economy implies that redistribution did not encompass the entire economy, although it was functional in specific economic sectors, such as the craft industry (Christakis 2011: 197; Earle 2011). It is, thus, possible to separate parallel but intersecting economies within the Mycenaean socio-economic system, and to examine them individually. The subsistence economy seems to have functioned more or less autonomously from the palatial economy. Therefore, it is logical to examine it in its own right, as will be done in the present study.

Unfortunately, there is much less evidence of transactions between rural communities or non-elite individuals, or economic activities related to everyday staple products. Therefore, indirect, non-textual evidence, such as the presence of ceramics and their distribution across the mainland has to be taken as an indication of the existence smaller-scale economic interactions. In addition, ethnographic accounts can help to shed light on the nature of resource acquisition and use in non-elite communities (see pp. 139-150).

Summary: Mycenaean society and economy

The picture of the society and economic system of the Mycenaeans emerging from the Linear B textual evidence is complicated and, in many parts, still unclear. Some interesting general aspects can be collected from the presentation above, however.

Firstly, although Mycenaean society was stratified, the top of the hierarchy, the *wanax*, nor the palatial elite held absolute decisive power over the society. Various parties had power to perform economic transactions (Lupack 1999: 2008). The ability to function independently without the intervention of the palatial authorities might have created opportunities to grow wealth and power (Halstead 1993: 2001).

The local *damos* communities had decisive or, at the least, negotiative power over land. These communities likely consisted of farming households and groups of households. It is possible that the *damoi* represent old power structures which by the LH III had been partially taken over by the newly emerged palatial elite (e.g. Deger-Jalkotzy 1983; Lupack 2008). This means that, politically, Mycenaean societies might have been in a state of transition, and that this could have created some level of social unrest (Deger-Jalkotzy 1983). This transition could have taken place at different times in different regions. This could even partially explain differences in settlement patterns between areas such as the Pylian state and the Argive Plain.

Secondly, land was held in high value in the Mycenaean societies, likely because it could be used for subsistence purposes, but also because it could provide small stock through bulk or specialized products. Complicated categorizations, agreements and rules regulated the use of (agricultural) land (Bennett Jr. 1956; Lupack 2008). Land could be divided into smaller plots, and one individual could own several plots located away from each other (Uchitel 2007). However, such organization does not seem to describe land fragmentation through a hereditary system, which has been characteristic of recent Greek agricultural communities. Land was an interest to the palatial authority, which means it was measured, and production targets were imposed on it (Killen 1998, 2008; Uchitel 2007). Textual evidence points to much of the land being used for agricultural production.

Thirdly, it seems quite possible that each individual or party holding some level of rights to production land were obliged to contribute part of its production to a higher authority. This authority could have been the palace, but it could also be a *damos*, or a sanctuary, or a private landowner. This provision had to be considered when anything was produced on the land (see Killen 2008 for further thoughts on provision). The provision could have been part of a tax system, in which case the production target was imposed over a larger community and overseen by the local administrative members of this community.

Finally, the Mycenaean economy consisted of various sectors which can be observed separately, although they did not necessarily function in complete independence (Earle 2011). The palatial economy formed its own entity and had diverse needs related to the subsistence economy of the local farming communities. While the first has been studied in detail, the latter remains more unknown. This book intends to contribute to the study of the Mycenaean subsistence economic sector through its case study area, the Argive Plain. The following chapter will, therefore, focus on examining this specific area in more detail.

Chapter 3

The Late Bronze Age Argive Plain

The Argive Plain is a fertile, sheltered plateau in the northeast of the Peloponnese. It is bordered by the Argolid Gulf in the south, and mountainous areas in the east, north, and west. The plain is part of the regional unit of the Argolid, which is archaeologically one of the most intensively studied areas in the Aegean (Darcque and Rougemont 2015: 557; Pullen 2013: 437; Voutsaki 1995: 55, 2012: 599). During the Late Bronze Age, the Argive Plain developed into a political and economic core of the eastern Peloponnese. Fortified settlements were located at relatively short distances from each other, and a broad road network was established (Cherry and Davis 2001: 143; Pullen 2013: 443; Sjöberg 2004: 130-146; Voutsaki 2012: 605). Burial finds and other material evidence testify to good connections to distant regions (Cline 1994; Vianello 2011: 164-65). Especially towards the end of the Late Bronze Age, manufacturing of valuables took place in the palatial workshops (Bennet 2008: 151-52; Brysbaert and Vetters 2010: 2013). Extraordinary skills in architecture are manifested in monumental fortification walls and tombs (Hitchcock 2012; Loader 1998; Maran 2006). These structures have inspired archaeological research for over a century.

The settlement pattern of the Argive Plain is unique in the Mycenaean context, since it contained multiple large sites located only a few kilometres apart. Their physical closeness has raised many questions about the local political and economic organization in the LBA. The section below presents an overview of what is known of the Argive Plain settlements and their development in the period. It further presents some of the most important theories concerning the settlement patterns and hierarchies in the LBA Aegean context and discusses how little is known of small farming communities.

Survey and reconnaissance projects in the Argive Plain

Large-scale intensive surveys have not been conducted in the Argive Plain. This is likely due to the thick layers of alluvial deposits (see pp.65-69), which cover large areas of the central plain, and have been estimated to cover most of the prehistoric and LBA remains (e.g. Wright 2004).

Smaller survey and reconnaissance projects have, however, shed some light on the local LBA settlement pattern. In addition, more recent rescue excavations in the inner-city areas of Nafplion and Argos have yielded new information about the extent of these settlements in the LH III period and uncovered some new sites, mainly single tombs and walls, as well as artifacts of LH date (Piteros 2002a, 2004b; Sarri 2008). Challenges in accessing these data outside of brief excavation reports have so far prevented analyses of the status of these sites in the Argive Plain settlement pattern. However, being found within the city areas, they are likely to have been part of the greater settlement rather than of individual dwellings. In general, data concerning smaller LH III settlements are limited, often poorly published or not published at all (Bintliff 2016: 36). To fully update the list of all Bronze Age recovered sites of the plain, both systematic survey and archival work are needed.

One of the most recent surveys within the Argive Plain has been the Mycenaean Survey, which was conducted in the 1990s in the immediate surroundings of Mycenae. The project (re)discovered over 200 archaeological sites, including dwellings, burial sites, and infrastructure (Iakovidis and French 2003). Many of the sites had originally been found in the 1880's by B. Steffen, a German topographer who surveyed the area in collaboration with Schliemann, who was excavating Mycenae. The survey area consisted of an area described as 'Greater Mycenae', *c.* 350ha in size, and extended further to the fringes of the modern village of Monastiraki, towards the Berbati Valley, as well as north and north-west along the modern highway and the village of Fychtia (Figure 3.1). Although not specified, the survey must have covered an area of about 10km2. All sites within the Greater Mycenae are thought to have been strictly controlled by the citadel, while most sites recovered outside this area were interpreted as satellite settlements.

Most of the discovered sites are individual chamber tombs or chamber tomb cemeteries, some of which include scattered wall structures nearby. In many cases, evidence of the actual settlement in terms of architecture or artifact scatters was not recovered. Five satellite settlements, Chania (Khani), Fychtia, Monasteraki, Tserania and Plakes, were recognized outside Greater Mycenae (Figure 3.1, Table 3.1). Another unnamed site along the modern Argos-Corinth road (no 29 in Figure 3.1) may have been a similar *mansion* to Chania (see p. 30), but the scarcity of architectural remains prevents conclusive interpretations of the site's nature. Additionally, sites such as the chamber tombs in Plesia and Sklaveika, as wells as terrace and wall structures in Gouves could represent small satellite settlements inside Greater Mycenae. These sites could not be identified with certainty due to landscape changes related to heavy cultivation. Besides including a potential settlement, some of these sites provided valuable resources, such as clay (Tserania and Plesia) or stone for quarrying (Iakovidis and French 2003: 24).

Another intensive survey, the Western Argolid Regional Project (WARP), directed by D. Nakassis, was conducted in the gently sloping hills west of Argos. Although some of the results of this project have been published (list of publications in Nakassis 2021), prehistoric and Late Bronze Age recoveries remain unpublished. These results are awaited with great interest, since they might reveal new insights into the distribution of small, rural sites within the Argive Plain.

In relation to the wider plain area, two site reconnaissance projects conducted in the 1960s and 70s still provide the most extensive records of the LBA sites in the area. Hope Simpson and Dickinson were the first to record the known sites of the plain and its surroundings. In the *Gazetteer and Atlas of Mycenaean sites* (1965), they listed all mainland LBA settlements by location, chronology, and, in some cases, by function and site size. The atlas was soon revised and complemented in *A gazetteer of Aegean civilization in the Bronze Age* (1979). The latter lists 20 to 25 Late Helladic settlements across and in the vicinity of the Argive Plain, together with many other sites, such as bridges, roads, cemeteries and single tombs (Hope Simpson and Dickinson 1979: 27-75).

Similar reconnaissance work of the LBA Argive Plain sites was conducted by Bintliff for his PhD dissertation (1977). As Bintliff (2016: 37) notes: '...since the 1970s the only notable addition to the key sites used in my settlement analysis for the Mycenaean period has been the poorly constructed and short-lived tholos tomb at Kokla...'. In his dissertation, he lists *c.* 20 LH settlements, and a few more sites of an unclear status in the Argive

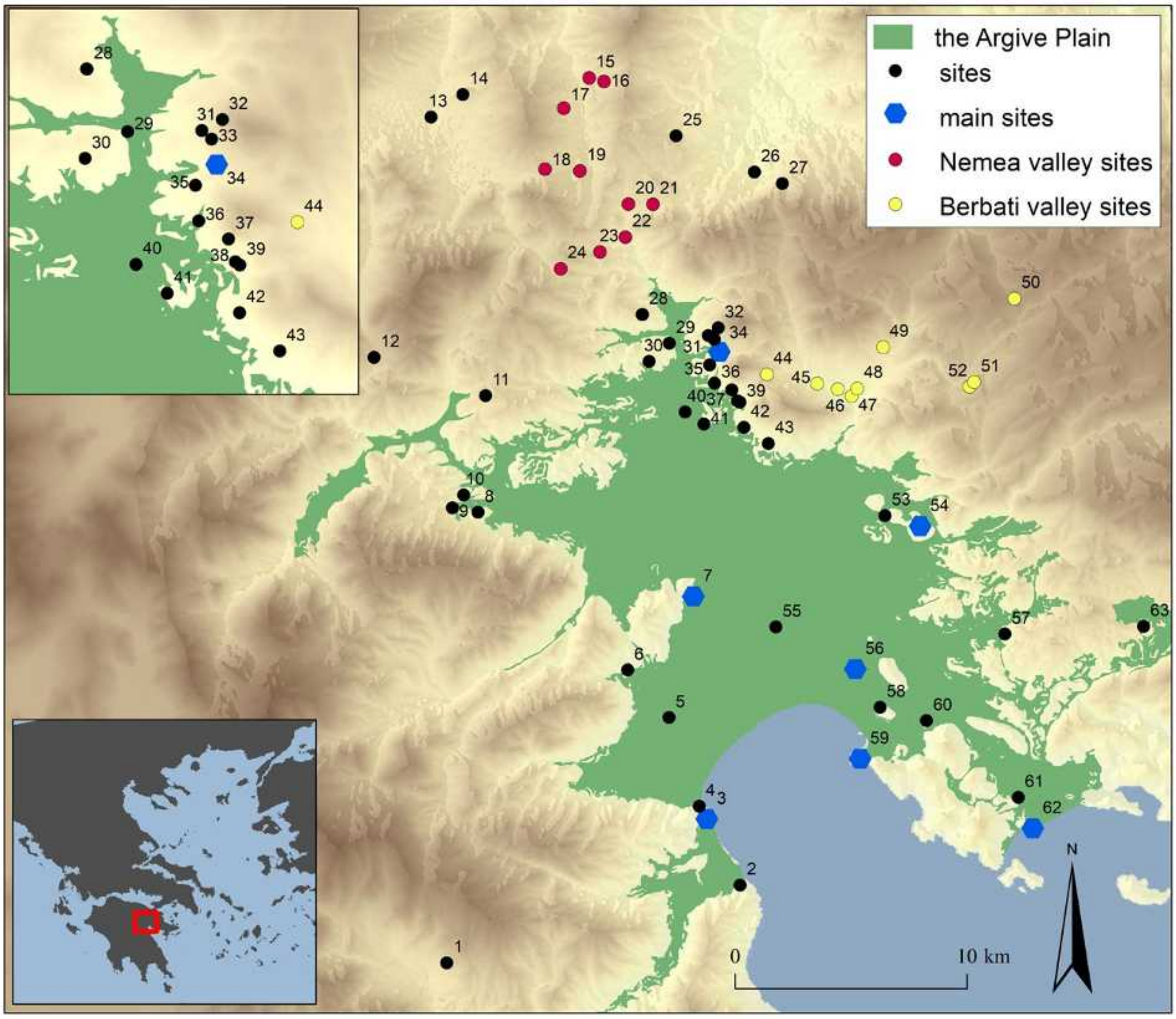

Figure 3.1. Known LH III sites in the Argive Plain.

Plain. Some settlements, such as Dalamanara, consist only of second-hand information of potential LH pottery sherds, whose presence Bintliff himself could not verify (1977a: 335). The information of the small surveys, the Gazetteers, and Bintliff dissertation, are all partially overlapping, and sometimes challenging to combine due to varying levels of locational data. Consoli (2019) has attempted to collect and publish the locations of these sites in Greece in an online database. Here, another attempt is made by mapping specifically the LH settlement sites in Figure 3.1.

Many of the sites previously documented have since vanished, either because excavation projects have ended a long time ago and the trenches have been covered, or because there were no more than a few sherds marking the location of the site to begin with. The difficulty of re-locating known sites was experienced first-hand by the author who, together with V. Klinkenberg (Leiden University), visited the sites listed by Bintliff (1977), the Gazetteer (1979) and the Mycenaean survey in 2016 and 2017. It was clear from the start that at most smaller sites, only the landscape features and visibility could be recorded. Nevertheless, 54 recognized LH sites (including dwellings, burial sites, and infrastructure) were recorded during these two field seasons. Figure 3.1 presents a map of the LH III Argive Plain sites compiled from the abovementioned sources. The site names are listed in Table 3.1. The map presents only settlements and gives some indication of the location of the LH III settlements in the Argive Plain and shows the relation of large and small sites.

Besides the disappearance of the material evidence of sites over time, other challenges complicate the understanding of the distribution of small, potentially agricultural settlements of the Argive Plain. As seen on the map (Figure 3.1), smaller settlements seem to cluster in the surroundings of larger sites such as Mycenae and Nafplion. This might be caused by research biases, such as the absence of systematic surveys and the concentration of research in these large sites. That said, it is possible that people lived close to the central places, having a better access to the resources of the more populated settlements and the protection offered by these centres. Data of small settlements are scarce. More data are available of single burial sites and cemeteries located across the plain, but cannot be connected to any settlement site. It remains an open question, whether the presence of a tholos tomb or a chamber tomb cemetery indicate the presence of a nearby settlement yet unfound. In the Mycenae survey, chamber tombs located within a short distance from Mycenae are often interpreted as individual satellite settlements (Iakovidis and French 2003). Smaller settlements would have used their own

Table 3.1. List of the numbered sites in figure 3.1.

Achladokampos	1	Plakes	33
Kiveri	2	Mycenae	34
Lerna	3	Kalkani	35
Myloi	4	Tserania	36
Magoula	5	Gouves	37
Kokla	6	Plesia	38
Argos	7	Sklaveika	39
Schoinochori	8	Chania	40
Melissi	9	Monasteraki	41
Skala	10	Vreserka	42
Malandrini	11	Argive Heraion	43
Gymno: Kastro	12	BLAS[1] 428	44
Agia Irini	13	Mastos	45
Phlious	14	BLAS 35	46
NVAP[2] 922	15	BLAS 306	47
NVAP 925	16	BLAS 301	48
NVAP 3	17	BLAS 414	49
NVAP 400	18	BLAS 12	50
Tsoungiza	19	BLAS 44	51
NVAP 205	20	BLAS 43	52
NVAP 209	21	Dendra	53
NVAP 213	22	Midea	54
NVAP 923	23	Dalamanara	55
NVAP 503	24	Tiryns	56
Kleones	25	Profitis Ilias	57
Zygouries	26	Ayios Elias hill	58
Agia Triada	27	Nauplion	59
Panorama	28	Aria	60
Argos-Corinth road site	29	Asine road site	61
Fychtia: Boliari	30	Asine	62
Batsourourachi/ Asprokhoma	31	Agios Ioannis: Kazarma	63
Souleimani	32		

[1] BLAS stands for the Berbati-Limnes Archaeological Survey. The number corresponds to the code give to the site by the survey.
[2] NVAP stands for the Nemea Valley Archaeological Project. The number corresponds to the code given to the site by the survey.

cemeteries instead of burying their deceased at the larger burial sites of "Greater Mycenae". With a similar logic, other small, clustered burial sites across the plain could be interpreted as signs of small communities. Mee and Cavanagh (1990: 229-31) have explored similar ideas in the Argive Plain context. While admitting that smaller settlements and cemetery sites may yet to be recovered in the LH III Argive Plain context, and that cemeteries are usually located in the close surroundings of settlements, they conclude that there is not enough evidence to prove that the Mycenaean occupation consisted of dispersed small clusters of settlements using their own cemetery sites. Furthermore, dispersed, seemingly loose cemetery sites and settlements are often dated to different periods (for example to LH IIIA or LH IIIB), and cannot as such be connected with each other. More systematically acquired data of the LH III Argive Plain settlements are needed to establish a clear idea of the level of urbanization, the scale on which immigration towards larger, densely populated centres took place in the area. In the meanwhile, its settlement pattern can be compared to other areas with LH III occupation, however. The following section presents an overview of surveyed areas nearby the Argive Plain in the eastern Peloponnese. This is followed by a discussion of the relationship between large and small settlements in the Argive Plain and in the Mycenaean Peloponnese.

Surveys in the eastern Peloponnese

Besides the reconnaissance projects in the Argive Plain, four intensive survey projects; the Southern Argolid Research Project (SARG), the Methana Survey, the Nemea Valley Archaeological Project (NVAP), and the Berbati-Limnes survey, were conducted in regions adjacent to the plain during the 1970s and 80s (Figure 3.2).

In the Southern Argolid Research Project, a total of 37 LH sites were recorded in a survey area of *c.* 44km2. Of these, 18 were identified as settlements. Two settlements were described as large (5.0ha and 7.7ha, respectively), three as medium-sized (1-2.5ha), and the rest as small (less than 1 ha) (Jameson *et al.* 1994: 253, 544-555, tables 4.7 and B.2). Most of the sites were classified as special purpose sites, farmsteads or smaller units with an agricultural function. No tombs were detected in the survey. The LH settlement pattern is generally described as dispersed (Jameson *et al.* 1994: 544-555, table 4.8). A sharp increase of small sites from the MH to the LH period was detected, and the largest LH sites concentrated upon EH sites (Fournoi, Koiladha and Ermioni) after a break in habitation in the MH (Jameson *et al.* 1994: 254). While in the MH period most of the settlements (75 percent) were located close to the seashore, in the LH 43 percent of the sites were located in hills and valley slopes and 19 percent in the rugged mountains (Jameson *et al.* 1994: 245, table 4.4; 254). The small LH sites were located on or close to fertile soils, while the largest sites were consistently located along good connection routes to the coast (Jameson *et al.* 1994: 352). Most of the sites were abandoned at the end of the LH period (Jameson *et al.* 1994: 371). The LH population size (with a density of 125 ppl/ha) of the surveyed area was estimated as 1800 people (Jameson *et al.* 1994: 547).

In the Methana peninsula, pedestrian survey covered *c.* 11km2 and recorded eight LH sites. The survey did not reveal sites which could be categorized as central places, and only a two-tier hierarchy of villages and hamlets/farmsteads was established. Most of the Bronze Age sites were located in the narrow coastal strip, close to arable soils and with easy access to the sea (Mee and Taylor, 1997: 53, table 4.4). The local geography, dominated by high altitudes, limited the site location in Methana, similar to the Southern Argolid peninsula. Methana is connected to the mainland Southern Argolid only by a narrow strip of land, and its central part is covered by a rough mountain range. The material evidence suggests that the region was connected to Mycenae and Tiryns, as well as to the island of Aigina (Konsolaki 2002: 35).

The Nemea Valley Archaeological Project covered an area of *c.* 85km2 around the ancient settlements of Nemea, Kleonai and Phlious. The survey recorded 10 LH settlements (although LH finds were recovered from 25 locations). Of these, the size of Tsoungiza, *c.* 7.5 ha, is comparable to the LH site of Mastos in the Berbati Valley, and potentially to LH Asine. In the regional context, Tsoungiza constitutes a central place, with a size three times as large as the other LH settlements, including a total of seven chamber tombs in its close surroundings, one in the hilly Barnavos area, and six others comprising a cemetery at Ayia Sotira (Dabney *et al.* 2004: 197-199; Karkanas *et al.* 2012; Smith *et al.* 2009). Evidence of religious feasting at Tsoungiza suggests that the site could have functioned as a regional centre where the inhabitants of farmsteads from the wider region came to participate in celebrations (Dabney *et al.* 2004: 213; Karkanas *et al.* 2012; Smith *et al.* 2009).[3] However, there are no clear indications that Tsoungiza controlled the surrounding settlements in a political or economic sense (more about Tsoungiza on pp.29-30). The remaining Nemea sites were small, less than 2ha in size (Cherry and Davis 2001: 148-50). The valley has undergone events of alluviation similar to the Argive Plain. Nevertheless, the LH settlements were located in various parts of the survey area, and it was argued that the alluviation did not cover LH sites nor distort

[3] See also the very recent publication by Smith, A.K; M.K. Dabney; E. Pappi; S. Triantaphyllou and J.C. Wright (eds.) 2017. *Ayia Sotira: a Mycenaean chamber tomb cemetery in the Nemea Valley, Greece* (Prehistory Monographs 56). Philadelphia: INSTAP Academic Press.

the recorded settlement pattern (Cherry and Davis 2001: 152-55; Wright *et al.* 1990: 587-91).

In the Berbati Valley, erosion due to deforestation and modern agricultural activities has stripped the valley of the majority of prehistoric and Bronze Age remains (Wells *et al.*: 1990, p. 214). The surveyed area comprises 60km^2, of which 25km^2 was walked intensively. Of the 20 LH findspots, 8 were determined as dwellings, most likely farmsteads (Schallin 1996: 166). The previously known pottery kiln and settlement of Mastos (the largest site, compared often to Tsoungiza in the Nemea Valley) in the centre of the valley was not included in the surveyed sites and there was only one other larger site (FS 14) with a size of 6ha (Schallin 1996: 166, Fig 31). Sites were discovered mainly in the centre of the valley and in the uplands in the east of the region, where erosion had not taken place. During the LH, the activity around the central place of Mastos decreased (see p. 29), and the settlement pattern became dispersed, extending into the Limnes uplands in the east (Schallin 1996: 124). This development is interpreted as an expansion and intensification of agriculture in the area under the direct influence of Mycenae (Schallin 1996: 170). The influence of Mycenae in the area is further attested by a well-built road, the 'Mycenaean highway', which was constructed between the valley and Mycenae in the LH III period (Wells *et al.* 1990: 213).

In each of these survey areas, small sites were found dispersed in the LH landscape, which did not exhibit notable clustering around central sites. It seems they were in most parts self-sufficient, controlling their own land and production, and located close to the fields which provided their inhabitants with sustenance. A rough estimation of the density of small sites in these areas (Table 3.2) shows that these farms or hamlets were located far apart which means that the rural population probably remained low.

Two of the surveyed areas included one or two larger sites which could be considered as central places. In Nemea, Tsoungiza (see also pp.29-30) was the only larger site. In the Berbati Valley, Mastos, with its pottery kiln and fortified acropolis (more on Mastos on p. 29), and FS14, which only yielded an artifact concentration,

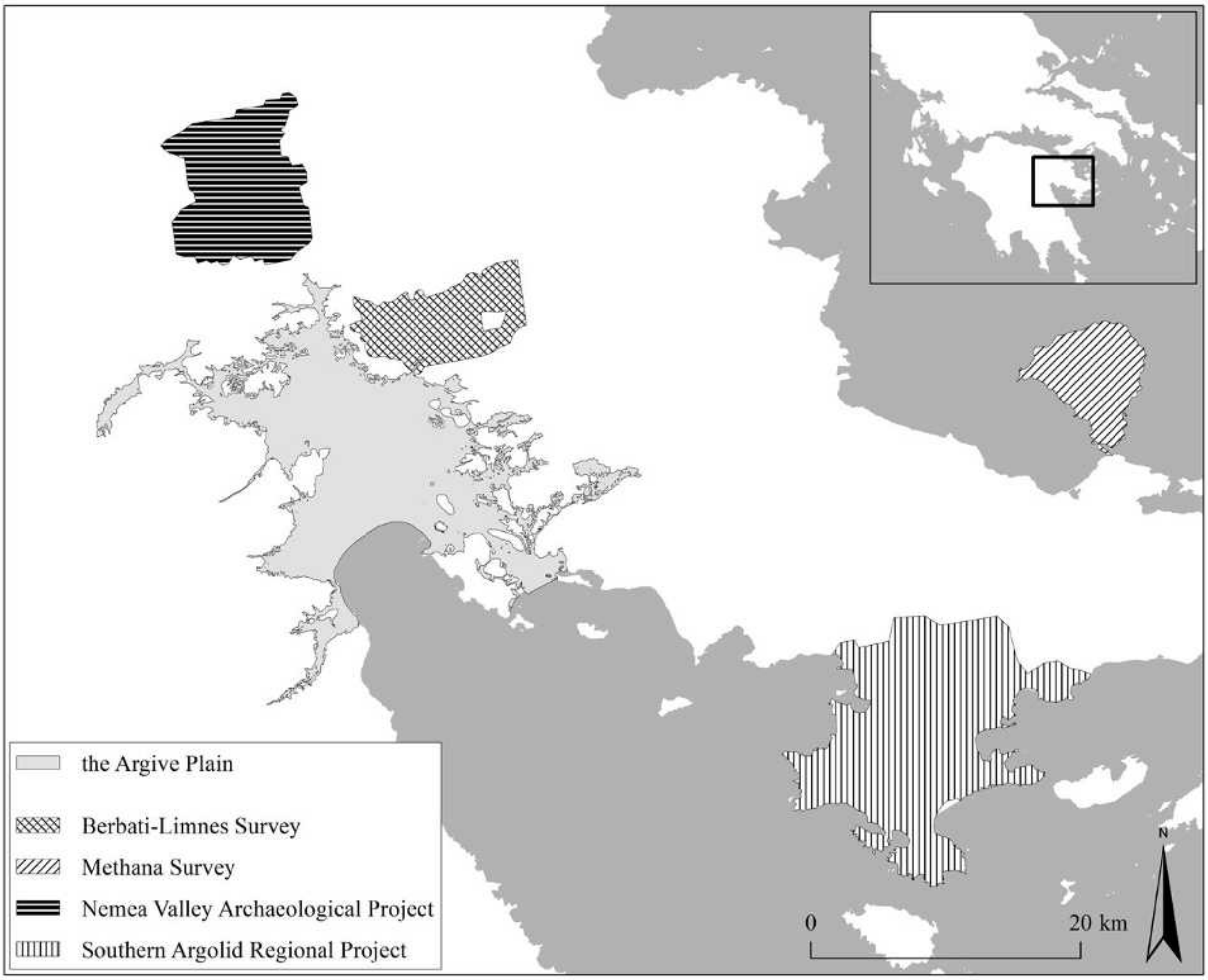

Figure 3.2. Major survey projects conducted in the surroundings of the Argive Plain.

Table 3.2. Estimation of densities of small settlement sites in the surveyed areas of the eastern Peloponnese.

Survey	Walked area/km2	LH Settlements total	Small LH settlements	LH Settlements/km2
SARG	44	18	13	0.3
Methana	11	8	8	0.7
NVAP	85	10	9	0.1
Berbati-Limnes	25	8[4]	7	0.2

were clearly larger in size than the other sites. However, the function of F14 and its relation to Mastos remain unknown. The growth and decline of Mastos and Tsoungiza seems to be connected to the activities of Mycenae in the LH III period (Cherry and Davis 2001; Schallin 1996). Compared to Mycenae, Midea and Tiryns, the three largest Argive Plain centres, these valley settlements remained small in size, architecture and wealth. However, both settlements had long life spans, from the Neolithic and Early Helladic periods to the end of the Late Helladic, similar to the Argive Plain citadels.

In the Southern Argolid, no central places were recovered that were visibly connected to the Argive Plain. Nevertheless, a few larger sites were present. Smaller sites showed a similar dispersed pattern as in the Nemea and Berbati Valleys. The Methana peninsula yielded only small sites with a likely agricultural function. In the Southern Argolid and Methana, challenges of the mountainous landscape may have resulted in a less hierarchical settlement pattern and a higher level of isolation and independence for small communities. Both regions may have further been connected to other areas, such as the Saronic Gulf through sea routes.

The Argive Plain settlements.

While survey and reconnaissance data have enlightened us about the smaller agricultural settlements around the LH Argive Plain, the plain itself has long been known for its larger sites, whose architectural remains have remained visible to date. Five to seven ‘major sites’, defined as such by their long occupation history, size, architecture, and finds of valuable materials, dominate the landscape of the plateau. These are Mycenae, Tiryns, Midea, Argos, Nauplion, Lerna, and Argive Heraion. Besides these, two other ‘major’ settlements, Mastos in the Berbati Valley, and Asine in the south of the plain are often counted as plain sites, although they are located just outside the proper plain area. Many interpretations have been made of the hierarchy and land use distribution between these sites in the LH III period. The following section presents the development of these sites and discusses their relation to each other.

Mycenae

The occupation history of Mycenae is long, the earliest sherd finds dating to the Neolithic period. From the Middle Helladic period onwards, material remains and architecture begin to show in greater frequency (Iakovidis 1983: 23). Additionally, over 100 tombs have been recovered on the west slope of the citadel in an area called the Prehistoric Cemetery (French 2002: 29-31). By the LH I period, Mycenae was one of the largest sites of the Argive Plain. Grave Circles A and B, two circular burial complexes including several shaft graves each, were built in the MH-LH transition, and an early ‘palace’ was constructed on the acropolis. At this time, habitation extended far beyond the acropolis hill (French 2002: 44-45). Most of the rock-cut chamber tombs, used for multiple burials, were also constructed during the early LH, and actively reused in the following periods (French 2002: 70-71; Shelton 2010: 187). The tombs are divided into a total of 27 cemeteries around the citadel and the residential area called Lower Town, located on the southern and western sides of the fortified centre. The location of the cemeteries might reflect landholdings of families or clans (French 2002: 70-71). The first tholos tomb, a large beehive-shaped structure, was constructed in LH IIA (French 2002: 44–45). The tholoi served to bury the Mycenaean elite.

Palatial rooms and other rooms inside the citadel walls, as well as the largest tholos tomb, the Treasury of Atreus, were constructed in multiple phases over the LH IIIA and early B periods (Iakovidis 1983: 27). Habitation in the unwalled Lower Town also expanded (French 2002: 52-61; Shelton 2010: 187). In late LH IIIA2, the citadel was partially destroyed, likely by an earthquake and subsequent fires. Rebuilding took place on a large scale around the city, but the event resulted in major changes to the city’s infrastructure (French 2002: 64-66; Shelton 2010: 199). New buildings with administrative, workshop, and storage functions were built inside the

[4] Excluding Mastos, which was not included in the surveyed area. The only large-sized site in this table is FS14 with an estimated size of 6 hectares (Schallin, 1996: 166, Fig 31).

citadel walls, whereas previously these had been located in the Lower Town area (Shelmerdine 1997: 394). This could indicate a stricter control over society, displayed also by the construction of fortification walls, the Lion Gate, the Cult Centre, and the more systematically organized layout of the palatial quarters during the LH IIIB (French 2002: 64-66; Mylonas 1966: 58-83; Shelton 2010: 199; Wace 1923, 1939, 1950, 1953, 1954, 1955). A complex named the Granary, possibly a central storage facility, was built close to the Lion Gate (see pp.82-85 for storage). Simultaneously, a complex of houses, the so-called Ivory Houses, was constructed outside the citadel. These houses functioned as commercial hubs and their storage spaces held a collection of Linear B tablets, connecting them to the palatial administration (Tournavitou 1995). Other tablets have been recovered in the citadel area (Shelmerdine 2008b: 122). In LH IIIB1/2 (1230 BCE/1250 BCE), the citadel was again destroyed by fire, which also spread to the Lower Town (French 2002: 64-66; Shelmerdine 2008b: 122). Only limited reoccupation of older buildings took place (Tournavitou 2015: 50-51). Material evidence attests to the end of most occupation at the site in LH IIIC Middle. The only exception is the East House in the Lower Town, which was erected in the LH IIIC Middle and Late periods (mature 12th cent. BCE) (Tournavitou 2015: 50-51).

Iakovidis and French (2003) defined the settlement area of Mycenae as *c.* 32 hectares, and the area of Greater Mycenae, the district directly under one administration, as *c.* 350 hectares during its peak in the early LH IIIB. The palace itself only covered an area of about 1 ha, while the palaces in Tiryns and Pylos were about 0.6 ha, and in Knossos 1.3ha (French 2002: 52-61; Shelton 2010: 186).

Tiryns

The earliest finds in Tiryns date to the Neolithic period, but it became a substantial settlement in EH II, when the settlement already extended over a considerable area (Maran 2012: 724). of the Rundbau, a tumulus was built in its place (although without burial use). In the Late Helladic period, the first levels of the Great Megaron of Tiryns were constructed at least partially on the location of the Rundbau (Maran 2016: 153-164). Some Middle Helladic structures are also found in the residential Lower Town area south from the palatial complex (Maran 2012: 724) suggesting that the site had a considerable size already before the Mycenaean peak.

The first palatial structures were erected in LH II-IIIA1, and it was during this period that the first Great Megaron, the core of the palace, was constructed. Unlike in most other Mycenaean palaces, a second megaron was also constructed at Tiryns during LH IIIA. At the same time, the first fortification walls were erected around the Upper Citadel (Iakovidis 1983: 3; Maran 2012: 725). Two tholos tombs were built within a *c.* 1km radius from the citadel, one of them excavated and published (e.g. Dragendorff 1913; Müller 1975) and dating to LH II / LH IIIA2-B1, and the other referred to as unpublished (Brysbaert *et al.* 2022: 39, footnote 1). In late LH IIIA2 - early LH IIIB the citadel was hit by an earthquake, likely the same that destroyed Mycenae. This event resulted in a massive project of rebuilding the palace area and the Lower Citadel (Avila *et al.* 1980; Grossman *et al.* 1980). Most of the cyclopean walls around the citadel and the Lower Town were also constructed in the LH IIIB2. Many structures which could be used for defence purposes were built, although most of them were also taken down soon after (Maran 2012: 727-28). Multiple galleries, likely serving as storage spaces, were added in the citadel area, and Linear B tablets were stored in the Upper and Lower Towns (Dörpfeld 2010 [original work from 1886]: 180; Shelmerdine 2008b: 122-24). Many of these activities seem to reflect political changes (Maran 2012: 727-28). In LH IIIB2, a major dam was built some 5 kilometres away from the citadel. This facilitated the extension of the Lower Town, parts of which had suffered from regular periodic flooding events until then (Maran 2009: 254; Maran *et al.* 2019; Stockhammer 2011: 215).

At the end of LH IIIB2, *c.* 1200 BCE, the settlement faced another major destruction, due to an earthquake. Similar devastations took place as in Mycenae and Midea (Maran 2012: 729). Unlike at Mycenae, rebuilding in Tiryns took place on a major scale after the second destruction of the site in LH IIIC. The citadel area remained occupied, and an underground cistern and a new monument called Building T were erected (Maran 2015: 282). Maran (2015: 284) describes the latter as the 'assembly hall of the post-palatial elite'. The Lower Town grew into a large, village-type settlement up to 25ha in size (Maran 2015: 283-84). The acropolis hill and Building T were not abandoned until the transition to the Early Iron Age.

The size of the site, including the citadel and the Lower Town in the LH III period, remains unknown, but the current estimations vary from 18ha (Bintliff 2020: 19) to 24.5ha (Zangger 1994a). According to Zangger (1994a) and Maran (2012: 730), the latter figure was the size of the settlement only in the LH IIIC period. In the LH IIIB the site is assumed to have been considerably smaller. Nevertheless, Wright (2004: 121) has argued that both Mycenae and Tiryns reached a considerable size of 35-50ha in the LBA.

Midea

Like Mycenae and Tiryns, Midea has a long history of occupation. The earliest sherd finds from the walled acropolis date to the Late and Final Neolithic periods.

EH and MH burials and architectural remains have been recovered on the acropolis. The EH habitation seems to have been limited to the summit of the hill, but in the MH the site extended onto the lower terraces (Demakopoulou 2015: 186). The habitation continued in the LH I, LH IIA and B, and LH IIIA1-B1 phases, but within the walled acropolis, the majority of finds date to the LH IIIB2. Similarly to Mycenae and Tiryns, this was the peak of habitation at the site (Demakopoulou 1995: 158). The citadel was fortified in the early LH IIIB2, and at that point consisted of two parts, the summit (acropolis), and the Lower Terraces (Demakopoulou 2015: 185). A megaron and most of the buildings in the core of the citadel were also constructed during the LH IIIB2. Evidence of any earlier phases of the megaron and the architecture of the acropolis have vanished over time (Demakopoulou 2015: 189; Schallin 2016: 79). Although valuable objects and raw materials are among the finds of the citadel, there is only scarce evidence of the production of crafted items in Midea (Demakopoulou 2015: 189; Schallin 2016: 80). The size of the citadel area has been estimated as some 2.4ha during its peak (Demakopoulou 1995: 153). Outside the citadel, the remains of a massive terrace wall have been recovered. The wall likely bordered the Midea Lower Town, a residential area which extended to the hill slopes in the northwest (Demakopoulou 2015: 185).

At the end of the LH IIIB2 the citadel faced a major destruction, evident from collapsed walls, burned layers, and even human remains crushed under large stone boulders. The event was likely an earthquake, which started fires in multiple places in the citadel (Demakopoulou 1995: 154; 2015: 186-87), similar to what happened at Mycenae and Tiryns. After the catastrophe, rebuilding took place on a small scale, and occupation continued at the site in LH IIIC (Demakopoulou 1995: 154; 2015, 192). The megaron was replaced by a smaller one in early LH IIIC. This development has been compared to the construction of Building T at Tiryns after the destruction of the citadel. At both sites, new buildings might have been erected for the purposes of a new political elite (Demakopoulou 2015: 189).

A large cemetery was located *c.* 2km away from the acropolis, at Dendra. It is assumed to have served the inhabitants of Midea (Schallin 2016: 76). The cemetery includes a tholos tomb and several large chamber tombs. Most of the tombs date to the LH IIA and B, but the tholos was constructed in the LH IIIA1, and two chamber tombs date to the LH IIIA2 - B periods (Schallin 2016: 87-89). The tholos contained objects of high value (e.g. gold and other precious materials), and three inhumations (Persson 1931: 68-69), suggesting elite use of the tomb.

Argos

The Bronze Age occupation of Argos covered two neighbouring hills, the northernmost Aspis, and the southern Larisa, and the Deiras ravine between them. Argos is well known for its extensive MH occupation, which included a settlement bordered by a fortification wall on the top of the lower Aspis hill until the MH to LH transition (Papadimitriou *et al.* 2015: 162-163; Philippa-Touchais, 2016: 651-657), and 'Quartier Sud' south of the Larisa slopes. The latter occupation area was abandoned by MH III, during which it was only used for burials (Touchais 1998: 74).

The layout of the LBA Argos is not well known. Rescue excavations have recovered remains all over the modern city, but large-scale systematic excavations are absent.[5] It has been suggested that by the LH III, Argos had diminished in size and status and was under the power of Mycenae (Voutsaki, 1995: 2001). However, considering the extent of the discoveries from the LH period in the modern city area, it seems that Argos was a relatively large settlement in the LH (Papadimitriou *et al.* 2015: 166, Figure 3b). Several buildings erected in the LH IIIA-B were still used in the LH IIIC (Papadimitriou *et al.* 2015: 168). A megaron-type building with fresco fragments and LH IIIA2 pottery (but with potential LH IIA-B dating) was also recovered in the modern city (Papadimitriou *et al.* 2015: 168). This recovery inspired speculations about the possible palatial status of Argos (Darcque and Rougemont 2015: 565; Tournavitou and Brecoulaki 2015). Papadimitriou and companions (2015: 179) suggests that Argos was a large secondary centre during the LH III period. LH IIIC sherds suggest use of the top of the Aspis Hill after the destruction that took place at Mycenae, Tiryns and Midea (see sections above), but other evidence of post-Mycenaean activities in Argos is scarce.

During the LH period, a large chamber tomb cemetery was founded in the Deiras ravine, on the slope of Aspis Hill (Touchais 1998: 75). The cemetery yielded some 40 chamber tombs, and dozens of pit and shaft graves. Two more chamber tombs were excavated on the other side of the ravine, on the slope of Larisa Hill. Unfortunately, the excavated tombs are not published in detail (Philippa-Touchais and Papadimitriou 2015: 449-51). Some of the tombs have been dated, the earliest to LH IIA-B, and the latest to LH IIIC. The peak of construction seems to have been in LH IIIA2-B (Philippa-Touchais and Papadimitriou 2015: 453, 462, tables 1 and 2).

[5] The rescue projects have been published as brief reports in the local archaeological series (Arch. Deltion). The work of the French School from Athens at the location is ongoing (Papadimitriou *et al.* 2015: 161).

LH pottery and some valuable foreign imports were also recovered on top of the Larisa Hill, which is now dominated by a prominent Byzantine-Medieval castle. Athanasoulis and Tsekes (2016) state that large boulders of Mycenaean origin were used in the construction of the historical fortification. Crouwel (2008: 268-69) argues that remains of a 10-14 meters long Mycenaean wall are located on the top of Larisa Hill, inside the Byzantine fortification walls. Additionally, a massive lintel (length 3.85m) was found reused within the fortification. The material of the block, conglomerate, varies from the material of the rest of the wall, and was typically used for the door frames in the other Mycenaean citadels of the area. These types of evidence could indicate that the site was a Mycenaean fortification.

Due to the nature of the investigation in the area, as well as the intensive modern occupation, the size of the LH settlement(s) of Argos is difficult to define. Whitelaw (2001: 29, Figure 2.10) (Whitelaw 2001: 29) has suggested a size of 17-18ha in the LH III period. Tomlinson (1972: 18) has estimated that the size of the city around 800 BCE was as large as 80 ha.

Lerna

Lerna is one of the few Bronze Age settlements located on the flat grounds close to the shore of the Argos Bay. Lerna's occupation history extends back to the Neolithic period. The site was inhabited during the EH and MH periods (Wiencke 2012: 661-67). In LH I-II, three early Mycenaean shaft graves were constructed in the settlement. Their presence has been linked to the emergence of an elite (Wiencke 1998: 207; 2012: 667). The LH III remains at the site are not numerous, although in LH IIIA2 some new construction took place, marking an expansion of the settlement (Wiencke 1998: 127). Additionally, some burials, including a LH IIIB1 horse burial, have been recovered at the site (Wiencke 2012: 667). Occupation appears to have ceased during LH IIIB2 (Wiencke 1998: 207, 2012: 667). Wiencke (2012: 660) has estimated the size of the site as 1.2ha during the Bronze Age. She further proposes (1998: 207) that by LH IIIB, Lerna became subservient to Argos, and its inhabitants switched to using the large chamber tomb cemetery of Deiras ravine instead of burying their dead within the settlement.

A LH chamber tomb cemetery was recovered some two kilometres south of the settlement. Seven more chamber tombs were recovered in the village of Kiveri, also a few kilometres south of Lerna (Wiencke 1998: 207). Although relatively far away, it is possible that these cemeteries were used by the inhabitants of Lerna.

Nafplion

Like Argos, the city of Nafplion is characterized by two hills, Palamidi and Acronauplia. Both hills are occupied by historical fortifications, and on Acronauplia, modern infrastructure has obliterated many historical remains (Piteros 2015: 253). Therefore, very little remains of the LH settlement of Nafplion. Sherd finds suggest a long occupation span from the Neolithic to the Late Bronze Age (see also references in Bintliff 1977: 309; Protonotariou-Deilaki 1971). Rescue excavations on Acronauplia yielded pottery from EH, MH and LH IIIA-B periods, as well as some Mycenaean figurines (Piteros 2015: 250-52). In the LBA, the coastline bordering the old city centre was located a few hundred meters further inland (Zangger 1993: 81, Figure 43). Piteros (2015: 250-51) suggests that the settlement served as an important harbour. Bintliff (1977: 310) and Piteros (2015: 253) have further argued that the LH III chamber tomb finds indicate that Nafplion was an important secondary centre.In the surroundings of the Nafplion city centre, several chamber tomb cemeteries have been recovered at Palamidi Hill, Aria, and Evangelistria Hill. They suggest that the settlement must have been large and prosperous in the LH period. Today, the total count of the chamber tombs exceeds 100. The tombs date from late MH to LH III(B) (Piteros 2002a; 2002b; 2003; 2015: 246-53). Furthermore, around one kilometre east from the modern Nafplion centre, the (former) village of Aria has a chamber tomb cemetery, and a settlement with continuous occupation from the Late Neolithic to the Archaic period. The finds include a building from LH IIIB-LH IIIC, and a dromos (walkway) of a large tholos tomb (Piteros 2003).

LH III burials were also recovered along the modern Nafplion-Asine road during rescue excavations (Piteros 2004b), suggesting that habitation could have been widely distributed in the coastal areas and the plain of Asine.

Argive Heraion / Prosymna

The Argive Heraion is best known as a Classical and Hellenistic sanctuary complex. The Bronze Age settlement is often referred to as Prosymna, according to the older name of the region (not to be mistaken for the modern village of Prosymna in the Berbati Valley). The BA finds are scattered among the later architecture. No fortification walls or other monumental buildings from the LH period have been identified. Therefore, it is difficult to form a picture of the size and layout of the site during the LH period (Wright 1982: 198). Nevertheless, all periods from the EH to the LH are represented in the find assemblages (Caskey and Amandry 1952: 169-73). EH and LH houses were located on the northern side of the Classical sanctuary, and on a terrace below the sanctuary's fortification wall, a LH III house and street fragments have been recovered (Blegen 1937: 12-13). Another LH III house was located next to a dried-out spring on a nearby hill north of the site (Bintliff 1977: 286). Since no LH IIIC finds have been recovered, the settlement was likely abandoned during the LH IIIB (Bintliff 1977: 286-287).

Besides settlement architecture, a chamber tomb cemetery of LH I-LH III date was excavated at the site and published by Blegen (1937). A tholos tomb has also been connected to the site. The tholos is from LH II, and lies one kilometre north of the site (Bintliff, 1977: 286).

Mastos

Mastos is located in the south-western fringes of the Berbati Valley. In the LH III period, the valley was connected to Mycenae and the plain by a Mycenaean "highway" that led from the gates of Mycenae directly across the mountains to the valley. In the MH period, Mastos was the main settlement in the area, and it remained so until the end of the LH (Forsén 1996; Schallin 1996: 170-72; Wells 1996b: 121-22). In the 1930s, an EH-MH settlement was excavated on the southern slopes of a hillock in the eastern side of the valley. Soon after, a cemetery named the Western Necropolis was recovered on the north-west projection of the hill. A LH settlement was further recovered on its eastern slopes (Wells 2011: 17). The remains of the LH site consist mostly of buildings connected to a site named the Potter's Quarter. The LH II/LH IIIA1 pottery kiln produced substantial amounts of tableware that was distributed over the Mediterranean to Cyprus and the Levant (Penttinen 2015; Whitbread *et al.* 2007). After LH IIIA1 the kiln was replaced by a larger LH IIIB building (Klintberg 2011: 97). Remains of LH walls are located around the lower slopes of the Mastos hill. They seem to be terracing walls rather than house structures or fortification walls (Klintberg 2011: 108). The surroundings of the kiln site have yielded a high density of LH III finds, but the area has not been further excavated. Mastos was abandoned during LH IIIB without traces of destruction or LH IIIC remains (Klintberg 2011: 111-12). A LH II tholos tomb and a chamber tomb were excavated a small distance away, to the north of the settlement (Wells 2011: 17).

Asine

Asine is located on the coast of the Argos Bay, some nine kilometres southeast from Tiryns, and seven kilometres from Nafplion. The main settlement, Kastraki, lies on a rocky outcrop protruding to the sea, bordered by a long sandy beach on its eastern side. On its north-western side, the outcrop is connected to another hill, Barbouna. Modern day Kastraki is dominated by a Hellenistic fortress, among which the prehistoric and LBA remains are preserved. Neolithic finds have been recovered at both sites, Kastraki and Barbouna. Both hills were occupied by the MH III. Kastraki further included a MH II-LH I cemetery on its eastern side (Dietz 1982: 99-101; Zangger 1994b: 222). On the flat plain surrounding Kastraki, MH II sherds and burials attest of the extension of habitation (Dietz 1982: 101). Kastraki and Barbouna were also inhabited in the LH IIIA and B periods (Sjöberg 2004: 41). Barbouna Hill had a substantial LH IIB/IIIA1 settlement, while the habitation of Kastraki did not increase notably until LH IIIB (Dietz 1982: 101). Traces of LH IIIA2 activity are found on the flat areas below and between the two hills (Sjöberg 2004: 41). Major house structures were constructed on Kastraki during the LH IIIB, but no traces of palatial architecture or fortification walls have been recovered. Similar to Argos, the building blocks could have been reused during later occupation phases (Zangger 1994b: 222). The current evidence seems to suggest that, compared to the other Argive Plain sites, Asine did not flourish in a major way in the LH IIIB (Dietz 1982: 102). However, LH IIIC remains have been recovered on the Kastraki acropolis, and it appears that the site peaked in the LH IIIC Middle and Late periods (Sjöberg 2004: 42). In the LH III period, a large chamber tomb cemetery was dug on the eastern side of Barbouna (Zangger 1994b: 222). Further LH III burials have been found during rescue excavations along the road leading to the Kastraki site from the modern inland village of Asine (Piteros 2004a, 2004b, 2004c).

Tsoungiza

Tsoungiza was the main settlement of Nemea valley in the Bronze Age. It was located on the northern side of the Argive Plain, some ten kilometres northwest of Mycenae. Tsoungiza was inhabited already in the EN and MN periods, although periodically abandoned (Wright *et al.* 1990: 629). The site was not inhabited for most of the MH period (Dabney *et al.* 2004: 197; Dabney and Wright 2020a: 85; Wright *et al.* 1990: 629). From the LH I, the habitation continued until the end of the LH III period. The LH II settlement has been described as a hamlet (Wright *et al.* 1990: 635). While the LH I-II architectural remains were recovered on a plateau on the northern side of the hilltop, the later LH IIIB settlement was located on the southern slope (Wright *et al.* 1990: 624-25). Material finds from LH IIIB2 are abundant, but only a few finds were recovered dating to LH IIIC. Evidence from walls and other architectural structures suggest that destruction and consequent rebuilding activities took place in Tsoungiza during LH IIIB2 and LH IIIC as well. The site was likely abandoned early on in the LH IIIC, coinciding the decline of activity at Mycenae (Dabney and Wright 2020a, 2020b; Wright *et al.* 1990: 637-38).

Close to the settlement, a LH IIIA2 chamber tomb has been recovered at Barnavos (Wright *et al.* 2008). Six other chamber tombs were excavated in the Ayia Sotira area nearby, in the Nemea Valley (Karkanas *et al.* 2012; Smith *et al.* 2009). Dabney *et al.* (2004: 214) suggest that Tsoungiza and other small settlements such as Kleonai, Zygouries, Phlious, and Ayia Irini located in the northern fringes of the Argive Plain belonged to Mycenae's political and economic sphere.[6] However, hierarchies, evolving from dynamic relationships among the regional elites, were present among the villages as well.

Other sites

Other Bronze Age sites of the Argive Plain landscape consist mainly of cemeteries and single chamber or tholos tombs. These tombs could have been used by the people living in small farming settlements nearby, or they may have belonged to larger village-type settlements yet to be discovered. Their existence, and the often high number of burials, have raised many questions about the settlement pattern and hierarchy of the Argive Plain. For example, the LH cemetery at Kokla included at least a tholos tomb dating to the LH IIB-LH IIIA1, and nine chamber tombs and five pit graves from the LH I-LH IIIB. The tholos contained several precious objects and a rare painted fresco above the entrance. The site, however, is distant from both Lerna and Argos (Demakopoulou and Aulsebrook 2018: 119). Similarly, at the modern villages of Kiveri and Myloi, Late Helladic chamber tombs and cist tombs were excavated in the 1950s. The seven Kiveri chamber tombs dated to LH IIIA-B, while the 11 cist graves of Myloi dated to MH-LH I-II (Bintliff 1977: 316). Neither site can be connected to a known settlement. A few cemetery sites have been located in the western reaches of the plain. Of these, Schoinochori and Melissi (Melichi)/Skala indicate the same site where chamber tombs were recovered in the Gazetteer catalogue (Hope Simpson and Dickinson 1979: 45), but in Bintliff (1977: 331) Melissi and Schoinochori these are recorded as two separate chamber tomb sites. Here, these two sites are considered as separate, following Bintliff (see locations in Figure 3.1).

A few settlements deserve further note: the site of Magoula near the modern village of Kephalari was a moderately sized (150-meter diameter) prehistoric mound with a long occupation span, from the Neolithic to the Classical period. The site yielded Mycenaean sherds and a cemetery of pithoi and cist tombs (Bintliff 1977: 325-326; Hope Simpson and Dickinson 1979: 46; Sarri 2008: 265-266). Bintliff (1977: 325-326) suggested Magoula may have been one of the main sites on the western side of the plain. Another possible mound site, Dalamanara, was located near the similarly named modern settlement in the central coastal plain. Only a few LBA sherds were recovered, however (Bintliff 1977: 335).

The farmhouse of Chania (Khania) lies within an area French (2002: 69) defined as the 'Greater Mycenae'. During the LH III, an important route from Mycenae to Argos ran past this settlement. Chania represents a unique site since no other buildings of similar function and type have been reported in the Mycenaean mainland. The settlement included a large building complex of *c.* 685m2 in size, and two other only partially restored buildings some 35 metres away. The buildings were connected by a complex design of border walls and courtyards (Palaiologou 2015: 56-58). The excavated building was a house complex, which included storage rooms separated from the living quarters and the courtyard by corridors and wooden doors. An ascending ramp led to the upper floor of the building, which held another roofed storage area. Two other staircases led to the upper floor from other sides of the building (Palaiologou 2015: 59-62). Inside the building were two hearths, one for cooking, one for symbolic functions. The non-excavated building at the same site had similar sizes. Chania was an agricultural site. Its material finds have yielded a large variety of storage vessels for foodstuffs, oil, and other liquids (Palaiologou 2014: 518). The settlement was constructed during the LH IIIB period, since only few sherd finds of earlier periods have been recovered. The building complex was destroyed in late LH IIIB (Palaiologou 2015: 73-74), but activities continued at the site until mid-LH IIIC, when a large stone tumulus was built on top of the previously destroyed architectural remains. The tumulus was used for burials until the LH IIIC Late (Palaiologou 2014: 518). Palaiologou (2015: 73) suggests that Chania was a hamlet of some 5.5 *stremmata* (0.05ha) in size, inhabited by farmers who constituted a small *damos*.

The LH (I-III) sites continue outside the immediate plain area with some notable settlements, such as Iria and Kandia at the fringes of the Southern Argolid peninsula. Of these, Kandia included a fortified acropolis hill. These sites were likely connected to maritime exchange, as suggested by the LH III Point Iria shipwreck located nearby. Along the south-western coast of the Argos Bay, near Lerna and Kiveri, the village of Ayios Andreas represents another acropolis site with cyclopean style

[6] Of these, only Tsoungiza has been included in the list of settlements in Figure 3.1 and Table 3.1. The other sites have been excluded due to their slightly closer connection to the Corinth region.

masonry and LH III finds. More LH III sites have been recovered along the modern Nafplion - Epidauros road (Hope Simpson and Dickinson 1979).

Summary: The Argive Plain occupational history

From the descriptions presented in this section it becomes clear that the LH III Argive Plain settlement system included settlements of diverse sizes and types. Settlements best known to us still include visible architectural remains. In most cases, these are also the sites where multiple long-lasting excavation and survey projects have taken place, and therefore their histories are relatively well known. These settlements appear to have had long occupation spans from EH to LH IIIB, but with pauses and fluctuations, for example during the Middle Helladic period. Some continued to be active also in the LH IIIC. When excavation records and survey data of the area are compared, one can start to see how smaller settlement types such as villages, hamlets and farmsteads were also scattered across the Argive Plain. These sites could have had agricultural function, which is why they are of special interest to this study. Understanding the settlement pattern of the LH III Argive Plain helps to reconstruct patterns of land use and to understand how distances between settlements and agricultural sites may have influenced crop and animal husbandry practices.

The Argive Plain settlement hierarchy and subsistence territories

Based on the special characteristics of the LBA settlements of the Argive Plain and its immediate surroundings, interpretations of the local settlement hierarchy have been put forward. Settlement hierarchies are used to express relationships between sites. They often relate to the local political system. Defining which sites are central can help to shed light on landownership and use. The following section presents the current understanding of the Argive Plain settlement hierarchy in the LH III period.

Hierarchical relationships between settlements are often reconstructed from the relative size of settlements. The idea originates from the Central Place Theory developed by Christaller (1933), who also argued that settlements are arranged within regular distances of each other. Based on the size and distance from other settlements, a site can be placed on a hierarchical chart. The largest settlements are usually considered central places, medium sized settlements as secondary centres (subsidiaries). Small settlements are considered as satellites to the larger sites. The same hierarchy can be constructed among smaller sites such as villages, hamlets and farmsteads. Besides the largest in size, a central place is usually the political and economic centre (Renfrew and Bahn 2008: 184). This means that any changes in the centre's social, economic, or political system likely introduces changes in the other settlements that are connected to it (Small 1999: 45-47). Of course, site sizes do not always fall neatly into distinct categories. Furthermore, research is often directed at larger sites, and smaller sites are rarely well-documented. In other words, recovery and interpretational biases can distort site size evaluations and their classification into site hierarchies (Hodder and Orton 1976: 69-73).

In the Bronze Age Aegean, Mycenaean and Minoan palaces are considered to be central places.[7] The Mycenaean palace was a hub for political, technological, administrative, and religious activities (Kilian 1988; Maran 2001). It can be recognized based on specific architectural features related to the abovementioned activities, and seems to have had a more or less standardized form everywhere in the LBA Aegean. Most pronounced is the megaron, a central hall including an impressive entrance, propylon, a hearth surrounded by four columns, and a throne. Monumental fortification walls, quarters for workshops, religious and administrative buildings, fresco decorations, large cemeteries, and the presence of tholos tombs are often connected to the LBA palatial settlements (Papadimitriou *et al.* 2015; Pullen 2013: 441; Shelmerdine 2008b: 117). The presence of Linear B archives has been considered as a good indicator of the status of a site, and of the presence of administrative structures and control (Bennet 2013: 243). Location can also provide indications about the status of sites. Mycenaean sites were often built on defensible or prominent locations on low hills or outcrops (Siennicka 2010: 72). Access to, or direct vicinity of fertile soils seems to have been a desired, although not a necessary feature for a central place location. For example, Mycenae has far less fertile soils in its vicinity than Argos, which is considered to be a secondary centre in the LH III period (Bintliff 1977: 336).

As described in section 3.3, characteristics of a palatial centre are found in several settlements in the Argive Plain. Linear B tablets or tablet fragments have been recovered in Mycenae (Bennett Jr. 1953; Bennett Jr. and Chadwick 1958; Chadwick *et al.* 1962), Tiryns (Godart and Olivier 1975; Naumann *et al.* 1977), and Midea (Walberg 1992). A *megaron* or megaron-like structures are found at Mycenae, Tiryns, Midea, and Argos (Fitszimons 2007; French 2002; Maran 2015; Papadimitriou *et al.* 2015).[8]

[7] As Shelmerdine (2008b: 117) points out, recent research is moving away from using such complicated, heavily connoted terms as "palace". Nevertheless, for the sake of clarity, the present study refers to palaces or palatial sites when it is necessary to highlight the leading position of the settlement.

[8] The *megaron* at Argos has been found in the lower town area, where the habitation moved after the settlement on the Aspis hilltop was

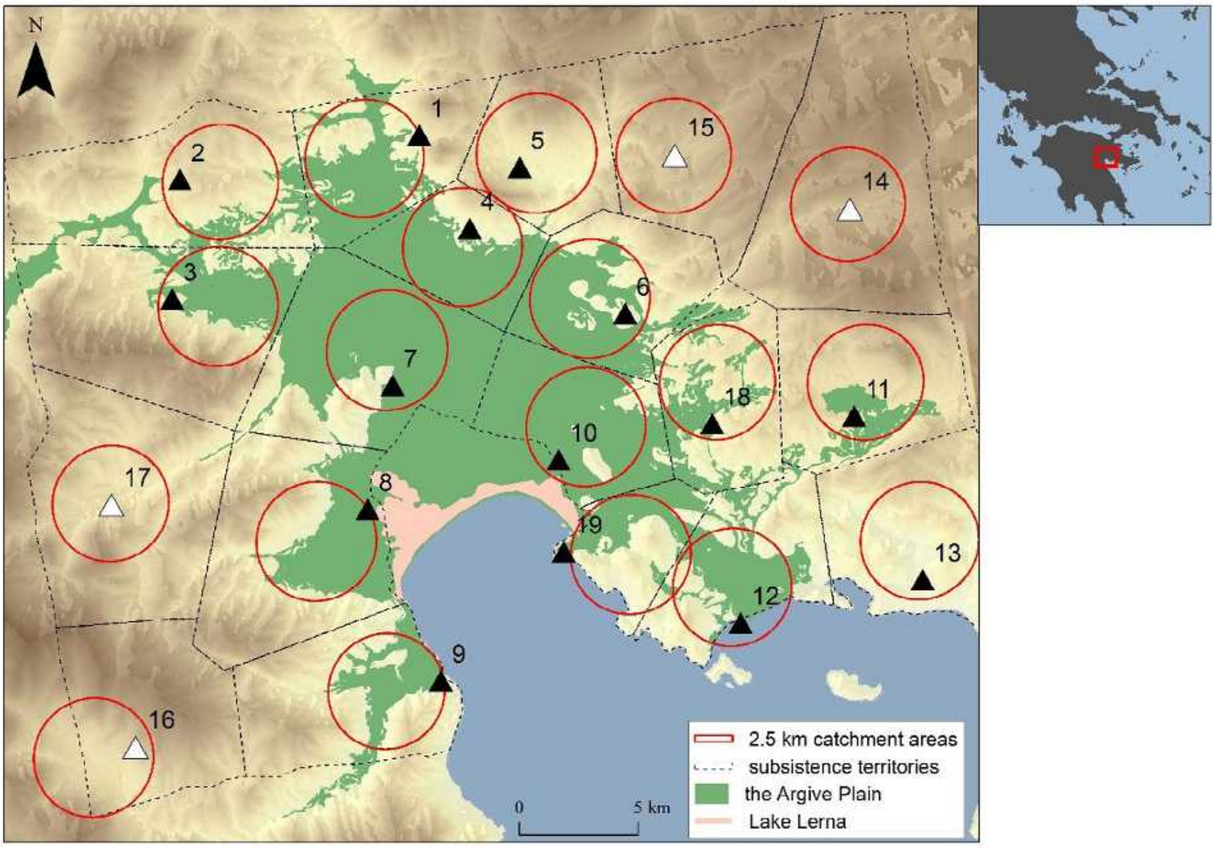

Figure 3.3. The Mycenaean Argive Plain settlement pattern with subsistence territories and 2.5km catchment areas according to Bintliff (1977b: Appx A, map 2A; map adapted from original by current author). Black triangles represent the main settlements of each subsistence territory, which are defined through Thiessen polygons. White triangles, numbers 14, 15, 16 and 17, represent yet uncovered or undefined sites. The known numbered sites (author's interpretation) are: 1) Mycenae, 2) Malantreni, 3) Schoinochori/Melissi, 4) the Argive Heraion (Prosymna), 5) Mastos, 6) Midea (Dendra), 7) Argos, 8) Magoula, 9) Kiveri, 10) Tiryns, 11) Profitis Ilias, 12) Asine, 13) Kandia, 18) Kazarma, and 19) Nafplion.

Pronounced fortification walls forming a 'citadel' are found in Mycenae, Tiryns, and Midea. Quarters for craft activities are identified at Mycenae, Midea and Tiryns (see Demakopoulou 2015 for the craft activities at Midea). Tholos tombs have been recovered in the vicinity of Mycenae, Tiryns, Midea, and Nafplion, the Argive Heraion (Prosymna) and Mastos. A single tholos tomb found at Kokla, some seven kilometres west of Argos, has not been connected to any specific settlement (Wiencke 1998: 207).

Based on these characteristics, Bintliff (1977) formulated a site hierarchy for the LBA Argive Plain in his PhD dissertation. Following Central Place theory, he defined the relationship between settlements through regular walking distances between sites (Bintliff 1977: 289). The distance between major sites was approximately one hour (by foot), and sub-centres were located a half-an-hour walk away from the major centres. This way he was able to define the status of sites which had not yet yielded material evidence indicating a palatial status, and suggest locations for new, unknown major sites. Bintliff's analysis (1977: 289) resulted in the identification of five major centres. Of these, Mycenae, due its exceptional burial wealth, was the highest-ranking settlement of the Argive Plain. The other central settlements were Tiryns, Argos, Dendra/Midea, and Berbati (Mastos). Other notable sites such as Nauplion, Priphtiani and Prosymna (Argive Heraion) were intermediate centres, surrounded by minor villages, hamlets and farmsteads (Figure 3.3).

Using Site Catchment Analysis (described on pp.43-44), Bintliff (1977: 136-137) used Thiessen polygons to create non-overlapping territories around what he defined as notable settlements. He defined 19 territories, or 'catchment areas' (Figure 3.3 polygons). Each territory had its own central place, which further controlled a main subsistence area in a 2.5km radius (Figure 3.3 circles). Bintliff's suggestion of a regular one-hour-by-

abandoned in the beginning of the LH I (Papadimitiriou *et al.* 2015: 177-179). Its location is unique, considering that all the other *megara* were built on the hilltops where the heart of the walled Upper Towns of Mycenae, Midea, and Tiryns were located.

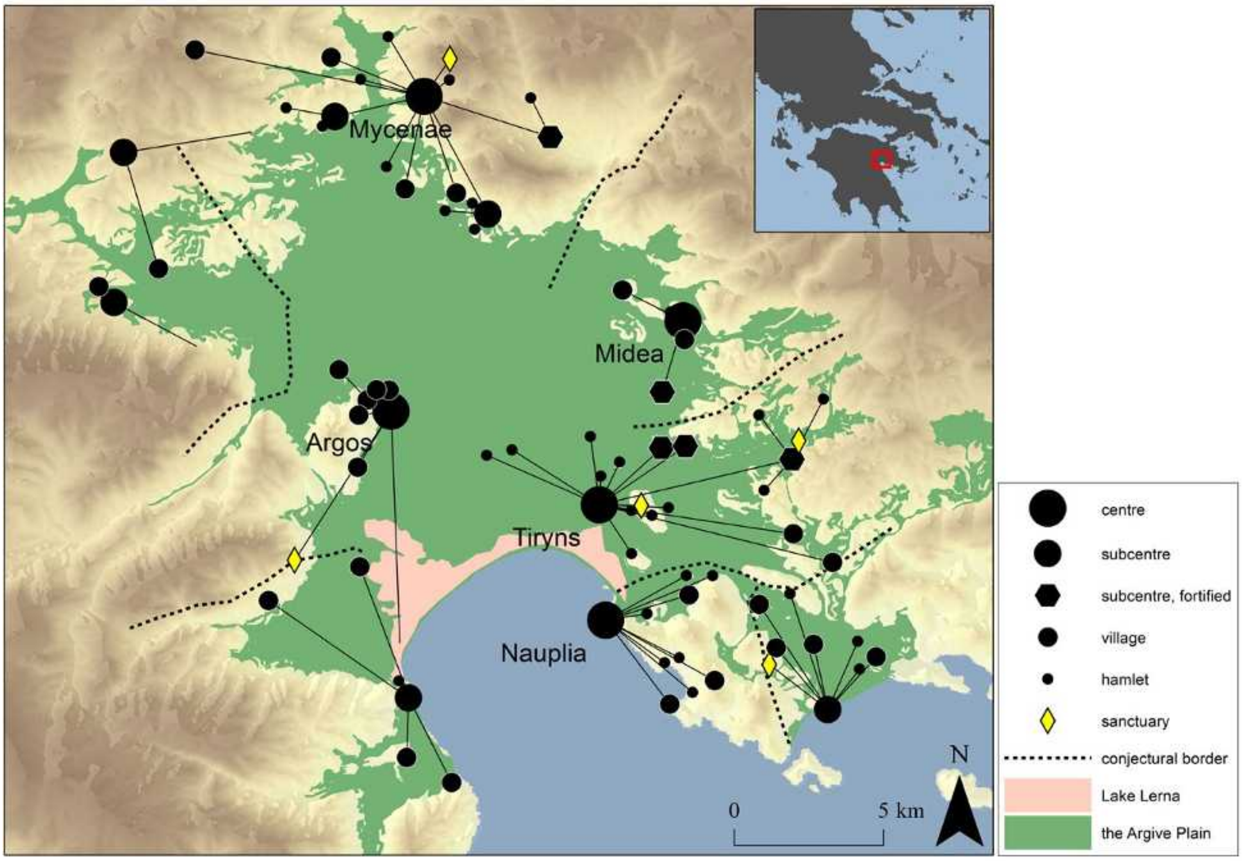

Figure 3.4. Hierarchy of the Mycenaean settlements in the Argive Plain according to Kilian (1988: 297, Fig. 3; map adapted from original by current author).

foot distance between central settlements has been less prominent in his more recent papers (2016, 2019), but he has kept the idea of a territorial division of the Argive Plain. Not all of these territories were able to support their populations. Mycenae's subsistence territory contained far too little fertile flat land, and the small territory of Nafplion does not seem to correlate well with its reconstructed population (see Piteros 2015). Argos would have had the best access to high quality soils, and thus the best opportunity to gain wealth through agriculture, which does not seem to correlate with its suggested lower status in the LH III period (Voutsaki 1995: 61). Bintliff suggested (2016: 142), that the more sustainable sub-centres could have provided enough surplus to support even the mega centres such as Mycenae and Tiryns.

A somewhat similar division between major centres and subcentres was presented by Kilian (1988: 296, Figure 3.). Figure 3.4 presents his reconstruction with nucleated settlement clusters, central places and their nearby subordinates. According to Bintliff (2016: 36), Kilian's reconstruction was strongly inspired by Bintliff's PhD work. Unfortunately, Kilian did not explain in detail how he reconstructed his settlement system. Although only a few sites are named in Kilian's interpretation, some settlements can be identified in the image, based on their location. Four sites, Mycenae, Argos, Midea and Tiryns are marked as centres. Nauplia (Nafplion) can likely be included among the central places as well. The central places are surrounded by smaller settlements whose connection to the centre is clearly indicated. Asine, and what appears to be Lerna on the western coast of the plain, are smaller independent sub-centres, each with their own village satellites.

Kilian also attempted to divide the Argive Plain into territories (dashed lines in Figure 3.4). As with the site hierarchy, the principles behind the territorial division were never explained. According to the figure, the Argive Plain included 8 - 9 territories, each with a central place. The sites in the centre of their own territory were Asine, Nauplia, Tiryns, Midea, Mycenae, Argos, and Lerna. The two remaining sites were potentially Malandreni or another site west from Mycenae, and either Schoinochori, Melissi, or Skala to the south side of the latter, across the river. It is unclear whether the river Inachos functioned as a border dividing these areas into two territories. Not all of the central places of the territories are defined as "centres" on Kilian's map. This suggests that smaller settlements, defined as villages, could have had some independence.

The problems arising from the lack of contextual information in Kilian's interpretations are manifold: firstly, it is not clear whether Kilian's map is based on some kind of assessment of material or textual evidence, or whether it is purely theoretical. Secondly, the image does not clearly define whether all sites marked as centres on the map present politically independent sites (Pullen 2013: 438). Despite its obvious shortcomings, Kilian's settlement hierarchy has found its way into several more recent studies concerning the Argive Plain settlement pattern (Pullen 2013; Sjöberg 2004; Small 1999).

The models of Bintliff and Kilian are likely the most well-known reconstructions of the Argive Plain site hierarchy. Both present the major Argive Plain centres as independent centres, supported by their own satellite settlements. Others have expressed similar ideas, but without providing detailed analysis of the relations between centres and satellites (Galaty *et al.* 2014; Parkinson and Galaty 2007; Pullen 2013: 2022). Among them, Galaty, Pullen, and others (Galaty *et al.* 2014; Parkinson and Galaty 2007; Pullen 2013: 2022) suggest that Mycenae, Midea, and Tiryns served as independent palatial centres or three 'mini-states' in the LH III. These three settlements can be identified as independent political entities, each of which had their own economic system and connections to sea and land routes. The wealth of Mycenae is explained by its location in the middle of a route network between the Argolid, Corinthian, and Saronic Gulfs. The political territory of the Argive Plain would have, according to them, expanded significantly towards the north (Galaty *et al.* 2014: 452-53; Pullen 2013: 438). The model of Galaty and co-authors (Galaty *et al.* 2014; Pullen 2022) of the political geography of the Argolis expands the territorial boundaries of the Argive Plain to one day walking distance (*c.* 10 hours). This territory would have had a size of *c.* 686km2, and more than 50 percent of its land would have been shared by two or more major settlements (Pullen 2019b).

The debate of the political geography and the relationship of the Argive Plain settlements with each other has also produced many opposing views on the independent state approach. As van Wijngaarden has recently presented (2022), the debate of the Mycenaean political territories stems from early 19th century excavations of the Mycenaean palatial sites, and their assumed connections to the Homeric epics, as well as comparisons of the Mycenaean palatial states to the Bronze Age Near Eastern states through textual evidence. This has created arguments for one unified Mycenaean state, the Mycenaean kingdom (more recently e.g. Eder 2009; Eder and Jung 2015; Kelder 2005; Waal 2019).

Of other perspectives, Crouwel (2008: 270) argues that the Argive Plain formed one 'state' where at least two palaces, Mycenae and Tiryns, maintained peaceful coalition with other major sites such as Argos and Midea. These sites formed a network of allies, whose rulers were connected for example through marriage or other family relations. The relatively simultaneous construction of fortification walls in many of the citadels was part of a coordinated plan of a central authority to protect the area from an outside enemy. This one-state formation is further attested by the Mycenaean 'highway' network that extends from Mycenae to all the major settlements of the area (see Brysbaert *et al.* 2020, 2022; Jansen 2002; Lavery 1995 for description of the Mycenaean roads). According to Sjöberg (2004: 133-43), in LH II - LH IIIA2 the Argive Plain hosted multiple wealthy centres, such as Asine, Dendra, Kokla, Mycenae and Prosymna (Argive Heraion), which exhibited no apparent hierarchical order among each other. However, by the LH IIIB, the region was dominated by three top level centres, Mycenae, Tiryns and Dendra (Midea). The adjacent regions to the plain, such as the Berbati Valley, fell under the control of Mycenae. Asine remained independent until the LH IIIB and functioned as a distribution centre for products transported from inland areas (e.g. Berbati) towards the sea (Sjöberg 2004; 136-38).

Mycenae has been seen as the settlement controlling the political and economic system of the Argolid by many (Cherry and Davis 2001; Dabney and Wright 1990; Dickinson, 1982; Eder and Jung 2015; Maran 2015; Palaiologou 2022; Sjöberg 2004; Voutsaki 1995, 2010, 2016). Voutsaki (1995: 59-61, 2001: 199-204, 2010: 97, 2016: 75-76) argues that in the MH III - LH I transition, exceptional wealth begun to concentrate towards the inland site of Mycenae. According to her (2010: 101-103), the combined evidence from mortuary, craft production, and exchange contexts all point to the control of one Argive Plain centre, Mycenae, over others in certain economic and political sectors. Firstly, a larger number of tholos tombs, considered as the burial type for the highest elites, present in Mycenae in LH IIIA and B, suggests that the centre surpassed the other Argive Plain citadels during this period. Moreover, the few tholoi situated in Berbati, the Argive Heraion (Prosymna) and Dendra stopped being used during the LH IIIA, which, according to Voutsaki (2010: 97) indicated the growth of influence by Mycenae. By LH IIIA2, these elite burial types were used only at Mycenae and possibly Tiryns, where the only high elites resided at the time. Voutsaki argues (2010: 99), that by LH IIIB, chamber tombs rich in valuables are also only found in Mycenae. The fact that in the previous periods, tholoi and wealthy chamber tombs were present at multiple Argive Plain sites does not indicate their political independency, but rather their role as allies to Mycenae who allowed these sites, Berbati, Prosymna, Midea, Tiryns, Asine, to gather certain palatial activities and a level of wealth.

Voutsaki sees other evidence of Mycenae's superior position in the Argive Plain in the activities of the palatial workshops. While in Midea and Tiryns they focussed on the working of raw materials of secondary value (e.g. bronze, lead, and semi-precious stone), gold and ivory was only crafted at Mycenae. Voutsaki suggests (2010: 101) that Mycenae had a strict control over the circulation of the most valuable raw materials in the Argive Plain. Finally, the latter is related to external exchange relationships many of the Argive Plain settlements maintained with foreign powers. Rather than emphasizing the independent status of the Argive Plain sites, which acquired valuable materials through foreign exchange, Voutsaki (2010: 103) promotes an approach in which the distribution of specific types of items, the most valuable recovered at Mycenae, indicates that the citadel maintained its hierarchical relationships with other Argive Plain centres by allowing them to participate in the Mediterranean trade in a semi-controlled manner.

Palaiologou (2022) has recently agreed with Voutsaki's approach, emphasizing the superior quality and quantity of valuable objects at Mycenae, which seems to point to the status of the centre as the political power of the Argolid, and in the Mycenaean world. Brysbaert (2020: 70) sees large-scale building activities taking place relatively simultaneously in various locations around the Argive Plain, referring to collaborative initiatives by the regional centres, led by one central authority. Similarly, Eder (2007: 18) suggests that Mycenae must have controlled foreign trade, as its role in the inter-Mediterranean exchange system was much more prominent than any of the other Argive Plain settlements, or the entire Mycenaean Greece, for that matter. Maran (2015: 278-82) and Eder (2007: 23) suggest that Mycenae consciously developed Tiryns as an important harbour site and palatial centre, although Eder (2007: 23) admits that both Mycenae and Tiryns could have controlled their own economic territories. According to Maran (2015: 278-82) the two *megara* of Tiryns were reserved for the ruler of Tiryns and the ruler of Mycenae, who would regularly visit the citadel. Stockhammer (2011: 208-9) has even suggested that after the LBA 'crisis' in *c.* 1200 BCE, the *wanax* of Mycenae (the king of the Argolid) preferred to make Tiryns his new centre, and thus decided against the rebuilding of Mycenae. This would explain why rebuilding took place to a greater extent at Tiryns in LH IIIC (see description on p. 26).

Finally, Wright's Central Place Model focused on the relationship of the Argive Plain with its neighbouring regions. Wright argues that the Argive Plain population was supported in a significant way by the neighbouring regions. The plain itself functioned as the Central Place for the Argolid (Wright 2004: 128). The adjacent Berbati Valley was dependent on the Central Place and its economy, thus representing a Dependency Model. During the LH IIIA, the Berbati Valley was agriculturally exploited by the closest major political and economic centre: Mycenae. Its settlement pattern was therefore linked to the rise and decline of Mycenae and its subsistence needs (Wright 2004: 123). Other neighbours, such as the Nemea valley, the Southern Argolid, and possibly Corinth were all peripheries. They were also exploited by the Central Place (the Argive Plain), but also enjoyed a stronger level of autonomy compared to the dependent Berbati Valley. The peripheries survived the exploitation by maintaining contacts with outside regions through land and maritime routes (Wright 2004: 127-28). Wright's model does not explain the internal dynamics of settlements within the Argive Plain, but seems to suggest that of its settlements, Mycenae was the most powerful since it was able to exploit its neighbouring valleys.

Despite years of research, no consensus has been reached on which of these models would best describe the Argive Plain settlement pattern. Furthermore, most of these models fail to exhaustively address the issue of small sites involved with farming. Close examination of the characteristics of the large Argive Plain sites seems to better support the presence of multiple independent centres. Based on their "palatial" characteristics, such as the presence of Linear B archives and *megara*, Mycenae, Tiryns and Midea appear to be autonomous from each other. In this context, the model suggested by Galaty, Pullen and others (2013, 2014) of three 'mini states' seems rather convincing. Nevertheless, their model does not discuss the status of other sites such as Nafplion and Argos, which might also have had a potentially high status. The question remains whether we can label these settlements as second-order cities or if we expect more Linear B archives to emerge amongst the scarce LH III remains in the future. With their elaborate cemeteries and relatively wide spatial distribution of LH III finds within the modern city areas, both settlements seem almost too large for second-order sites. Furthermore, evidence of maritime exchange has shown that besides Mycenae, Tiryns and Midea, Nafplion, Asine and Mastos also had autonomous contacts with several locations across the Eastern Mediterranean (see details on pp.85-86, but also counterarguments by Voutsaki in this section). These data seem to argue against the dominant position of Mycenae. Even if Voutsaki's well-placed arguments for Mycenae's control over the other Argive Plain settlements would be considered to reflect the LH IIIA and B situation better, as she herself notes (2010: 104), 'centralized control over *certain* spheres of life does not in any way rule out negotiation, manipulation, subversion and resistance...'. Control over the circulation of valuables, and the exhibition of power in the mortuary sphere does not mean that Mycenae controlled the other centres in their everyday subsistence strategies.

Summary: Models of the LH III Argive Plain settlement and land use distribution

To summarize, very few efforts have been made to analyse the land use distribution of the plain in the LH III period. The lack of such analyses is odd, considering how agriculture in the surrounding region provided the basic subsistence for each of the large and small sites of the plain. The main question must be whether the land use in the plain was somehow organized collectively among the leading settlements of the area, or if each site controlled its own subsistence territory. One may also speculate if the agricultural land was controlled at all by central authorities, or instead belonged to rural communities and farmers who also supported the palatial activities with their production.

The only models addressing the issue of smaller LH III habitation sites are those of Bintliff (1977) and Kilian (1983). The list of sites compiled in Table 3.1 seems to confirm the regular presence of village and hamlet types of settlements in the LH III Argive Plain, but many of these are only theorized based on the presence of burial sites for which the actual settlements have not yet been identified, as in the cases of Melichi and Fychtia/Boliari. Both Bintliff and Kilian placed these hypothetical smaller sites under the dominance of a centre or a subcentre. The map of Kilian seems further to include a higher number of villages and hamlets than what the current evidence of known Mycenaean settlements allows (compared to Figure 3.1). Neither of the models includes single farmsteads, which are admittedly scarce (more on survey data on pp.20-23). Both models thus seem to suggest that the LH III Argive Plain settlement pattern consisted of settlement clusters surrounding independent and relatively equal central places. In this way, the Argive Plain system appears to be more 'urbanized', in other words, a larger share of the population lived in town-like centres and in their vicinity rather than dispersed in the rural areas. Such organization has implications for the ways agriculture might have been practiced in the area, and therefore this study returns to the topic on pp.36-38 and again in the final sections on p. 132.

The Argive Plain population estimates

The population estimates for the major Argive Plain settlements may give some indications of the total population of the area in the LH III period and may help to identify the settlement hierarchy. Unfortunately, however, very few estimates for the Late Bronze Age settlements have been given, although methods for population estimates have been generously presented for the ancient (Classical) Greek world (e.g. Foxhall and Forbes 1988; Gallant 1991; Garnsey 1988; Hansen 2006; Hanson and Ortman 2009; Osborne 1987; Scheidel 2003). The following section presents some of the most used methods and population estimates for the Late Bronze Age Argive Plain.

Settlement data have been used to estimate population sizes in the LBA and Classical Greek contexts. Such data can be used to estimate population numbers in two ways: firstly, average site sizes and numbers are used to formulate population densities. Secondly, data on the number and size of excavated houses and their floor spaces are used to estimate settlement populations (Whitelaw 2001). Often these methods are used in combination, since house sizes enable the formation of average settlement population densities, which can be extrapolated to a regional population density (Branigan 2001; Bintliff 2020; Whitelaw 2001). Both approaches have significant biases. For example, population number estimations based on settlement sizes often use ethnographic, region-specific data as analogies for past communities (Carothers and McDonald 1979; Whitelaw 2001). Furthermore, (LBA) sites are rarely excavated to their full extent, and site size estimates based on survey results are not unproblematic. Thus, the excavated area may present only a fraction of the real site size in question (Carothers and McDonald 1979: 434). Finally, if house sizes and floor areas are used as the basis for family sizes, assumptions about relatively standardized architectural design, as well as standard family sizes have to be made (Branigan 2001: 17-18). Average household sizes are often taken from historical and ethnographic examples, which may not represent good analogies.

One of the most cited floor area estimates is likely that of Naroll (1962), who, based on ethnographic data from 18 societies around the world, defined the floor area in a prehistoric settlement as 10m2 per person. Estimates for the LBA are limited, and household and family size estimates have mostly been presented in relation to the Neolithic or Classical Aegean. Based on skeletal analysis on ages and birth rates in combination with data on the number of burials and excavated houses and their sizes, Angel (1971: 74-76, 1972: 96) suggested

Table 3.3. Size, population, and population density estimates for the larger Argive Plain sites in various sources. The total population is calculated according to the density estimate given in the reference.

Site	Size size/ha	Density ppl/ha	Population	Reference
Argos	18	200	3600	Bintliff 2020
Argos	18	200-225	3600-4050	Whitelaw 2001
Asine	3-8	112	336-896	Bintliff 2020
Asine	1.5	-	-	Wright 2001
Berbati (Mastos)	3-8	112	336-896	Bintliff 2020
Berbati (Mastos)	6.5	-	-	Wright 2004
Lerna	1.2	-	-	Wiencke 2012
Lerna (MH)	-	-	570-800	Angel 1971
Midea	3-8	112	336-896	Bintliff 2020
Midea (acropolis)	2.4	-	-	Demakopoulou 2015
Mycenae	32	200	6400	French 2002; Bennet 2007, 2013; Brysbaert 2013
Mycenae	35-50	-	-	Wright 2004
Mycenae	30	200	6000	Bintliff 2020
Nafplion	3-8	112	336-896	Bintliff 2020
Tiryns	18	200	3600	Bintliff 2020;
Tiryns	18	200-225	3600-4050	Whitelaw 2001
Tiryns	24.5	200	4900	Zangger 1994; Shelmerdine 2008b; Brysbaert 2013
Tiryns	35-50	-	-	Wright 2004
Tsoungiza	7.5	-	-	Cherry and Davis 2001
Tsoungiza	3-8	112	336-896	Bintliff 2020

an average of 5.7 people per household for MH Lerna. From this, he extrapolated the total population of the site, thus arriving at 570-800 people in the MH period (1971: 75, 1972: 96). Following Angel's (1971: 75, 1972: 96) estimates, Sarpaki (1987: 116-118) suggested that an average LBA family size was five to six people. This means that one inhabitant in the LBA West House of Akrotiri Thera had some 16.6m2 floor space. As a comparison, Allbaugh (1953: 89-90) calculated a floor space of some 9m2 per person for post-WWII Crete. Finally, Whitelaw (2001: 17-18) argued that the rather small and standardized house sizes in Neopalatial (*c.* 1700-1450 BCE) Gournia, Crete, indicate small family sizes, nuclear units of four to five people.

Commonly used LBA population densities are those by Whitelaw (2000, 2001), Renfrew (1972), Branigan (2001), French (2002), and Bintliff (2015a, 2019). All but Bintliff used excavation and survey data as the basis for settlement population densities. Renfrew (1972: 251) derives his figure, 300 people/hectare (henceforth ha), from the density of large urban settlements in Mesopotamia (400 people/ha), arguing that since the LBA settlements in Crete and Greece were smaller in size, their population density would have likely been lower. Branigan (2001: 46) examined *c.* 1200 Late Minoan sites in Crete and derived his population density of 150 - 200 people/ha from the recalibration of Renfrew's data, based on more recent survey evidence. Whitelaw (2001: 20, Figure 2.3) bases his estimation of 200-225 people/ha on 270 Neopalatial (EBA) Minoan house structures, combined with housing data from palatial sites around the Eastern Mediterranean. French's (2002: 64) population density of 200 people/ha is a good example of a 'guesstimate', which in time transforms into a factoid. While French herself is not convinced of the suitability of the density for Mycenae by stating it 'implies a closer density than the evidence seems to allow', her figure has been later used for example by Bennet (2007, 2013) and Brysbaert (2013). Similar questions about a lower population density at Tiryns Lower Town have been raised by Kelder (2005: 151).[9] Finally, in his recent paper, Bintliff (2019: 19) suggests a density of 200 people/ha for the largest centres with the size of 20-30ha, and a lower population density of 112 people/ha for the smaller 'village-towns'. The lower figure of 112 people/ha is derived from a modern analogy presented by Aschenbrenner (1972) in his ethnographic study of the village of Karpofora in Messenia. In the Argive Plain context, Bintliff uses the higher density figures for the three largest settlements, Mycenae, Tiryns and Argos, and the lower

[9] After Papadimitriou, A. 2001. *Tiryns*, Athens. The author of this book does not have access to the original publication.

Table 3.4. Population numbers for the sites for which only a size estimate is given. The 200ppl/ha population density by Whitelaw (2001) was used to formulate the hypothetical population numbers in this table.

Site	Size size/ ha	Proposed population with 200 ppl/ha	Reference
Asine	1.5	300	Wright 2001
Berbati (Mastos)	6.5	1300	Wright 2004
Lerna	1.2	240	Wiencke 2012
Midea (acropolis)	2.4	480	Demakopoulou 2015
Mycenae	35-50	7000-10,000	Wright 2004
Tiryns	35-50	7000-10,000	Wright 2004
Tsoungiza	7.5	1500	Cherry and Davis 2001
Total		**17,820-23,820**	

density figures for Midea, Navplion, Berbati, Asine and Tsoungiza.

The abovementioned population densities are mostly used for large, 'urbanized' settlements. This raises a question of their suitability for smaller sites. Furthermore, the high densities for Minoan-Mycenaean palatial settlements have themselves been questioned. Bintliff (2019: 15), points out that Greco-Roman town densities were often around of 125/ha, half of the density suggested by Whitelaw for the LBA. Whitelaw (2001: 19-22) himself noticed that larger, 'urban' settlements have higher population densities than rural villages, and thus his estimate can be applied only to the larger LBA sites. Table 3.3. compiles the estimations for the largest and best known LBA Argive Plain sites based on these population densities. The question remains whether all the Argive Plain sites were urbanized enough for the rather high-density estimates.

Density estimations are closely tied to site sizes. The size of Mycenae, 32 hectares (French 2002: 64), is quite firmly established, but only few estimates of the sizes for the other settlements of the LH III Argive Plain exist. The estimate of Mycenae is based on a survey conducted in the surroundings of the citadel (Iakovidis and French 2003), but there is a lack of similar research at other Argive Plain sites. In Midea, to give an example, only the fortified acropolis has been excavated (Demakopoulou 2015). The excavations are ongoing in the Lower Town of Tiryns, the size of which remains unknown. Table 3.3 below compiles the size estimates already mentioned in section 3.3 of this book.

Table 3.4 gives an idea of what the urban population of the LH III Argive Plain could have looked like. If the highest population densities and site sizes are examined, the total urban population would have comprised about 30,000 people. Bintliff has recently (2020) suggested a more modest total population of 14,700 for the urban sites, and a maximum population of 20,000 for the Argive Plain. Thus, in his model the Argive Plain was highly urbanized with up to 85 percent of the population living in or within close range of large sites. In this model, rural, widely dispersed small settlements are few. In most of the estimates in Table 3.3 the populations of the two largest sites, Mycenae and Tiryns, already total over 10,000 people, 50 percent of the total population of the Argive Plain according to Bintliff's estimate. In Table 3.4, if Wright's (2004) site sizes are used together with Whitelaw's (2001) population density of 200 ppl/ha, the population of the two largest sites would potentially exceed Bintliff's (2020) estimate for the entire region. Bintliff (2020) offers the only total estimate for the region, but his figure has not been scrutinized.

The topic of the Argive Plain total population will be revisited in Chapter 7 pp.182-185, where the agricultural potential of the area is compared with the population numbers given for the abovementioned settlements.

Summary: Large and small settlements in the LH III Argive Plain

The Argive Plain settlement pattern in the LH III period was different from any other Mycenaean area. Within its small, 250km2 plateau, it contained at least three major settlements: Mycenae, Tiryns and Midea, with similar sets of structures indicating their palatial status. Additionally, two further settlements, Argos and Nafplion, might also have had palatial status (Darcque and Rougemont 2015; Piteros 2015; Tournavitou and Brecoulaki 2015).

The hierarchy amongst the Argive Plain settlements would have likely influenced the local land use. If the major sites are considered as independent, they were likely also relatively self-sufficient. Each of the major sites must have had at least some kind of internal administrative system, which supervised the economic activities taking place in the territory. These sites could have possessed agricultural land of their own, or each of them could have collected subsistence products as taxes from the inhabitants of their territories. Unfortunately, there is hardly any evidence of either of these systems being in place, although recently, Efkleidou (2022) has offered some interesting suggestions about the Mycenaean territoriality in the Argive Plain, by exploring the cadastre maps of the area from the Venetian Rule in detail. Based on the survey evidence and the remaining road network, it seems Mycenae was tightly connected to the Berbati Valley, which likely provided the citadel with part of its subsistence products (Schallin 1996). It has also been suggested that Mycenae was more interested in the areas north of the Dervenaki pass, and perhaps controlled the region towards Corinth (Bintliff 1977: 345-346; Shelmerdine 1999a: 557-560). Thus, it may not have needed the fertile areas of the Argive Plain for subsistence purposes, leaving more territory for the other major sites.

Whatever the case with the land division between the central settlements of the Argive Plain was (see e.g. Voutsaki 2010 for one-state approach), however, the more important question is how it influenced the work of the farming communities. Although this question is further examined in the second last chapter (pp. 138-139) of this work, it must be noted here that although much scholarly work has concentrated on examining the internal relationships between the major settlements of the Argive Plain, very little is known about these communities. One of the main reasons for this lack of interest is the absence of data on medium and minor settlements. This shortage of data stands against the considerable amount of evidence pertaining to the palatial centres of the Argolid.

The known smaller (and larger) LBA sites are compiled in Figure 3.1. Only a few of these sites are located on the flat plain, and most of them are in the vicinity of one or more larger settlements. The scarcity of evidence has created an image of the local settlement pattern as urbanized, focused on large, city-like settlements, while the plain proper was used mainly for agriculture (e.g. Bintliff 1977). However, the known landscape changes in the EBA and LBA include major events of alluvial deposits in the central plain (see Zangger 1994, and section 5.1. for further description), which may have covered small sites completely. Thus, the absence of evidence does not necessarily mean that small villages, farmsteads or hamlets did not exist. Nevertheless, according to Bintliff (2016, 2020), the majority, up to 75-80 percent, of the Late Bronze Age population lived in the large settlements or in their immediate surroundings. The small remainder occupied more remote rural sites. The agricultural land of the plain was supposedly mainly cultivated by the "urban" dwellers, who commuted daily to the fields. Bintliff (2020) derived his idea from the descriptions of Aschebrenner (1972) in modern (1960s) rural Messenia and compared the large modern Greek village to a Mycenaean town, denoting the settlement pattern of the LBA Argive Plain as a 'rustic town' model. This view is contrary to a more traditional understanding of people dwelling where their fields are and remaining therefore in small agricultural estates or village-communities surrounded by agricultural land (Halstead 1999a: 320-21).

Comparison of the Argive Plain survey data to the adjacent regions seems to reveal two types of settlement patterns. In the adjacent valleys and peninsulas people were scattered across the landscape in a few larger settlements and many small sites far away from each other. According to Wright (2004: 115-16), the individual characteristics of the landscape in the Nemea, Berbati, Southern Argolid and Methana regions shaped their settlement patterns into different directions, making them incomparable with the flat, easily accessible Argive Plain. While recognizing the differences in the landscapes, the results of surveys in these regions can still provide some insight into the types and sizes of settlements typical for the Argolid regions and the time. Each survey showed (see pp.23-25 for further details) that there were many small agricultural sites located in a relatively dispersed way in valley bottoms, hills slopes, and anywhere where fertile cultivation land was available. Small rural settlements were therefore likely to be a common sight in the LH III landscape.

In the Argive Plain, clustering of small sites can be seen in the surroundings of large settlements such as Mycenae and Nafplion (although there is no certainty of the status of the latter) (see also p. 28). More surveys and reconnaissance projects are needed to confirm whether the clusters appear only due the more intensive research in the surroundings of the large sites. Nevertheless, having farms and hamlets located in the vicinity of large central places would have ensured good access to products exchange and people, as well as protection in the form of military forces and fortifications.

Several small and medium sized settlements were, however, also located across the plain, mostly on the gently sloping edges but also further down on the flat plateau (see Figure 3.1 in section 3.1). Unlike in the pedestrian surveys, where artefact scatters mark the location of the site, these settlements were often recognized through burial places (pp.20-23). Thus, it cannot be always confirmed whether a cemetery of chamber or tholos tombs was used by a known LH settlement further away, or if another, yet undiscovered site was located nearby. Since many of these finds are chamber and tholos tombs, they are naturally found in gently rising slopes instead of flat lands where their chambers underground could not have been dug (more on the location of LBA burials, see Cavanagh and Mee 1990; Turner 2020). The location of the settlement itself could have been on the flatter grounds, close to fields and waterways.

Not all habitation in the Argive Plain is found in the immediate surroundings of the large central places, as indicated by the location of some of the relatively remote sites such as Melichi, Skala and Kokla (see Figure 3.1). The chamber tombs found in these locations suggest the presence of small to medium-sized communities. The sizes of such sites are unknown, but since multiple chamber tombs were found in the same locations, it is possible that these settlements were occupied by multiple households. Thus, they could have been hamlet type of communities, like Chania on the central plain. The evidence of very small sites such as single farmsteads is scarcer, perhaps only including the LH IIIB house nearby Argive Heraion (see description on p.29). The house could have been a farmstead connected to the larger site but independent in its subsistence. The absence of evidence is not enough to conclude that farmsteads did not exist in this environment. It would seem likely that people were spread out in small subsistence farms across the more far-away areas of the plain in the north-western and south-western fringes, just like in the nearby valleys. Survey evidence, such as the potential new discoveries of the WARP survey in the back lands of Argos, can shed light on this issue in the future (Nakassis 2021).

It is also possible that the LH Argive plain had a vastly different settlement pattern compared to its neighbours and even compared to other Mycenaean core areas in the Peloponnese. Since the Argive Plain seems to have held at least three palatial settlements (see also pp.31-36), the area was already more urbanized than for example Messenia where only one central site, the palace in Pylos ('the Palace of Nestor'), has been named (see also Shelmerdine 1997, 1999a for comparisons of these areas). However, this palace was also surrounded by multiple satellite sites and potentially hundreds of small settlements which formed a dense pattern across the wider landscape (Davis *et al.* 1997). If the LH Argive Plain was urbanized, the vast majority of people would have lived within or in the immediate surroundings of the largest settlements, and probably commuted daily to their fields. The clustering of settlements around the Argive Plain central places does not necessarily indicate that the rest of the plain had only a small rural population, or that sites were not located far away from the centre. It could be caused by a bias towards the palatial centres in surveys. It is possible, however, that the Argive Plain farming population preferred to live in hamlets rather than single farmsteads and perform some of the heavy agricultural tasks communally, as has been customary for more recent rural communities in the area (pp.138-139). There could also have been an increasing movement towards the largest settlements of the plain, since this could have guaranteed better access to protection, supplies and connections. Nevertheless, the plain was probably not yet empty in the LH III.

The idea of the presence of agricultural hamlets in the LH Argive Plain landscape has important implications for the analysis of the agricultural potential because small farms and communities are usually related to small-scale subsistence agriculture rather than large-scale surplus or specialized production, and because the locations of such settlements shed light on the commute to fields and pasture sites. The discussion of the Argive Plain settlement pattern continues in chapters 6 and 7, where the settlement pattern is examined in relation to the LH agricultural practices. The archaeological evidence to support mixed subsistence farming is presented in Chapter 5. The following chapter presents, first, the methodology for the reconstruction of ancient agricultural systems.

Chapter 4

Reconstructing agricultural systems and agricultural potential

The research of human subsistence strategies has a long history originating in ecology and anthropology, later adapted to archaeology through processualism. In archaeology, societies practicing agriculture as their main subsistence strategy have often been studied through ethnoarchaeology, or economic approaches. With the latter, the emphasis has been on the relationship between societal stratification and economic and political control, with agriculture being considered as one of the main economic sectors. Such studies regularly focus on numbers of consumption, production, and exchange extracted from written testimonies. In the LBA Aegean context, these two approaches are often separated. Ethnoarchaeology examines farming practices and population through a combination of ethnographic observations and archaeological evidence, while the study of ancient economies has often focused on the information in Linear B archives. Some studies have combined several types of data to examine agriculture in the Mycenaean societies. The following chapter presents, firstly, an overview of the economic and ecological background to the study of agriculture in the LBA Aegean and Argive Plain context. The second part of the chapter presents how a model to estimate the LH III Argive Plain population can be created through the analysis of agricultural potential.

Approaches to agriculture in the LBA Aegean

Agriculture in the Bronze Age Eastern Mediterranean has traditionally been examined from various perspectives, of which ancient historical approaches, specialist archaeological sub-disciplinary studies, and landscape archaeology are the most common. The following section introduces these briefly. Particular focus is on the ways agricultural subsistence landscapes have been reconstructed in the Aegean context.

History of approaches

Studies of past agricultural production in the Aegean have traditionally been included in the domain of ancient economies and ancient history. Models created by Polanyi (1977), Finley (1973) and Renfrew (1972) of the development of economic and political systems have had a major influence on the ways prehistoric, LBA, and Classical societies and their subsistence strategies were reconstructed (introduced on pp.15-18). The deciphering of the Linear B script by Michael Ventris in the 1950s sparked a major interest in the examination of the 'Mycenaean' culture. In the following decades, translations of the inscriptions on clay tablets recovered in Knossos, Pylos and Mycenae were published at a quick pace (Bennett Jr. 1953; Bennett Jr. and Chadwick 1958; Chadwick 1972; 1973; Chadwick *et al.* 1962; Ventris and Chadwick 1956). These texts included references to agriculture as records of cereals, figs, and domesticated animals, and as contracts of land tenure and ownership (see Chapter 2 pp.10-14).

Examinations of Linear B records resulted in economic reconstructions that focused mainly on activities such as stock production, taxation, and land control of the Mycenaean palatial centres (Bennett Jr. 1956; 1983; de Fidio 1977; Halstead 1999a; Killen 1984). Based on the titles and professions of individuals recovered in the texts, the Mycenaean society could be divided into elites, and 'commoners'. The latter was seen to include rural farming communities, *damoi* (e.g. Hiller 1988; Kilian 1988). Although traditional ideas of a clearly defined Mycenaean societal hierarchy and a redistributive, centrally controlled economic system have since been under scrutiny (more details on pp.15-18), agricultural subsistence strategies are still often examined from the palatial economic perspective. This approach focuses on analysing the ways the Mycenaean elites maintained themselves and gained potential surplus by benefitting from the labour of rural communities (e.g. Earle 2011; Halstead 2011a; Nakassis *et al.* 2011).

Specialized processual approaches

Somewhat In the 1960s and 1970s, somewhat simultaneously with the interest in ancient economies and their reconstructions through ancient texts, processual approaches became important in the Eastern Mediterranean archaeology, resulting in the development of specialized scientific methods for the use of archaeology. Many of these methods could be used to study various a variety of aspects of related to agriculture. One of the early developers of processual approaches in Europe was Grahame Clark, whose work touched upon various themes such as demographics, economy, and the material culture of prehistoric populations (e.g. Clark 1965, 1970, 1986). Together with Eric Higgs and other colleagues, Clark initiated the study of the prehistoric agricultural economies during his time in Cambridge in the 1960s (e.g. Brothwell, Higgs and Clark [eds] 1963; Higgs [ed.] 1972). The work initiated by them later produced scholars such as Claudio Vita-Fintzi (e.g. 1969; Vita-Finzi *et al.* 1970; Vita-

Finzi and Stringer 2007), Gordon Hillman (e.g. 1973a, 1973b, 1973c; Moore, Hillman and Legge 2000), Andrew Sherratt (e.g. 1972, 1981, 1983), Paul Halstead (e.g. 1989, 1992, 1995, 2006, 2011, 2020; Halstead and O'Shea [eds] 1989) and Glynis Jones (1983, 1987, 1998, 2005; Jones *et al.* 1986, 2000) who have substantially contributed to the studies of the LBA Aegean and Eastern Mediterranean landscapes, subsistence strategies, and rural populations (Outram and Bogaard 2019: 6–7). Due to their versatile backgrounds and specializations, the members of this groups have been able to examine Bronze Age populations from wider multi-disciplinary perspectives. They created the foundation for the later studies on integrated subsistence systems and agricultural economies that are central to the present study.

The origins of agriculture and its spread across Europe were among the key topics of processual approaches in the Eastern Mediterranean and the Near East (Barker 2006: 17). Environmentally focused sub-disciplines such as archaeobotany, zooarchaeology, and geoarchaeology were developed and integrated into new intensive survey projects, which explored areas outside the known ancient population centres. In Greece, the first archaeobotanical remains were already retrieved and identified at the end of the 19th century at Tiryns and Knossos, but systematic specialized studies exploring new methods started only in the 1960s and 1970s. Higgs, one of the founders of the Cambridge paleoeconomic school, was involved in the development of the flotation technique for the recovery of plant remains. It was first used successfully in the 1970s in the excavations of the Franchthi Cave in the Southern Argolid (Livarda 2014: 107; Watson 1997: 22). Alongside van Zeist, Hopf and J. Renfrew, Higgs laid the groundwork for archaeobotanical reference materials in Greece and more widely in the Eastern Mediterranean. Human relationships with the environment aroused interest in zooarchaeology (Albarella 2017; Thomas 1996). The prehistoric and Bronze Age finds in Greek archaeological sites, including the Argive Plain, were published by notable specialists of the time such as Gejvall (1969), von den Driesch and Boessneck (1990), and Bökönyi (1986). Many of these specialist studies provided detailed data on animals, plants, human remains and soils, which could be used to examine past subsistence strategies. J. L. Angel pioneered human skeletal analysis in Greece from as early as the 1940s. He examined a considerable amount of the Bronze Age osteological finds of the mainland, including Lerna (1971), Mycenae (1973), and Asine (Angel 1982). Instead of only focusing on taphonomic analysis, Angel took a wider approach by also investigating the social status, health, and living conditions of prehistoric and Bronze Age populations.

Despite their ability to go into great details of the past human-related activities, the focus in these studies was on taxonomies, and lacked integration into a wider research framework. Faunal, botanical, osteological, geological, and other specialized studies were often included in the excavation projects of Bronze Age sites (e.g. Lerna, Tiryns, and Asine as seen in Chapter 5). However, the results of these studies often remained separate from the wider project results, as they were published only in the margins of large project publications (Albarella 2017). The results mostly presented taxonomic and quantitative data, without addressing the social context (Outram and Bogaard 2019: 12). Scarcity of research specialists resulted in a situation where all materials of simultaneously excavated sites were studied by the same people, such as Hopf and Kroll in archaeobotany, and Angel in osteoarchaeology. Since many of the specialists working in these projects had their background in natural sciences, they sometimes lacked the skills to recognize the importance of the archaeological context of the finds (Martinón-Torres and Killick 2015: 14).

Post-processualism developed in the 1980s as a critique of processual approaches, such as the idea that human activities could be explained through specific 'laws' which could be applied to all societies. Others targeted the trend focusing on creating taphonomies and catalogues without relating these to wider contexts and research questions (Outram and Bogaard 2019: 2). In Greece, many of the old material records from Bronze Age sites were re-investigated with wider societal and cultural questions in mind. For example, the LBA skeletal materials recovered in the Agora of Athens (Kirkpatrick Smith 1998) and the remains of the Grave Circle A and B of Mycenae (Dickinson *et al.* 2012; Nafplioti 2009, 2010) were re-investigated from a perspective focusing on social status. Other types of mortuary evidence, such as burial objects and tomb and cemetery locations were used to extract information on social, cultural and political issues in the Mycenaean context (e.g. Cavanagh and Mee, 1990; Voutsaki, 1995, 2001).

Overall, processual approaches have had a significant impact on the ways Bronze Age Aegean is still studied today. Although the focus has partially shifted towards new, fresh perspectives about past scent and soundscapes (e.g. Knapp 2011; Murphy 2013), memory (e.g. Dakouri-Hild 2021; Hamilakis 2014), individuals (e.g. Nakassis 2013), *chaînes opératoires* related to labour (e.g. Brysbaert 2013; 2021; Brysbaert *et al.* 2022), and the ways archaeology is practiced and how it may create biases, much of the hands-on research taking place in Mycenaean contexts still follows very traditional ways of work. This holds true also for the work at hand. Not only is much of the data used to reconstruct the LH III agricultural practices deriving from the scholars mentioned above, who have become the canon of the Aegean, and in a broader sense Eastern Mediterranean archaeology, but the approach of this book strongly reflects the methodical, processual way of studying the Mycenaean world. In many parts, this is caused by the type of data on agriculture that is available in the Late Bronze Age context. This can to some extent be balanced with ethnoarchaeological approaches which are necessary to tie the fragmented archaeological data into socio-cultural context. In the end, a study of ancient farming as an integrated system has to consider the cultural aspects of agriculture and therefore cannot be approached from a fully processual perspective.

Settlement patterns and landscape analyses

Environment and its resources were seen as pervasive factors in the development of settlement patterns, subsistence strategies and population numbers in the processual approaches to archaeology (Watson 2008). These ideas inspired developments in survey and sampling methods. Field expeditions especially from the 1960s and 1970s onwards consisted of systematic multiperiod surveys. The emphasis was placed onto the relations of sites with each other, their location in the landscape, the land use of these sites, and the resources and characteristics of the environment (Muskett 2014: 52).

Greece was one of the locations where such surveys pioneered. The use of aerial photography during the wars enabled much better survey of the landscape and the detection of visible remains of sites (Gill 2014: 68-70). The prehistoric and LBA sites of the southern mainland and the Aegean were among the places that were targeted by intensive site reconnaissance expeditions, which also examined environmental resources as defining factors in site location (e.g. Hope Simpson 1965; Bintliff 1977; Hope Simpson and Dickinson 1979). The new, intensive, systematic surface survey projects such as the Minnesota Messenia Expedition (McDonald and Rapp 1972), the Southern Argolid survey (Jameson *et al.* 1994), the Methana Survey (Mee and Taylor 1997), and the Nemea Valley Archaeological Project (Wright *et al.* 1990) in the Peloponnese included environmental studies aiming to reconstruct past vegetation and geography (see pp.23-25 for survey details).

The emerging need to understand the evolution of settlement patterns resulted in new methodological approaches which could be used to examine settlement locations and their relations to each other (Outram and Bogaard 2019: 9-11; Yesner 2008: 42). In the LBA context, the interest of such surveys shifted from the examinations of already known large palatial sites towards the landscapes and territories controlled by these palaces. Site hierarchies and reconstructions of political geographies were linked to theoretical approaches such as Central Place Theory (explained on pp.31-36) and Site Catchment Analysis (see below). For example, the Argive Plain surroundings, the valleys of Berbati and Nemea, and the peninsula of Southern Argolid were investigated with the prospects of connecting their LBA status to the development of Mycenae as the major palace of the Greek mainland (Cherry and Davis 2001; Jameson *et al.* 1994; Wells and Runnels 1996; Wright 2004; Wright *et al.* 1990).

Site catchment analysis

Site Catchment Analysis was introduced by Vita-Finzi and Higgs (1970), two members of the Cambridge paleoeconomic group. It was enthusiastically applied in the Eastern Mediterranean archaeology, and famously used by Bintliff (1977; also pp.31-36 of this book) to examine the LBA sites and their sustainability in the Argive Plain. Vita-Finzi and Higgs (1970: 5) define site catchment analysis as 'the study of the relationships between technology and those natural resources lying within economic range of individual sites.' In the catchment analysis, a settlement is examined in its wider environmental context in order to define the area from which the settlement received its subsistence, in other words, its catchment area. The catchment is thus defined by the most available food resources, but this availability is strongly dependent on the technology and on the level of challenges in the resource procurement. The choice of the main subsistence strategy, such as herding or cereal cultivation is reflected in the site location. The main resources further fluctuate seasonally, creating seasonal and spatial variation in land use (Vita-Finzi *et al.* 1970: 1-3). Although Vita-Finzi and Higgs mainly focused on staple foods as the main defining factor of the catchment area, they acknowledged (1970: 5-7) that sites tend to be located in places which have an access to a wide range of resources, including for example building materials, fertile soils, water, or long-distance routes. Ideally, a settlement could exploit multiple economically complementary resources.

In practice, Site Catchment Analysis entails a series of calculations of the productivity of the land, and the maximum distance within which subsistence activities can be conducted with relative ease. The catchment area of an agricultural site can be examined through a weighting factor, which calculates the decline in the net output (yield) when distance from the settlement increases. The decline is caused by transportation costs from the fields to the centre. A commonly used threshold is five kilometres from the settlement, and the catchment area is commonly exhibited as a circle, or a set of concentric circles, which represent subsistence economic zones one kilometre apart from each other (Vita-Finzi *et al.* 1970: 28–29). The productivity of the land is then calculated within these circles. In cultivated areas, the size of the area is multiplied with estimations of the average crop yields. In pasture areas, the size of the land can be compared to herd sizes. In forested areas, it might be possible to estimate how much timber was available for construction, and so on. Today, various GIS (Geographic Information System) approaches such as the Least Cost Path analysis, Digital Elevation Model, and Kernel Density Estimation are used for creating more sophisticated estimations of the size and nature of catchment areas.

The size of the catchment area has often been connected to the size of the settlement, as well as to its status in the local settlement hierarchy. Bintliff (1977: 136-137) for example defined a catchment area of 2.5 kilometres for each central place (large settlement) of the LBA Argive Plain. He further suggested that smaller sites with smaller territories supported the larger settlement and their high populations. Thus, the larger and more powerful the site, the larger its subsistence territory supposedly was. Bintliff (1977: 111) emphasized closeness to fertile soils and water resources as the defining factors in settlement location in the LBA Argive Plain. Ideally, the settlement would be located in the middle of a zone that included very fertile soils. On the edges of the zone would be areas where more environmentally tolerant crops could be grown. Sites which were located far away from fertile areas likely received their livelihood from the sea. Bintliff's approach has had a profound influence on the way the LH III Argive Plain landscape and land use has been understood in its more recent research history. He reasoned that the known LH III settlements appear to be located on the edges of the Argive Plain, because the central plain was not suitable for cereal cultivation, and only the edges provided sufficient resources such as quality soils and water reservoirs. This, and his more recent suggestions of an urbanized LH III Argive Plain in which the population of the large citadels commuted to their fields on a daily basis (Bintliff 1989, 2019), have created an idea of an 'empty' central plain.

As Outram and Bogaard (2019: 20–22) point out, site catchment theories have been criticized for their determinism towards landscape variables, and subsistence-related decision making. Besides population levels, social factors such as the desire to acquire and display power, could have played a role in the catchment territory of a settlement. Many site catchment analyses lack consideration of the relationship of site locations to religious and cultural aspects, such as sacred places or places of memory. Furthermore, laws, regulations, customs and family history – besides the environmental resources – can determine where and how subsistence activities are practiced, and who can benefit from them. There is a danger of the reconstruction becoming a description of the landscape without considering cultural and political factors (Forbes 2007: 17–18; Graves McEwan 2012: 527).

This study aims to examine the Argive Plain as one subsistence agricultural landscape. Therefore, site catchment estimates for individual sites are not given, and the only catchment area is the plain itself. Arbitrary division of the plain into territories controlled by its main settlements has been attempted before (Bintliff 1977; Galaty *et al.* 2014; Kilian 1988) but these divisions do not necessarily reflect agricultural land use, nor are they useful to examine variation in the production potential across the Argive Plain. Nevertheless, some thoughts about the control areas of individual sites in relation to their sustenance are included in the discussion of the agricultural potential (final section of this work on pp.178-180). As seen in Chapter 7, the calculations of the agricultural potential raise questions about the self-sustainability of the largest settlements, such as Mycenae and Tiryns. After establishing the agricultural potential of the entire region, this study asks if the close surroundings of these sites were able to sustain populations of several thousand individuals and if not, if this would have implications for the previous population estimates of these sites.

As is acknowledged above, in the present study the subsistence area of the Argive Plain is taken as one unit. The Argive Plain was connected to its neighbouring valleys and plains, and the LBA settlements continued between the plain and Epidavros in the east, and Corinth in the north. Nevertheless, borrowing from the ideas of the catchment analysis, it is proposed that the inhabitants of the plain would not have travelled extreme distances to tend their fields. Thus, a 2.5km radius around the flat plain is selected to represent the subsistence area of the plain inhabitants. Considering that most of this buffer zone includes relatively high and steep hillslopes, the furthest border was likely much closer to the flat plain, when the estimation is transformed into walking distance. However, this way the area can also include some of the potential grazing sites along the steeper slopes, as well as sites for the collection of firewood, terraced fields, and other subsistence activity areas that use hillslopes. In addition, although LBA sites continued beyond the natural borders of the Argive Plain, it is proposed that sites towards Epidavros and Corinth belonged to other political entities (see pp.23-25 and p. 31). This suggests that the subsistence landscape around them was also used to benefit other communities than those inhabiting the Argive Plain.

Carrying capacity analysis

Carrying capacity analysis has commonly been used to estimate the potential of catchment areas to sustain their populations. The method forms the basis for the calculations of the agricultural potential performed in this study. Central to the carrying capacity analysis has long been the Malthusian (1798) population theory, in which population is thought to grow exponentially as long as food production remains static. However, Malthus never mentioned the concept of carrying capacity, which as a term originated in the 19th century from fields such as mechanical engineering and biology in which it meant, in a literal sense, the capacity of a vehicle or a pack animal to carry loads (Sayre 2008). The concept was adapted to anthropological and archaeological research from ecology, in which it was used to determine the subsistence territories of animals (Outram and Bogaard 2019: 43; Zubrow 1975: 6). Although in archaeology it was originally applied to hunter-gatherer societies, more applications to early farming societies have since appeared.

According to Zubrow (1971: 128), 'carrying capacity is the maximum number of organisms or amounts of biomass which can maintain itself indefinitely in an area...' In the context of early agricultural societies, the maximum carrying capacity indicates the point beyond which the land cannot be agriculturally exploited without causing severe damage to the environment. Thus, carrying capacity analysis results in a maximum number of people who can be sustainably supported by the land area which they inhabit with specific subsistence economic means, for example with a given technological level (Brush 1975). When targeting agricultural societies, the analysis requires data of environmental restrictions to agricultural production as well as data of the land use, cultivation, and animal husbandry strategies most commonly used. The Malthusian idea of indefinite growth of production and resource exploitation, as well as the thought of human societies always aiming at the highest production targets have naturally been criticised (most recently by Erdkamp 2021). The Mathusian approach does not consider societal factors such as political and (market) economic systems, which influence land use, landownership and food production targets. In fact, as Erdkamp (2021: 431-434, 2022: 104-107) points out, societies do not always comprehensively use the arable land available for agriculture, nor do they aim for the maximum use of resources. These aspects look very different when they are observed in communities aiming at basic sustainability than in communities involved with market production of food.

According to the Malthusian principle, exceeding the carrying capacity inevitably leads to the rapid decline or even extinction of a population. Criticism toward such determinism rightfully argues that responses to the resource shortage can also be cultural, emerging for example as measures to regulate birth and death rates, mass migrations to areas with more resources, or as new technologies that intensify food production (Brush 1975). Boserup (1965: 21–22) in her famous dissertation suggested that instead of exploiting the landscape until it reached its limits, past populations were able to adapt to the needs of the environment by applying intensive cultivation methods such as short fallow, crop rotation, terracing, manuring and irrigation. Contrary to the prevailing idea in which intensification of agriculture resulted in a population growth, she argued (1965: 35–42) that population increase could lead to the intensification of agriculture. This intensification would exhibit as expansions of cultivated land and as shorter fallow periods (Darity 1980: 137–38). The declining return of investment caused by the growing demand of labour could be avoided because the increased agricultural production resulted in a larger work force (1965: 35–42). Although Boserup's case studies did not concern Bronze Age Greece in particular, her theoretical ideas are visible in the interpretations of many survey results of the BA settlement patterns. For example, the Berbati-Limnes survey credited the LBA site expansion from the Argive Plain to the Berbati Valley and Limnes uplands to the intensification of agriculture - the need for more cultivation and pastureland (Schallin 1996: 170).

The applications of carrying capacity have often been demographic. When possible, they use census records and other historical and statistical archives to observe changes in population, household and family sizes, or fertility, mortality, and migration patterns (Bayliss-Smith 1974; Bintliff 1989; Zubrow 1971). In the context of the LBA populations, the challenge of the carrying capacity is to acquire relevant data to perform the demographic analysis. Furthermore, as Outram and Bogaard (2019: 43) point out, the results are more often relative rather than absolute. Moreover, the most recent discussion related to the carrying capacity of ancient (agricultural) societies has taken influences from other fields such as paleoclimatic and resilience studies (see overview of the methodological challenges of this approach in Degroot *et al.* 2021). The Boseruppian ideas about the intensification of food production through innovation and adaptation are now often accompanied by investigations of the vulnerability and resilience of past societies when the prevailing conditions for agricultural growth face challenges such as rapid climatic changes (e.g. Allcock 2017; Roberts *et al.* 2019; Weiberg and Finné 2018, 2021; see also pp.51-60 of this work). Resilience Theory analyses a variety of methods of past communities to control, protect and reorganize themselves and the environmental resources they use. Thus, instead of remaining dependent and vulnerable to changes in natural conditions according to the deterministic Malthusian perspective, past communities were able to survive even rather drastic changes in the environment

(Erdkamp 2022: 108-109; Weiberg and Finné 2021: 216-228). Their level of vulnerability and resilience can be, to an extent, measured. Resilience Theory uses the concept of the Adaptive Cycle Model, in which a society goes through a cyclical pattern of Growth, Conservation, Release, and Reorganization (Erdkamp 2022: 109; Freeman *et al.* 2017: 84; Peeples *et al* 2006). Of these, Growth refers to the exploitation of resources which, contrary to Malthusian perspective, does not continue growing until a maximum capacity has been reached, but instead is preserved. This state of Conservation creates vulnerability to unexpected changes in external conditions. Vulnerability is followed by Release and Reorganization when the existing system stops working and a new system needs to be created. The key tool which enables the measuring of vulnerability and resilience s connectiveness, which refers to the impact of each phase of the cycle on each other (Holling and Gunderson 2002; Peeples *et al.* 2006).

Despite the issues related to its measurability, and the critique of its earlier approaches that may have had deterministic ideas about the use of landscape data, the principal idea of the carrying capacity analysis about the extent of landscape exploitation forms the basis for the analysis of agricultural potential used in this study. Its value is its ability to offer tools to quantify subsistence. The agricultural potential and its subtle differences to the carrying capacity analysis are further discussed on pp. 51-60. In summary, in this study agricultural potential is preferred as a term due to the emphasis on agriculture as a subsistence strategy for the vast majority of the investigated people, and because the study of agriculture includes, to some extent, the idea of farming as a cultural phenomenon – an approach that is often missing from carrying capacity estimations.

Current approaches to the LBA Aegean and subsistence

Recent archaeological projects on LBA Greece have become increasingly interdisciplinary, although specialist research remains important. Botanical, faunal, osteological, geological and climatic evidence is increasingly being investigated through scientific methods such as aDNA extraction (e.g. Bouwman *et al.* 2008; Chilvers *et al.* 2008), and isotopic analyses of cave speleothems (e.g. Finné *et al.* 2014, 2017). Although such specialized studies are increasingly examining past subsistence strategies as integrated systems, broader interdisciplinary analyses remain limited. In addition, floral and faunal datasets published decades ago remain central to Bronze Age subsistence studies in Greece. Among the few new key studies of the LH III Aegean are, for example, isotope analyses on early Late Bronze Age burials of Mycenae (Richards and Hedges 2008), Knossos (Nafplioti 2016), and Pylos (Papathanasiou *et al.* 2012). These analyses have yielded information on variations in health and diet of Late Helladic elite individuals. However, their results are not fully placed in the context of other previously-published data, such as zooarchaeological or botanical assemblages, which could offer broader insights into dietary resource management.

Studies concerning LBA subsistence strategies have focused on storage strategies (e.g. Christakis 2004; Forbes 2017; Margomenou 2008; Privitera 2014), resilience (e.g. Finné and Weiberg 2018; Timonen and Brysbaert 2021; Weiberg and Finné 2018), or the way the LBA 'collapse' related to climate change and resource depletion (Brysbaert 2020, 2021; Finné *et al.* 2017; Izdebski *et al.* 2016; Kaniewski *et al.* 2013; Timonen and Brysbaert 2021). These themes have, in part, brought new perspectives to the carrying capacity, adaptation, and agricultural intensification discussions. However, the study of agricultural practices in the LBA Aegean is still strongly related to the fields of archaeobotany and zooarchaeology (Bogaard *et al.* 1999, 2013; Jones *et al.* 2000, 2010; Vaiglova *et al.* 2017). These studies shed light on manuring, irrigation, crop selection, animal diet and movement, and the various uses of plants, among other topics. While there is a need for more of such specialized studies to create a sufficient database for further comparative analyses, there also remains a need for comparisons among these field-specific studies. This study attempts to draw together results from these various lines of evidence.

Many of the current scholars studying BA subsistence practices in the Aegean originated from the Cambridge paleoeconomic school. Paul Halstead's work in particular has laid a firm foundation for the study of integrated agricultural systems. Halstead has systematically explored various aspects of past agricultural practices by integrating archaeological evidence (settlement patterns, faunal and botanical remains), archival sources (Linear B texts), and ethnographic testimonies (mostly of traditional Greek farming communities) (e.g. Halstead 1992; 1996; 1999b; 1999c; 2003). Other paleoeconomists who have considered agriculture in Bronze Age Greece include Amy Bogaard (Bogaard *et al.* 1999, 2013, 2016), Lin Foxhall (Foxhall 1995; 1996; 1998; Foxhall and Forbes 1982), Glynis Jones (Jones 1987, 1995; Jones *et al.* 1986, 2000), Evi Margaritis (Margaritis 2013; Margaritis *et al.* 2014; Margaritis and Jones 2006), and Tanya Valamoti (Valamoti 2002, 2009, 2011b, 2018; Valamoti *et al.* 2007, 2011; Valamoti and Charles 2005). Most of the scholars within this group initially specialized in archaeological sub-disciplines, such as archaeobotany and zooarchaeology, before expanding their focus towards more interdisciplinary projects centered on early agriculture. Their research often involves by collaboration with other specialists in archaeology and natural sciences, as well as the utilization of ethnographic data. Such interdisciplinary mindset, and the use of multiple cutting-edge methods to analyse different sets of data, have enabled the examination of ancient farming from a holistic point of view, and include cultural and social aspects into the study. Some of the central concepts used in this study, such as the cost-effectiveness of farming strategies, the relationship between settlement patterns and cultivation methods, stem from the paleoeconomic research tradition. Thus, this study applies an integrated paleoeconomic approach to ancient farming within a specific case-study area. This approach helps to shed light on the relationships between socio-political organization, environmental sustainability, and farming strategies within one of the Mycenaean heartlands: the Argive Plain.

Models of intensive and extensive agriculture

Among the prominent approaches concerning agriculture in the Neolithic and Bronze Age Aegean are the intensive and extensive farming models, notably illustrated by paleoeconomic scholars such as Paul Halstead and Amy Bogaard. Intensive agricultural practices are characterized by small-scale private ownership and management of land, low levels of land fragmentation, labour-intensive strategies and, consequently, higher yields. Extensive agriculture, on the contrary, aims at increasing profits by cultivating on larger quantities of land with less labour-intensive methods. Draft animals are increasingly used in extensive farming to commute longer distances to fields, and to assist in heavy farming tasks. The following section introduces these farming models in more detail, and discusses their relevance to the agricultural potential model presented in this study.

Traditional studies of ancient farming methods in the Neolithic and Bronze Age Aegean have often focused either on crop cultivation or animal husbandry, and published as independent chapters of the reports of these projects (more on research tradition on pp.41-43). Paleoeconomic approaches have drawn more interest towards the integration of cultivation and animal husbandry (e.g. Halstead 1987b: 82; Bogaard 2005: 177). At the core of this integrated approach is the idea of intensive and extensive farming regimes that can be examined for their practical aspects such as actual farming methods, but also for their embeddedness in the prevailing socio-political system. In the Mycenaean context, focus has often been on the larger-scale agricultural production of palatial administrations which is partially documented on Linear B tablets. However, contrast between textual and archaeological evidence of Mycenaean farming suggests the prevalence of smaller-scale farming, referred to by some as a system of 'small-holdings' (Halstead 1992: 69; 2001: 39; see also pp.15-18 of this publication). The question arises whether these small-holdings maintained more intensive cultivation practices despite the likely tendency of the palaces and their inhabitants to shift towards extensive farming.

According to Halstead (1987, 1989), Neolithic and Early Bronze Age communities in the Aegean typically lived in small, dispersed units and exploited the land close to their dwellings, farming mostly for their personal use. The Neolithic household, serving as the fundamental agricultural unit, was well-equipped to meet the labour demands of subsistence farming in this environment, with fields and pasture located close to the settlement, and labour force consisting mainly of the household members. Early farming in Greece can, thus, be characterized as intensive, involving methods of crop and animal husbandry that demanded a higher workload but operated on relatively small land plots. Bogaard (2005: 179) calls this system 'garden-cultivation'.

Intensive farming methods encompassed practices such as crop rotation, weeding, manuring, hand irrigation, and the keeping of a small number of domesticated animals. Under crop rotation, cereals and pulses (or leguminous plants) alternated on the same plot every other year. Pulses helped in maintaining soil fertility which was depleted by the previously cultivated cereals (more on pulses on pp.95-97). Conversely, pulses, requiring more water than cereals, likely necessitated regular hand-watering. This would have increased the labour intensity of farming. To enhance crop yields, methods such as middening and manuring may have been employed despite the increased need to weed (Halstead 1987: 83). Manure from the limited number of animals kept by prehistoric households would be collected for fertilization, possibly also serving as fuel. Household waste could have also been collected for fertilization, or to feed a pig or two.

In the intensive farming regime, the number of kept animals would depend on the ability of the household to manage them. Therefore, animals with smaller labour and economic costs, such as sheep and goats, were preferred over cattle, oxen, or horses (Bogaard 2005: 179, 2016: 29; Halstead 1987: 81-83). Animals were primarily raised for meat, although other products such as milk and dung were also utilized (Bogaard 2005: 180). If herd sizes remained modest, animals could graze on the fringes of fields and unused wastelands near dwellings, as well as on stubble after harvest. This would ensure that herding or the application of manure did not result in unmanageable labour costs (Halstead 1987: 81-83).

Methods used in the intensive farming regime would result in periods of high workload (Bogard 2005: 179). Nevertheless, by strategically using the available labour, a Neolithic household could schedule these tasks within the annual farming cycle with relative comfort. A crucial factor for successful crop and animal management would have been the short commute to fields and pasture sites. In addition, with most resources readily available in close proximity, and production targets kept in manageable limits because of the limited size of the household, farming remained sustainable.

The intensive model challenges the idea presented by Boserup (1965: 21-22 and 35-42; see also p. 45 of this publication) that past populations adopted intensive cultivation methods to handle population increase. While Boserup (1965: 35-42) argued that the adoption of intensive farming practices would result in a population increase, thereby balancing the increased demand for labour, other scholars (Bogaard 2005: 180; Halstead 1987; Nitch *et al*. 2019) suggest that intensive methods are best suited for small household units capable of managing the associated workload. Larger communities would organize themselves differently, living in more nucleated settlements with longer commutes to fields and pasture. This, in turn, would result in varying agricultural practices.

The intensive model also contradicts the idea of farmers consistently aiming to minimize effort in their subsistence strategies. In fact, high-workload tasks would be adopted as long as they provided a profitable output (Bogaard 2005: 178). Halstead (1987a) and Forbes (1982) have sought examples of the relationship of labour inputs and outputs within traditional Greek farming communities which relied minimally on machinery or fertilizers. For instance, raising animals for dairy proved more beneficial for traditional small farming communities than raising them for meat, despite the notably higher labour costs in dairy production. Similarly, the labour costs in crop cultivation could surpass those in animal husbandry, but cereals might still provide the best subsistence and financial support for a community of specific size (Halstead 1987a: 80). The possibility of dairy production in the Mycenaean context is proposed based on limited Linear B and zooarchaeological evidence (presented on pp.106-114). However, careful consideration is required to ascertain whether Mycenaean rural communities had the adequate workforce to manage larger herds and the associated tasks related to dairy production.

Although intensive methods such as watering and manuring would generally provide higher crop yields, unforeseen environmental crises could lead to crop losses and subsistence challenges. Related to the intensive and extensive models, Halstead (1989) introduces the concept of a 'normal surplus'. An early farming household could use certain methods, such as growing a diverse range of species to ensure the survival of at least some, to overcome poor production years (Halstead 1989: 72). However, as Halstead (1989: 72) points out, survival would always have to be secured by producing moderately beyond the needs of the household. This normal surplus included agricultural staples, some of which could be stored for up to a year, as well as livestock that could be slaughtered for food during severe economic crises (Halstead 1989: 73). Normal surplus would also involve social storage through connections with other communities and households. Transactions with neighbours could encompass the exchange of essential resources such as grain or oil for other items such as pottery or more specialized craft products. Neighbouring communities could also offer food aid during severe crisis years. Additionally, these connections would provide a social supply for marital and other bonding agreements. Such transactions could lead into relationships of favours, dependency, and ultimately increasing social complexity.

Halstead (2006: 26-27) proposes a shift in agricultural practices from the Neolithic era to the Bronze Age, coinciding with the formation of nucleated communities with higher populations. Centralization of population resulted in longer travel times to fields which, in turn, increased agricultural workload. Within nucleated settlements, labour specialization into tasks beyond farming took place. To adapt to these changes, a different set of farming methods had to be adopted (Halstead 2006: 26–27). These methods are included in the extensive agricultural model that finds some similarities in the farming practises of recent historical communities in Greece.

When travel times between fields and settlements are extended, intensive work tasks such as hand-watering, manuring, and weeding become impractical as they require regular visits to the fields, and the transportation of heavy loads (e.g. manure) over long distances (Halstead 1987: 82). On the other hand, with greater distances between dwellings and pasture sites, animals of single households could be herded together further away from habitation. This would free hands for other labour-intensive tasks such as garden-cultivation of vegetables and pulses, but challenge dung collection, unless animals were penned overnight. Other means, such as bare-fallowing, had to be introduced to replace fertilization with manure (Halstead 1987: 82). In the bare fallowing regime, the field is left uncultivated for a full year (or more) in order to restore soil fertility. As hand-watering and manuring are not usually used for extensively cultivated fields, these produce lower yields than fields cultivated with intensive methods. However, lower yields are compensated by larger area sizes (Bogaard 2005: 179; Halstead 1987: 82). Additionally, crop species with higher tolerance towards dry and poor soil conditions can be chosen. In hierarchical communities, elites may have had the privilege to select areas with better soils for personal or specialized production (Halstead 1987: 83; Nitsch *et al.* 2017: 123, 2019: 164). Before plots are cultivated again, the fallow is ploughed to prevent excess weed growth. Various other tasks, such as harvesting and crop processing, could be done collectively. Borrowing pack and plough animals between households could facilitate more efficient transportation and field preparation (Bogaard 2005: 179; Halstead 1987: 83). In fact, in the Mycenaean context, the exploitation of animals, especially large and expensive ones such as cattle and oxen, for their power and secondary products forms the basis of the extensive farming system. Since these animals could be used to plough fields, carry heavy loads over long distances, and assist in crop processing for example by trembling crops on threshing floors, they enabled the opening of larger land areas for cultivation, and the location of these areas further away from settlements. Animals did not only provide power, milk, and resources for crafts such as hides and bone, but they could also function as a type of storage. For example, in severe cases of crop failure, higher volumes of dairy and meat could be used for survival, or animals could be exchanged for other products (Forbes 1982; Halstead 1989).

In the Mycenaean palatial economy, agricultural production such as wheat cultivation and sheep (wool) husbandry likely held a specialized production status. Palatial interest in agricultural production concerned a small variety of products (Halstead 1992: 58, 2001: 38). Contrast between the textual and archaeological (especially archaebotanical) evidence of Mycenaean farming suggests the prevalence of a system of 'small-holdings' (Halstead 1992: 69, 2001: 39; also pp.15-18 of this work). It is probably that these farms, farmsteads and hamlets maintained more intensive cultivation practices simultaneously with extensive farming being practiced by the inhabitants and administrations of large, nucleated settlements, much like in more recent history. However, the extensive agricultural regime need not be solely related with highly hierarchical societies and elite economic activities; it can also emerge in farming village and town level. For example, if, as Bintliff suggested (2019), the LH III Argive Plain represents a highly urbanized settlement pattern, and people mostly commuted to their fields from urban settlements, cultivation practices might have generally followed the extensive regime with bare fallowing, long-distance winter and summer pasture, and use of large animals for ploughing and transportation. Cereals intended for palatial use would have been cultivated on high quality soils, as the need for them to produce sufficient harvest for rations and elite use was highly important. Manuring would have been challenging because animals were grazing away from habitation and crop fields. That is why cereal production for palatial use would have taken place on plots of notable sizes, and likely under extensive regime. Legumes could have been grown closer to settlements in garden plots which allowed hand irrigation and fertilization, although their abundance in the archaeobotanical samples of the LBA Greece suggests cultivation on a notable scale. Nevertheless, as noted by Heinrich and Erdkap (2021: 4), in Roman agriculture the expansion of major centres led to an increase in the price of land in their immediate vicinity. On this expensive land, the opportunities presented by the growing markets of these centres made the use of intensive farming methods, such as manuring, more appealing despite the associated labour costs. Extensive farming was still practiced further away from the centres, but it did not present the only sufficient option for food production. Although, what may be effective in the Roman context does not necessarily offer a suitable parallel for the Mycenaean economy, the example can shed light to the general trends and decision-making processes in agriculture. In other words, while there is often a tendency to segregate the two agricultural regimes in recent scholarship, historical and ethnographic evidence suggests that both extensive and intensive farming practices were concurrently employed, possibly even by the same individuals across various plots in order to ensure sustainable production. Moreover, these methods were embedded in the prevailing social, political, and environmental systems.

The selection of intensive and extensive farming methods is, thus, connected to the political and societal systems of the Neolithic and Bronze Age Aegean, as, for example, settlement pattern could impact on the distance and commute to agricultural land. While small-scale subsistence farming has traditionally been considered the prevalent agricultural strategy for Neolithic and Early Bronze Age communities in the Aegean, but also more widely in Europe and Near East (e.g. Bogaard 2004, 2005; Halstead 1987; Sherratt 1980) the Mycenaean palatial elites are believed to have engaged in more large-scale farming that focused on producing specific crops and agricultural products (e.g. Foxhall 2013; Halstead 1992). Therefore, by looking at the evidence of farming practices, it is possible to gain insights into the extent and costs of labour of past subsistence strategies in different times. Growing communities with evolving complexity tend to adopt more restricted subsistence strategies, transitioning from hunting to crop cultivation, and from meat to dairy production. The choice between adopting extensive and intensive farming methods depends of on various factors such as technology, population size and organization, and the aims of agricultural production, for example whether production is subsistence oriented or targeting notable surplus (e.g. Halstead 1987a: 80-81). The complexity of agricultural economy is created by the interplay of these factors. This complexity highlights the challenge of reconstructing the past using recent and historical examples. Recent historical agricultural practices are inseparable from the social and political climate of their time and, as such, cannot be directly compared with past societies, who existed in a different socio-political situation (e.g. Halstead 1987b: 84; Halstead and Isaakidou 2011a). Nevertheless, ancient farming in Greece has often been examined through Classical, later historical, and ethnographic analogies, as these can offer quantifiable data used in detailed reconstructions of labour costs, production capacity, and agricultural calendar.

Even though intensive and extensive agricultural models have great importance in estimating regional agricultural potential, and explaining variation in crop yields, field sizes, and herd sizes and compositions, both models are presented in a rather generic way. Studies in which these models have been test in past regional contexts (e.g. Neolithic Thessaly, see Bogaard 2004, 2005), have not thoroughly considered the possibility that a variety of agricultural strategies could have been practiced simultaneously in the same region. Moreover, the impact of the palatial activities on the lives of subsistence farmers has not been exhaustively examined. Therefore, in this study, there is an excellent opportunity to review the strategies of agriculture in one specific area in the light of several types of archaeological data. By comparing these data, it is hopefully possible to say, how these farming regimes were integrated in the LH III Argive Plain social, economic, and political organization, and reconstruct the local farming system and land productivity.

Agriculture as an integrated system

'Farming' is defined as 'the business of cultivating land and raising stock'. It is equated with 'agriculture', which is 'the science and art of cultivating the soil, including the gathering of crops and the rearing of livestock' (Barker 2006: 2). At the same time, as its name indicates, agriculture is also cultural. Therefore, contrary to the definition above, agriculture is not only the tending of crops and animals, but regulated by the ways communities organize their daily lives. The aim of this book is, thus, to develop a holistic understanding of the Mycenaean agricultural practices and how they were interconnected with environmental resources, and the Mycenaean societal, political and economic organization. Theoretically this approach builds on a long tradition of specialized archaeological research, influenced by ecology, anthropology, and economic studies.

The present study approaches the LBA agriculture through a concept named 'agricultural potential'. While the end result - calculations of the size of population sustained by a land area - resemble that of carrying capacity analysis, the agricultural potential has the ability to better include cultural aspects and human agency. This approach is more holistic, as it argues that while environmental conditions regulate peoples' survival through chance and natural selection, people also modify their environments through social and cultural processes. These modifications can happen over long or short periods of time. Such understanding of human agency leans on ideas from Resilience Theory (introduced on p. 46) but are also familiar from other fields of research such as Niche Construction Theory, used in biology, and more recently in archaeology (Boivin *et al.* 2016: 6389-91). Thus, the LBA Argive Plain agricultural landscape is the product of generations of environmental shaping, which is connected to changes in settlement patterns, and political and economic changes of the people inhabiting the area.

The approach is indebted to the paleoeconomic school, which, as discussed earlier, originated in Cambridge and continued evolving in Oxford and Sheffield. The main aims of this book are to study the food production and land productivity of the Late Bronze Age Argive Plain, resulting in a number of people who could be sustained by farming in this region. By doing so, this study contributes to the analysis of the sustainability, resilience, and vulnerability of the Mycenaean societies at their peak, moments before the Bronze Age collapse. For these purposes, the analysis of the regional agricultural potential, based on a carrying capacity assessment, is best suited.

A variety of other approaches can be adopted to study changes to study population numbers, farming practices, or land use. However, demographic approaches most often require textual evidence of a statistical nature, or mortuary data (e.g. numbers of burials and deceased individuals) to produce sufficient results on population numbers, fluctuation, and societal structures. In the Late Bronze Age Argive Plain context, these data are currently unavailable in formats or volumes which would allow extrapolation into population numbers. While mortuary data is present, it mostly derives from Middle Bronze Age contexts. Textual evidence (i.e. Linear B tablets, seals, etc.) from the Argive Plain is too fragmentary to extract a sufficient picture of the local socio-political situation, even just for the purposes of comparing it with other LBA regions and systems. Farming can be studied from archaeobotanical and zooarchaeological data which does exist also in the LBA Argive Plain contexts. These data sets form important parts of this book as well, but alone cannot be used to establish solidified figures about land productivity. As explored further in Chapter 5, it is often difficult to correlate these data sets with each other due to their unstandardized nature, and due to the long period of time that has passed since some of these studies were conducted and published. Standardization of these studies is, however, needed to form a better picture of the agriculture and other subsistence strategies taking place in the Argive Plain at this time. Finally, land use can be, to some extent, studied by looking into changes in settlement patterns. Since the LBA textual evidence has not given firm evidence of the settlement hierarchy of the Argive Plain, divisions of the region into sub-regions, each controlled by their central settlements, have been attempted for example by Thiessen polygons by Bintliff (1977) and Kilian (1988) (see also pp.32-34). As mentioned before, these divisions can shed light on the political organization of the region but might not reflect well land use for agricultural purposes. Therefore, it is argued here that without the knowledge of the type of agriculture practiced within each territory, or the number and size of the farming communities residing in these areas, such arbitrary divisions do not contribute in a major way to the analysis of land productivity. In the future, new survey data can help to better estimate the type of farming that was practiced in the LBA Argive Plain (e.g. WARP data on potential rural sites, further notes on p. 21).

Promoting interdisciplinarity, the paleoeconomic approach allows the use of multiple data sets deriving from previously published sources, and this way provides the most suitable basis for the analysis included in this study. The approaches of the paleoeconomic school have been criticized for their environmental and economic determinism, meaning that on certain occasions, economic systems or environmental constraints are used to explain societal or cultural changes. However, the critique has been most often geared towards earlier methods and approaches such as site-catchment theory, and carrying capacity analysis. The criticism of the carrying capacity analysis is discussed elsewhere (pp.45-46), but it includes many of the critiques exposed over paleoeconomy on the whole. critique on environmental determinism of the paleoeconomic school However, paleoeconomy is interested in the role of human individuals in shaping their environment and their own subsistence-economic and societal systems. This underlying motif is also visible in this study, as it analyses farming as an integrated system of human agency and environmental factors. This is best visible in the ways the Mycenaean communities modified their environment in the Argive Plain, but also in the fact that it is still difficult to understand in detail how the subsistence-economic cycle was organized between the larger and smaller communities residing in this area. It seems clear that in this regional, chronological, and political context, communities did not always follow the most practical or sustainable ways of living. It is acknowledged that a certain amount of determinism is included in the concept of agricultural potential, as it results in a maximum limit of productivity of an area. However, as discussed in the following section, and again in Chapter 7, this study also takes interest in the ways the Argive Plain communities organized their daily lives and interacted with each other. The following section explains the agricultural potential in detail and ends with an overview of the types of data used in this analysis.

Agricultural potential

The analysis of the agricultural potential uses ideas of carrying capacity and places them in the framework of agricultural societies. The analysis examines what kind of environmental constraints might regulate human activities, as well as the ways people intentionally modified the environment to be better suited for subsistence production. Biological and cultural aspects present opportunities, or potential, that invite human activity. This activity that can be physical, for example clearing land for farming, and non-physical, for example giving symbolical value to specific characteristics of the landscape. Recent tradition has identified these opportunities as 'affordances', which is a concept originating from ecological psychology (Gibson 1977; Heras-Escribano and de Pinedo). Here, the term 'agricultural potential' is preferred, to emphasize the focus of this book on the potential and the modifications of the environment specifically for agricultural purposes.

Agricultural potential is formulated through a large number of variables (Figure 4.1), which in this work are divided into two categories. The first includes the most important characteristics of the past agricultural system. The practices related to cultivating crops and tending animals that would have been essential for what could be produced, how much was produced, and where this production took place. In this book, activities related to food production are emphasized, although other subsistence activities such as building and maintaining living spaces, tools, clothes and other material items are also important. Agricultural practices can include choices about which crops and animals are exploited, or if manuring, irrigation, weeding and fallowing are used to improve crop growing conditions. Culture, religion, political organization and connections to other groups are all embedded in agricultural practices, for example, as regulations of who can practice farming, which crops are valued, and whether there are products which are only used in elite or religious contexts. In this study, the focus has been placed on the farming communities as opposed to the Mycenaean elites.

The second category by which this study examines agricultural potential consists of factors which evaluate the size of population that could be sustained in an environment with agriculture as their main subsistence strategy. These include various aspects of the environment that created opportunities and constraints to agricultural activities in the past, such as topography, soil consistency and climate. These aspects must be considered in combination with the ways people modified their environment to create more opportunities. These methods can be explored by reconstructing the past agricultural systems and include, for example, ploughing, building terraces and water management installations, or choices about cultivating drought-tolerant species in years of low rainfall.

While the carrying capacity analysis believes in the tendency of human populations to grow until they reach the environment's capacity to sustain them, after which they might whither by extinction, migration, expansion, or some other dramatic event, the agricultural potential seeks to understand the humankind's role in shaping the environment according to its needs, and its tendency to maintain stability, to remain sedentary. Therefore, the agricultural landscape of the LBA Argive Plain was the creation of generations of modification and maintenance of the environment for agricultural purposes.

The calculations of the agricultural potential consider the size of the agricultural area, the volume of production in this area, and the average consumption of these products. Each of these variables are dependent on both environmental and cultural characteristics. The results are presented as a (maximum) number of people sustained by the land area over one year's cycle.

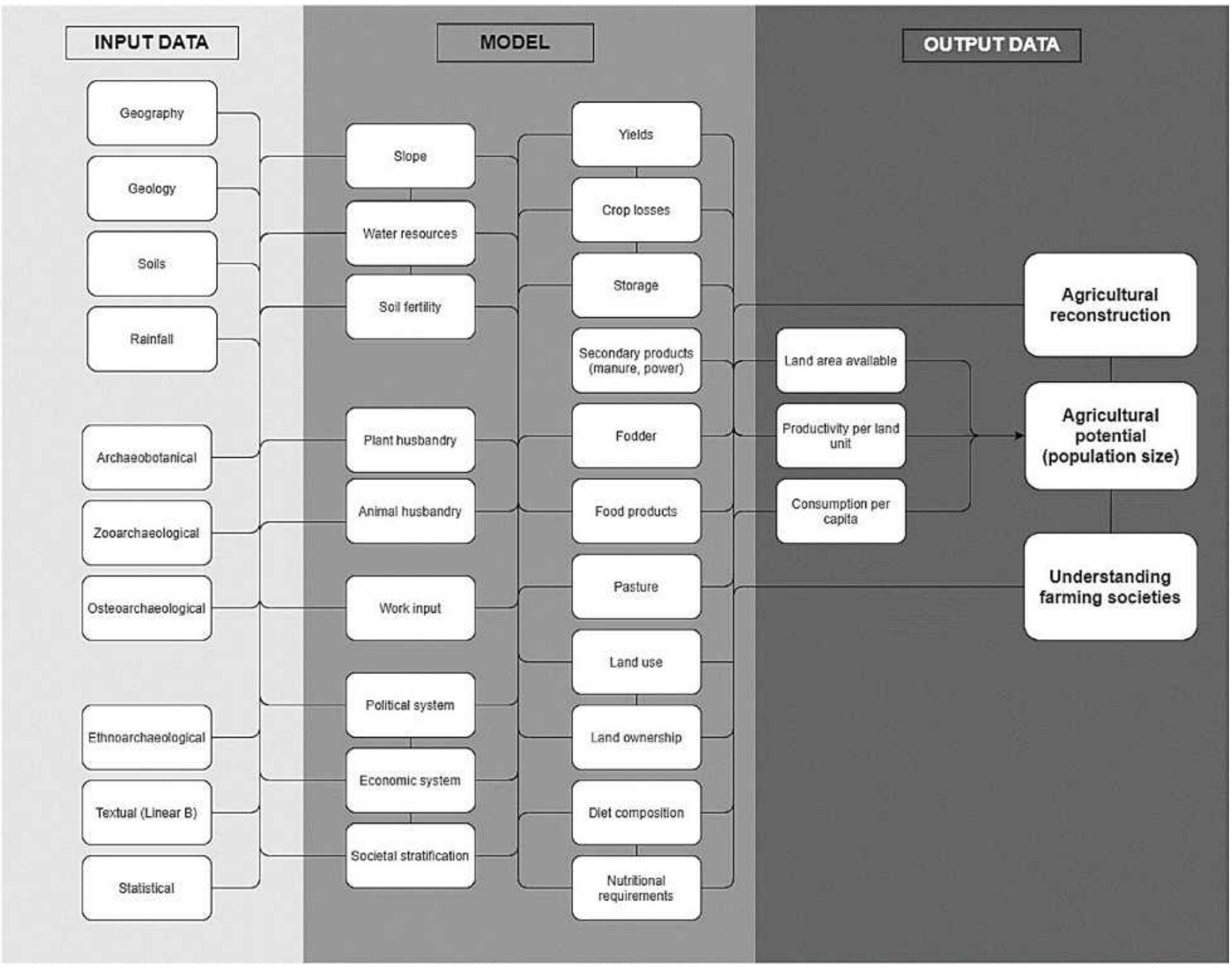

Figure 4.1. Visualization of the reconstruction model of the LBA Argive Plain agricultural potential.

In a simple form, the calculation is , where
P = the agricultural potential
a = the area of production,
y = yield, and
c = consumption per capita.

The process begins with the evaluation of the size of the land area that was suitable for agricultural production in the LBA. In this study, land area is expressed as hectares. The next phase evaluates, firstly, the day-to-day diet composition of one LBA person, and, secondly, the potential to produce each food item in this composition. With plant crops, this potential equals their yields and is expressed as kilograms per hectare. With animal products, yields can be transformed into milk or meat production per unit of pasture. The food that one person consumed in one year is considered as the annual production target of this person. Once this target is known, the average yields of each food item can be divided by the production target. The result is an amount of land (ha) that is needed to fully sustain one LBA person with all food items in their diet composition, a personal subsistence area. In the final phase, this individual subsistence area is used as a divider for the total land area available. The final result is, therefore, the number of individual subsistence areas, i.e., the number of people, who could fit into the total land available.

While the process of calculations to produce the agricultural potential is straightforward, the challenge of the method lies in defining certain key variables such as diet, production targets, or the available agricultural land in the distant past. In this study, the variables to estimate the agricultural potential of the LBA Argive Plain are collected from several types of data, of which archaeological, ethnoarchaeological, and nutritional data are the most important. The following section briefly presents the ways these data are obtained, and what has to be considered (i.e., biases) when these data are examined in a Late Bronze Age context.

The approach

The data used in the analysis of the agricultural potential in this study are collected from published literature and reports. The long history of archaeological projects in the Argive Plain and more widely in the Peloponnese has produced a considerable number of publications about various aspects of the Bronze Age. Of several types of published data, environmental such as studies of animal and plant remains, and material-architectural such as descriptions of the excavated settlements and their finds, are most comprehensively available of the LBA Argive Plain. However, these analyses rarely address the 'big questions'. The substantial number of publications on specific data sets or recovery methods has created an idea of the Mycenaean Argive Plain as a thoroughly investigated region. However, a closer look at wider themes such as agriculture quickly reveals the gaps in our knowledge and shows that much research is still centred around the Mycenaean elite. There is clearly a need for more synthetic studies.

This study provides such a synthesis by examining the available data in an integrated manner, to better understand Mycenaean agriculture and farming communities. These data sets include: l) modern and LBA soils and geology; 2) modern and paleoclimatic data; 3) evidence on LBA agricultural tools and other objects, 4) archaeobotanical data; 5) zooarchaeological data; and 6) osteoarchaeological data about human diet and health. These datasets, presented in detail in Chapter 5, are placed in the overarching framework of studies on ancient agricultural practices. The data derive from various sources, of which the archaeological data are obtained through excavations and surveys. Other sources include ethnoarchaeological studies, analogies from the Classical period in Greece, and modern nutritional ecology, which aims at understanding human metabolism and diet. These three sources are presented in more detail in the following subsections.

The challenge of this approach lies in the fact that only published data are used. There have been no attempts to re-examine the material remains. Special attention is paid to the find contexts of the LBA material remains (when published). Depositional processes can distort the evidence of the past and the present (Verhoeven 2005: 256). Careful consideration of the formation of find contexts, in particular including any new interpretation that has occurred since the original studies were conducted (many of the studies used here were published some 30-50 years ago), can help us to decide whether material remains represent specific human activities. An example of this is macrobotanical remains recovered at archaeological sites, which are often interpreted as plants used for food. However, as discussed in further on pp.90-100, botanical remains can also be transferred to settlements in dung, in which case they can be used to study animal husbandry practices or fuel and fire use instead. In relation to ethnographic applications in archaeology, Hollowel and Nicholas (2008: 69) suggest that the best results are achieved by producing several models to which archaeological data can be applied. Therefore, in this study the results of the agricultural potential will be presented as a range of numbers (of population, yield, and consumption). This can help to avoid an overly deterministic approach to the LBA population and to the analogues offered by traditional (usually referring to early 20th century, non-mechanized agriculture in the Eastern Mediterranean) and ancient historical examples of crop production. Furthermore, the reconstruction of the LBA agricultural practices will consider the current knowledge of the prevailing LBA political and economic organization in order to detect the dissimilarities between the past and the present farming communities, and to better weigh the value of the analogous relationship established. These approaches, and their results, are presented in Chapter 6.

Ethnoarchaeology and the use of analogies

Reconstructions of agricultural practices presented in this study rely on the results of several ethnographic and ethnoarchaeological studies conducted in Greece and the Eastern Mediterranean in the latter half of the 20th century. O'Connell (1995: 205) has defined ethnoarchaeology as 'the study of relationships between human behaviour and its material consequences in the present.' Ethnoarchaeologists seek to obtain knowledge on traditional practices which could be relevant to the reconstructions of the past. Its methods usually include observations and surveys of and interviews with people who live in specific social and cultural settings considered 'traditional'. Although the definition of traditional is complicated, in such contexts it usually refers to long-established customs and practices, often considered as habitual and even conservative, which are usually handed down through generations. The focus of ethnoarchaeology has long been on reconstructing the activities of small-scale societies by observing modern indigenous groups following traditional lifestyles (Lane 2008: 238). Studies of past agricultural societies benefit from ethnographic approaches, for example by obtaining information on traditional cultivation and animal husbandry practices, but also by examining cultural conventions which regulate subsistence strategies within these communities (Outram and Bogaard 2019: 18). Traditional agriculture and traditional farming practices are often described as non-mechanized, family-based, and subsistence-oriented. Fertilizing takes places with animal manure instead of chemical products, most work tasks follow seasonal cycle of climatic and environmental fluctuation, and the entire family or extended household participates in the completion of these tasks as an effective work unit (Brassley and Soffe 2016: 87–88). Although this characterization might change over time, for example when milking or crop processing machinery are introduced on a farming household level, most of the features described above are still traceable for example to the early 20th century farming communities of southern mainland Greece (see pp.139-149 and below).

In Greece, ethnoarchaeology has been among the most important approaches in studies of prehistoric and Bronze Age subsistence strategies, land use, settlement and population sizes, and diet (e.g. Chang 1981, 1994; Forbes 2007, 2017; Halstead 2014; Halstead and Jones 1997; Halstead and Tierney 1998; Jones 1983; Jones *et al.* 1999). Ethnographic examinations gained popularity in particular from the mid-20th century onwards when they were included in some of the large-scale survey projects in Greece. During the Minnesota Messenia Expedition, for example, Aschenbrenner (1972) studied the activities of a traditional farming community living in the survey region. His observations were used by the survey project to model the agricultural practices and land use of the LBA population in the area. In the Argolid, the ethnographic investigations of Forbes (1982b) in the Methana peninsula and Koster (1977) in the Southern Argolid have enabled similar comparisons between the LBA and traditional societies (see also Forbes 1976a, 1989; Forbes and Koster 1976; Koster 1997; Koster and Koster 1976).

Ethnoarchaeology functions through analogies, correspondences or comparisons between present and past activities. Similarities are often first noted between past and present material phenomena. Such discoveries might result in new behavioural models, based on the idea that similar behaviour in the present and in the past may have caused similar phenomena (O'Connell 1995: 208). For example, in the Aegean, botanical and faunal species recovered at archaeological sites have been compared to the crops and animals tended in traditional farming communities. Similarities in species selection between traditional and past farmer households have been used as the basis to form further assumptions about similarities in crop processing and food preparation activities (Halstead and Isaakidou 2011a; Margaritis and Jones 2006; Valamoti 2009; Valamoti *et al.* 2011). Furthermore, by making observations of animal kill patterns, the locations of activities within traditional farms, or of the seasonality of farming activities, ethnoarchaeological studies have increased the understanding of how archaeological deposits (e.g. botanical or faunal) are formed, and how these deposits can be used to reconstruct past subsistence strategies.

The approach based on analogies has been criticized for remaining too descriptive on one hand and exaggerating the similarities between past and current human activities, on the other. Ethnoarchaeologists may have the tendency to limit themselves to material culture and behavioural patterns which are comprehensible to them, dismissing behaviour that remains unfamiliar (Anderson *et al.* 2014: 7–8; O'Connell 1995: 206). At the same time, when some similarities between the past and the current are found, expectations of further similarities can lead to the overlooking of significant differences. Wylie (2002: 149–50) argues that dissimilarities are, in fact, rarely examined as carefully as similarities, and that these two are almost never weighed against each other. These issues can result in analyses that are unbalanced (Chang 1994: 354).

Analogies are sought through 'natural or cultural' links between present and past communities (Verhoeven 2005: 254-55). In early ethnoarchaeological studies, ethnic and geographical closeness between the past and modern societies were considered particularly important (Yesner 2008: 42). Often this is still true, as seen in this study as well as in many ethnoarchaeological studies concerning the Bronze Age Aegean. For example, the traditional rural communities studied by Koster (1977) and Forbes (1984) in the Southern Argolid appear to resemble the LBA Argive Plain rural communities in their climate, geological environment, subsistence strategies, and to some extent, plant and animal species tended. It is, thus, easy to assume that there could have been further similarities in diet, land use distribution, or crop yields. However, even if archaeological material suggests that some (or many) aspects between these communities were similar, it does not mean that the people living in these communities acted in a similar way in other aspects. It would be dangerous to assume a direct relationship between traditional and past peoples. Furthermore, Politis (2016: 705) has noted that there seems to be an unspoken assumption that 'traditional communities' are better analogies to past communities than today's modern cultural groups which have been influenced by post-modern phenomena such as globalization. However, this denies the dynamics in communities in the past. It is impossible to determine the point at which a community cannot be used as an analogy anymore (Politis 2016: 706).

Chang (1994) has discussed this issue in relation to the study of Bronze Age pastoralism in Greece. While the domestic animals were the same in the BA as in recent times, as indicated by zooarchaeological evidence and by observations of traditional rural communities, a variety of aspects related to husbandry practices might have been different. Pastoralism is a subsistence strategy that comes in various forms (for example as full-time nomadic, or small-scale sedentary) and is usually tightly connected to the prevailing political and socio-economic system (Chang 1994: 355-58). The prevalent economic system, such as the market economy of today, strongly influences the way sheep and goats (and other animals) are raised, whether they are kept for milk, meat or wool, where and in what kind of flocks they are kept, and so forth. When severe crop losses or subsistence difficulties occurred in traditional communities, ovicaprids and other domestic animals have presented a survival strategy, stock that could be sold for money. Before market economy systems, animal slaughtering might have represented a practical survival strategy instead. In addition, the prevailing political system and social organization have implications for land use rights, pasture size and the arrangements of either communal or individual animal husbandry strategies (Chang 194: 360). This holds true for crop cultivation practices and other subsistence-related activities as well.

One solution to overcome the challenge of assuming too many similarities between present and past societies could be to compare many types of evidence. According to Forbes (1992: 89), both scientifically produced data (e.g. modern statistics), and data collected in non-scientific contexts (e.g. interviews with people living in the examined communities) should be used. However, he cautions that both types of data may be problematic. Traditional farmers interviewed by an ethnoarchaeologist can be reluctant to give information about average yields, flock sizes, or numbers of workdays included in their everyday farming practices. This is because each aspect can change according to the given seasonal, environmental or economic situation. To farmers, giving standard information on workload may seem redundant. It is then the task of the ethnographer to extrapolate from the observations she/he makes, but these can be biased, for example due to the short time spent in the community or because the specialization or research interests of the scholar guides them in a specific direction (for further discussion see the critical assessment of Hollowell and Nicholas 2008). In this study, for example, modern data of human nutritional needs are used to evaluate the sustainability of the LBA diet (analysed on pp.150-166). These data, however, are based on recommendations for a person living in the 21st century, who might have conducted vastly different levels of physical labour and who is mostly expected not to feel hunger. These aspects might have been different in the LBA. Chang (1994: 362) emphasizes the contribution of material (archaeological) evidence in studies which use ethnoarchaeological observations. According to her (Chang 1994: 353), assumptions based on ethnographic observations are not sufficiently evaluated against archaeological data that could help to make them less speculative.

In this publication, these problems will be tackled using several types of data. These data consist of archaeologically produced material evidence, ethnographic observations of the activities of traditional farming communities, recent nutritional data, and data extracted from the LBA textual archives. By comparing several types of data, similarities between past and current phenomena can be better detected. In addition, dissimilarities can be more easily noticed through the discrepancies between these data. As an example, observations of the land use and ownership of traditional farming communities compared to examination of the past textual records can help to better understand the differences in the social, political and economic organization between past and present. It is also important that the contextual information (environmental conditions, social and political systems, community sizes) of the ethnographic and ethnoarchaeological studies used in the present study (Appendix 2) is presented with similar detail as the contextual data related to past LBA societies.

The ethnographic studies used in this study all come from the Eastern Mediterranean, and four out of seven main studies from Greece (see Appendix 2 for the metadata of these studies). It is assumed that if the past climatic and environmental conditions can be compared to current conditions (discussed on pp.74-80 of this book), these studies compare well to the Argive Plain environmentally. The ethnoarchaeological studies of Forbes (1982) in the Methana Peninsula, eastern Peloponnese, and Koster (1977) in the Southern Argolid are geographically the closest to the Argive Plain. However, Methana has a challenging landscape formed by a volcanic, rough mountain range and a slim, fertile coastal area surrounding it. Areas suitable for agriculture are not abundant, and the peninsula resembles more of an island environment than a mainland plain environment. The Southern Argolid is also mountainous and difficult to access by land. Vast plains suitable for agriculture are absent, but fertile valleys can be found across the region. The studies conducted in these areas are based on interviews with local farmers by ethnographers who stayed in the communities for longer periods of time. The communities form small villages in which the vast majority of inhabitants practice crop cultivation and animal husbandry. In both studies, the villages were mostly self-sustaining. They only conducted small-scale cropping and crop fertilization. Therefore, these studies seem to suit well as comparative case studies for the past agricultural practices.

Two additional studies provide information on small Greek agricultural communities. These are Allbaugh's (1948) survey in post-World War II Crete, and the small ethnoarchaeological study of Halstead and Jones (1997) on the islands of Amorgos and Karpathos. Allbaugh studied the population and sustainability of Cretans as a part of a United Nations (UN) food aid program in countries which had suffered notably from the effects of World War II. Thus, his study is not an ethnographic analysis, but his target was to collect data on the local population for the use of the UN. Due to this agenda, his study includes details on local diets, professions, material culture, and subsistence strategies, which are not necessarily available in most ethnographic studies. Nevertheless, since the study is done without an ethnographic or archaeological approach, it is not informative about agricultural practices, or the experiences and customs of local communities. The study by Halstead and Jones (1997), by contrast, was conducted for ethnoarchaeological purposes: to observe the agricultural practices of the local island communities. This study is valuable for examinations of past agricultural systems. However, island environments differ notably from mainland environments, and the limited space provided by these small, closed spaces can result in specific agricultural practices, for example the increased use of terracing.

The environment that seems to best resemble the Argive Plain is presented in Hillmann's study of Asvan, Central Turkey (1973). Although far away from the eastern Peloponnese, the environmental aspects include an alluvial plain bordered by mountainous ranges, and an annual rainfall above 400mm. In addition, the cultivated plant species resemble those recovered in the LBA contexts in the Argive Plain (see pp.90-100). The Asvan community is the only one of those considered in this study that was not using chemical fertilizers when it was explored by ethnographers. The site has the potential to give some indications of crop yields in pre-modern conditions. However, Asvan is also located deep in inland Turkey. Distance from the sea may suggest differences in vegetation, climate, or in subsistence strategies (e.g. fishing was not an option for the inland inhabitants) when the region is compared to the Argive Plain.

Another study deriving from far-away contexts is that of Gibbon (1981) in the Aleppo Province of northern Syria. The study area included many different environments. Small farming communities had adapted to these environments with various subsistence strategies, some more focused on animal husbandry and others relying on irrigated cultivation. Gibbon conducted his research as a desktop study based on earlier survey data in the area. Due to its distance and differences in environmental conditions (e.g. lower rainfall), the study is perhaps the least suitable for the purposes of this book. However, the various subsistence strategies and the data of yields produced in dry conditions provide interesting comparisons to the yields produced in more favourable environmental conditions. Besides these main studies, other ethnoarchaeological studies might be used to collect additional information on specific issues such as agricultural tools or storage spaces. These studies are selected on a similar basis as the ones above, for their closeness (environmental or other) to the study area of this book.

Classical analogies

Data of Classical Greek and Roman agricultural systems have sometimes been used to reconstruct agricultural systems of earlier chronological contexts, such as the LBA Greece (e.g. Jardé 1925). Textual sources describing farming practices are mostly included in the literature from the 5th and 4th century BCE onwards. Textual references concerning pre-Classical agriculture in the Aegean are scarce, consisting mainly of Hesiod's *Works and Days* (*c.* 700 BCE), Xenophon's *Oeconomicus* (*c.* 400 BCE) (Isager and Skydsgaard 1992: 7), and of the few references to cultivation and animal husbandry in Homer's works.

Classical textual references can provide numerical data on crop yields, plot sizes, and food rations offered in exchange for labour services – information notably absent from the Late Bronze Age textual records. Although some similarities exist in environmental conditions (e.g. landscape and plant growing cycles) and common cultivation methods (e.g. fallowing and manuring) between the Classical period and the Late Bronze Age, these influence and exploitation of these aspects were tightly linked to the socio-political and economic environments of their respective times. As a result, analogies drawn from Classical Greek and Roman contexts are infested with similar biases as those from more recent historical periods.

What is more problematic, is the tendency of studies reconstructing Classical farming to base their observations on recent historical examples of rural life. Thus, analysis of the Late Bronze Age agriculture using Classical analogies faces the issue of double filtering, first through the generalizations made of recent historical farming, and secondly through the use of these models to extrapolate figures and practices in the prehistoric past. The use of Classical sources is often justified by the strong constraints that natural conditions, such as climate, geology, and soil consistency, pose on all pre-industrialized agriculture in the Mediterranean (Halstead 1987: 77). It can be lightly assumed that before chemical fertilizers or mechanized aid could be used to enhance crop yields or assist with heavy tasks such as ploughing and transportation, the limitations to farming resulted in similar yields, farming methods, and land use through time. This becomes quite clear when examining some of the key publications about farming and rural life in Classical Greece. For instance, Garnsey's much-cited *Famine and food supply in the Graeco-Roman world: responses to risk and crisis* states (1988: 8-9) that 'the broad pattern of food crisis in antiquity can be recovered if such ancient evidence as exists for food crisis is combined with modern data on climate and agricultural yield'. It further argues that this is possible because the Mediterranean climate has always fluctuated, and this has always caused regional crop failures. Furthermore, to impose information on recent historical rural communities on the ancient past, the author acknowledges (Garnsey 1988: 46-47) the existence of 'a core of recognizably peasant attitudes and practices' that remain constant through time and cultural contexts. Such assumptions seem obviously risky when laid out so visibly, but still often influence studies concerning agricultural surplus production, or the use and (potential) minimization of workloads in ancient farming.

As Halstead (1987: 78-81) points out, the assumption of pre-mechanized farming being strictly bound by nature has created an idea of 'ancient' farming as inherently unproductive, when, in fact, demands of the market economy have sometimes led to more unproductive strategic decisions by recent historical farmers. Farming in the Late Bronze Age and the Classical periods may have been more profitable than in recent history if it aimed at self-sustainability rather than larger profits. This could be enabled by a lesser degree of land fragmentation resulting in shorter commutes between fields and dwellings, and the possibility of using more intensive farming methods that increased yields. According to Halstead (1987: 83), Classical authors describing (or advising on) contemporaneous farming could have been contemplating the idea of switching to intensive methods in these extensive agricultural compounds. This would mean that the practical reality of farming in the Classical period was rather contrary to what the texts present.

In Greece, Late Bronze Age society looked rather different from Classical society in political and economic sense. One of the major aspects that was different in the local agricultural system was the extensive production of crops for trade in the Classical period (e.g. Garnsey 1988; Amemiya 2007). Some crops were produced to be traded with states across the Mediterranean, while other low-cost food crops were imported. Cash cropping[1] would result in a greater focus on valuable crops such as bread wheat and figs, or on fodder production, as animal power was increasingly being used, but also in specific landownership and land use arrangements (e.g. Gallant 1982, 1991; Garnsey 1988; Osborne 1987; White 1970). According to the current evidence, such systems did not exist in the LBA mainland societies, although trade of items increasingly took place towards the end of the period (more on trade on pp.85-86). In the Classical period, the state-controlled extensive agriculture likely played a much larger role in the local economy than the Mycenaean palatial production in the LBA. Simultaneously, small peasant communities practicing mixed farming were abundant outside the Classical city-states (Garnsey 1988; Isager and Skydsgaard 1992: 69). Landownership in the Classical period was based on the relationship between rich landowners offering plots for lease, and farmers who rented these plots for

[1] As explained by the Eurostat Agricultural Glossary (Eurostat 2023), farmers grow cash crops for the purpose of making a profit, either by selling them at local markets or by exporting them.

subsistence purposes. The latter often had to settle with plots located on marginal lands, because the most fertile areas were reserved for cash cropping. Yields drawn from historicaltexts can be biased since the information may not represent an 'average year', but a very good or very poor crop harvest (Killen (2004: 161), or yields of rich landowners altogether. Of common farming practices, manuring may have been more widespread in small Classical farms (e.g. Jones 2012: 15), simply enabled by the abundance of dung to contemporaneous farmers (see e.g. Osborne 2004: 37 about the requirements for manuring in the land leasing agreements of Classical Athens). On the other hand, as mentioned earlier, due to shorter commutes, intensive methods such as manuring could have been more common in the LBA. Ethnographic testimonies and historical texts can offer arguments for and against both views, which is why placing studies in their regional contexts is crucially important in Greece.

In addition to the diverging political landscape, Classical sources that offer the much-needed data on crop yields, rations, and plot sizes, are provided by elite authors who mostly describe the actions of the state or rich landowners (Foxhall 1996: 44). The problem is similar to that of the Linear B evidence. Perhaps these figures were very different in the peasant farming contexts. For example, (bread) wheat appears to have been the most important cereal crop grown extensively by the city-states in the Classical period. Barley is described as a famine and fodder crop. Nevertheless, Amemiya (2007: 114, Appendix 6.2) has suggested that, in fact, low-income Classical households (and slaves) mainly consumed barley. Furthermore, slaves were common in Classical society. Some of them worked in agriculture, providing a workforce for large estates. Slavery (at least to such an extent) was not a part of the LBA societal and economic system, however (see pp.8-15). This likely resulted in a different availability and organization of the agricultural workforce. Thus, in most cases, it is not wise to directly link historical text fragments with types of data with archaeological or ethnographic records, as they often present situations that are tied to the intentions of the author (Foxhall 2017: 298-300). Nevertheless, the tendency to do just that is strong because especially quantifiable data gathered from textual sources is considered as hard evidence with a more objective nature than, for example, fragmentary archaeological data, or images and oral traditions (Forbes 2007: 70).

Although the above offers a limited overview, it is clear that there were major differences between the agricultural systems between the LBA and the Classical period, and that biases might be related to the use of Classical references in other chronological or cultural contexts, as their interpretation is often based on the perception of farming and farmers' intentions in modern times. These differences must be acknowledged when Classical figures are used as comparative data for the LBA. Nevertheless, when these biases are acknowledged, reconstructions of Classical farming can offer additional information for modelling of Late Bronze Age agriculture.

Nutritional analysis

Diet is an essential aspect of the analysis of agricultural systems. Therefore, reconstructing the average diet of an LBA inhabitant is also an important part of the calculations of the agricultural potential of the LH III Argive Plain. The reconstruction includes evaluations of the potential dietary composition, and its nutritional content in relation to the subsistence needs of the population. Dietary composition consists of a list of the foodstuffs consumed by the LBA Argive Plain population, and an estimation of the proportion of each of these items in the regular diet. Food was acquired either by farming, collecting wild food plants and hunting, or by importing foodstuffs. Estimates of the proportion of different foodstuffs (e.g. plants versus meat and dairy) in diet assume that some foods were consumed more than others and, therefore, had to be available in greater volumes. Analysis of the nutritional content of the (assumed) average food composition can, in turn, suggest whether the diet – and with it the food production or acquisition system – was sufficient to sustain the inhabitants of the area in the long term. Dietary composition and the minimum nutritional and energy requirements to sustain an average LBA Argive Plain individual can be examined with methods of nutritional ecology (Raubenheimer *et al.* 2009; for nutritional ecology in archaeology see Wing and Brown 1979). In this study, the basic quantitative methods of nutritional analysis are used to evaluate the sufficiency of the LBA diet.

The analysis of dietary nutritional composition is preceded by mapping out the most common available resources, plants and animals native to the study region, and the evaluation of whether these were used as food items. In the LBA Argive Plain context, a combination of archaeological, ethnographic and textual data provides evidence of food resources and their use. These foodstuffs are then assembled into a model diet, which gives estimates of the consumption of different foods in volumetric units. The consumption of food depends, among other things, on the age, sex, size, and activity level of the individual. Societal, cultural and religious rules can also regulate the consumption, volume, and variety of food items. The average consumption of agriculturally produced food items can be investigated to a certain extent, through environmental and biological data. However, in the

Mycenaean Argive Plain context, little information is available on the cultural or religious conventions related to food. Elite feasting, with a large variety of foodstuffs, including meat, is attested to in the Linear B and material evidence (Dabney *et al.* 2004; Palaima 2004; Walberg and Reese 2008), but this does not represent everyday diet. In this study, data bearing on Classical Greek and traditional farming are combined with recent isotope studies of Bronze Age skeletal materials (introduced on pp.126-129 of this work). For the moment, a combination of these data provides the most secure way to analyse the LBA diet composition. In the future, more information can hopefully be gained through isotope and skeletal analyses on human and animal material, studies on dental wear, and through chemical analyses on cooking wares.

In this study, two different LBA diet models are provided in order to avoid some of the biases related to the use of textual and ethnographic evidence. These are necessary so that the opposing views between traditional studies, which put great emphasis on the consumption of (wheat) cereals, and archaeobotanical evidence, which has an abundance of pulses, can be compared. The Mycenaean Argive Plain population clearly thrived through many generations with the available foodstuffs. This suggests that their diets were able to meet the basic requirements of calories and other nutrients (see Hastorf 2017: 27; Wong *et al.* 2017: 437). Therefore, diets including similar foodstuffs to the LBA, even if coming from different chronological contexts, can be used for a nutritional and compositional analogy.

It is generally assumed that the basic nutritional needs of people acquiring their food by agriculture have remained the same through time (Wong *et al.* 2017: 437). Basic human subsistence consists of intake of energy, which is spent by essential bodily functions such as blood circulation and the maintenance of organs (the basal metabolism), general physical processes such as sweating and excreting, and additional physical activities such as working and exercising. What remains of the energy intake after these processes is stored in the human body as fat (Wong *et al.* 2017: 437). Basic energy needs, called the basal metabolism, are dependent on physical factors such as age, sex, height and weight of the individual, but also for example on pregnancy and lactation. Even geographical location can influence the basal metabolism if more energy is needed to maintain body heat and other functions in very cold climates (Snodgrass & Leonard 2009: 222). Energy needs can be calculated through a formula which considers this variation. In this process, the Basal Metabolic Rate (BMR) represents the minimum amount of energy needed to maintain biological functions (Snodgrass and Leonard 2009: 222), and the Physical Activity Level (PAL) measures additional energy needed to perform any additional physical activities. BMR is usually expressed as a number of required calories (kcal) per person per day. When the examined individuals are from the past, evidence of their physiology can be deduced from osteoarchaeological records, for example, their average heights and ages can be measured from skeletal material. Body Mass Index (BMI), which measures the relationship of 'ideal' weight and height is commonly used to extrapolate body weights from heights (Crittenden 2017: 93; Wong *et al.* 2017: 437). It should be noted, however, that the index follows modern recommendations of weight-height relationship and can be problematic when used in archaeological contexts.

Physical Activity Level (PAL) is presented as a multiplier that varies according to the activity level of an individual. The Food and Agriculture Organization of the United Nations (FAO) divides (2004: 38, table 5.3) physical activity into three levels, 1) sedentary or light activity lifestyle, 2) moderately active lifestyle, and 3) vigorously active lifestyle. An adult living in the 21st century and working in an office has a low PAL and needs to receive much less energy from food than a farmer or a hunter-gatherer (modern or ancient). However, a LBA farmer likely had a vigorously active lifestyle and therefore had a very high PAL. The definition of such a lifestyle includes 'non-mechanized agricultural labourers who work with a machete, hoe or axe for several hours daily and walk long distances over rugged terrains, often carrying heavy loads' (FAO/WHO/UNU 2004: 39). However, the LBA elite, individuals working as scribes in the Mycenaeans palatial centres or, perhaps, the religious staff of Mycenaean sanctuaries, could have had less active lifestyles. Osteoarchaeological material might give some indication of the level and type of physical activities conducted by individuals with different social statuses. Long-term repetitive movement caused by heavy activities, such as carrying, pulling or pushing heavy loads is usually visible in the skeletal material (further details on pp.120-125).

Multiplying the Basic Metabolic Rate (BMR) with PAL gives an estimation of a person's Total Energy Expenditure (TEE). TEE is expressed as the number of calories (kcal/day) a person with given qualities and lifestyle spends during their day. Ideally, the energy they spend on a daily basis is matched by the calories in the food they consume. These calorific requirements can be compared to the calorific content of foodstuffs in the model diet, and to the calorific content of the foodstuffs that could be produced or were available in the given geographical area.

Energy can be received from food in different forms, as carbohydrates, protein, and fats. In addition, various minerals and vitamins are needed for long-term health (Wong *et al.* 2017, 437). The World Health Organization (WHO) together with FAO have listed the specific nutrients, vitamins and minerals that are considered essential to human life. They also give recommendations on the amounts of these that are needed in an everyday diet (FAO 2013; FAO/WHO 1998, 2004; FAO/WHO/UNU 2004). In this study, the LBA diet is examined for its energy (calorific) content, protein, fats, and carbohydrates. Although the importance of vitamins and minerals in human sustenance is acknowledged, it is believed that these macronutrients can give reasonable indications of the sufficiency of the average LBA diet.

Different foodstuffs contain different amounts of carbohydrates, protein, fats, minerals and vitamins. Modern databases, such as the food composition data published by the United States Department of Agriculture (USDA), provide data on their content (USDA 2019). Although the USDA database is specifically used in this study for the mapping of the nutritional content of foods, problems may occur when these are compared to ancient foodstuffs. Chemicals contained by modern crops and domestic animals may have changed their nutritional content. The genetic history of food crops has affected their nutritional content too, as most of the favoured cereal and legumes species have been genetically modified to tolerate a variety of growing conditions or produce higher yields. These enhancements have been proven to change their nutritional values, for example the amounts of vitamins and minerals they contain (Heinrich and Erdkamp 2018: 1017; Wong *et al.* 2017: 437). Nevertheless, for now, these databases provide the most reliable and accessible source for reconstructing ancient food contents. As Wong *et al.* (2017: 437) suggest, in the future, nutritional analysis of ancient foods could be improved by growing crops without chemical, genetic or mechanical interference. In some cases, ethnographic data of dietary compositions and nutritional values of foods are scarcely available as well (Crittenden *et al.* 2017: 87). Such data does not exist for the Greek rural context.

Nutritional values of foodstuffs can also vary according to how the food is 'manifested'. Firstly, when different foodstuffs are compared with each other, it should be noted whether they are measured in dry mass or wet mass, or if they are measured in their raw or processed (i.e., cleaned) forms (Crittenden *et al.* 2017: 88). Secondly, cooking changes the structure and nutritional and chemical content of food. These changes include various aspects, from simple weight and energy loss through drip loss (of fat) when meat is cooked (Crittenden *et al.* 2017: 88) to the better digestibility and access to vitamins and minerals when cereals are cooked in water or milk (Valamoti 2011a). Fermentation can also alter the nutritional values of food (Crittenden *et al.* 2017: 88-89). Although the USDA database offers nutritional values of cooked foods (although it does not consider the bioavailability of nutrients in cooked or raw food), various issues related to aspects of cooking such as seasoning, or the use of cooking fats and oils make comparisons to past cooked foods unreliable. In the LBA context, some archaeological evidence exists for the processing and cooking of foodstuffs for human consumption (introduced on pp.90-100), but too little is known to make nutritional analysis of cooked LBA foods feasible. Therefore, here the approach is based on raw food values, which are more comparable with each other. However, any significant changes to the nutritional content of foods through cooking must be considered in the final analysis. Although it would be intriguing to extend the analysis of the LBA diet composition and nutritional content of food further, such additions would likely not offer significant improvements to the analysis of the agricultural potential.

Summary: Modelling Late Bronze Age farming and food production

The study aims to develop a comprehensive understanding of Mycenaean agricultural practices by examining their interconnections with environmental resources, societal structures, and political and economic organization. The approach involves the methodological concept of 'agricultural potential', which is based on the carrying capacity analysis, but also includes considerations of cultural aspects and human agency in the environment's food production potential. Such an approach enables the examination of levels of sustainability and vulnerability in the Argive Plain communities in the period preceding the Bronze Age collapse, and can contribute to the studies exploring the potential role of resource depletion in the Bronze Age socio-political crisis.

While various approaches could be adopted to study farming practices, land use, and population sizes, the study argues that the analysis of regional agricultural potential is most suited for this purpose in the Argive Plain context. Challenges in data availability, for example the lack of ample collections of Linear B texts or burial data, prevent statistical demographic analyses. Lack of intensive survey data, and the difficulties in correlating archaeobotanical and zooarchaeological data provide unstable basis for land use analysis based on settlement patterns.

Acknowledging the criticism of the early work of the paleoeconomic school for environmental determinism, the present study promotes interdisciplinarity by using multiple data sets to analyse farming as an integrated system. One of the key interests of this study is to understand how communities organized their daily lives and interacted in the Argive Plain.

The analysis of the agricultural potential includes the use of ethnographic and ethnoarchaeological studies to observe traditional farming practices that could be relevant to past reconstructions. In Greece, ethnoarchaeology has played a crucial role in studying prehistoric and Bronze Age subsistence strategies, even though its criticisms emphasize the risk of overlooking dissimilarities between these two periods. Recent historical farming strategies and Late Bronze Age food production must be observed in their respective cultural, political, and economic settings. Farming communities (across time) do not always make decisions based solely on low input/ high output mentality, nor do they necessarily live on the very edge of their labour and subsistence capacities. This contrasts the results of the calculation related to the agricultural potential analysis which mainly measures the maximum capacity of an environment to provide sustenance for a group of people. Therefore, these discrepancies, demonstrated by ethnoarchaeology, have to be considered when the resulted numbers are analysed.

Additionally, the present study uses some data from Classical Greek and Roman farming to compliment the reconstructions of Late Bronze Age agriculture in Greece. Classical textual sources can provide quantifiable data of certain aspects of farming, but caution is advised due to the differences between the agricultural systems of the Late Bronze Age and Classical periods, influenced by varying political and economic situations. In addition, Classical farming studies are most often based on the assessment of pre-mechanized rural practices, using recent historical examples to understand farming in the ancient past. Therefore, using Classical studies to study Late Bronze Age agriculture without caution can lead to double biases.

In conclusion, this study adopts a multi-faceted approach, integrating archaeological data, ethnoarchaeological, nd classial analogies, and modern statistical data to reconstruct agricultural practices in the Mycenaean Argive Plain. The study emphasizes the importance of contextual information, acknowledges potential biases, and aims for a comprehensive understanding of past agricultural systems. The archaeological data is presented in the following chapter 5, and the analysis of the agricultural potential takes place in Chapter 6, where these data is discussed through the lenses of ethnographic and modern nutritional studies.

Chapter 5

Late Bronze Age agriculture in archaeological data

The following chapter introduces the various sets of archaeological data used to reconstruct the agricultural system of the LH III Argive Plain, and to formulate the agricultural potential of the area. These data are collected from published works. The chapter is divided into six parts, each presenting the data from a particular, archaeological source of evidence about the agricultural system: landscape (pp.64-74); climate (pp.74-80); technologies (pp.80-86), flora (pp.86-100); fauna (pp.103-119); and osteology (pp.119-129). Although the focus is mainly on the archaeological data, the Linear B evidence is included when pertinent. These data form the basis for the analysis which is presented in Chapter 6.

The geography and soils of the Argive Plain

Reconstructions of the past landscape and soil conditions of the Argive Plain are crucial when LBA agriculture is analysed. Estimations of past yields using recent data from textual, ethnoarchaeological, or experimental studies remain inconclusive (see pp.54-58 for the use of analogies). However, similarities between the Bronze Age and modern soils enable a more controlled comparison of possible historical yields with the potential yields of the LBA. The yield estimations for this period will be discussed in more detail in the analysis section (pp.144-149). Besides soil fertility and geography, crop productivity is also

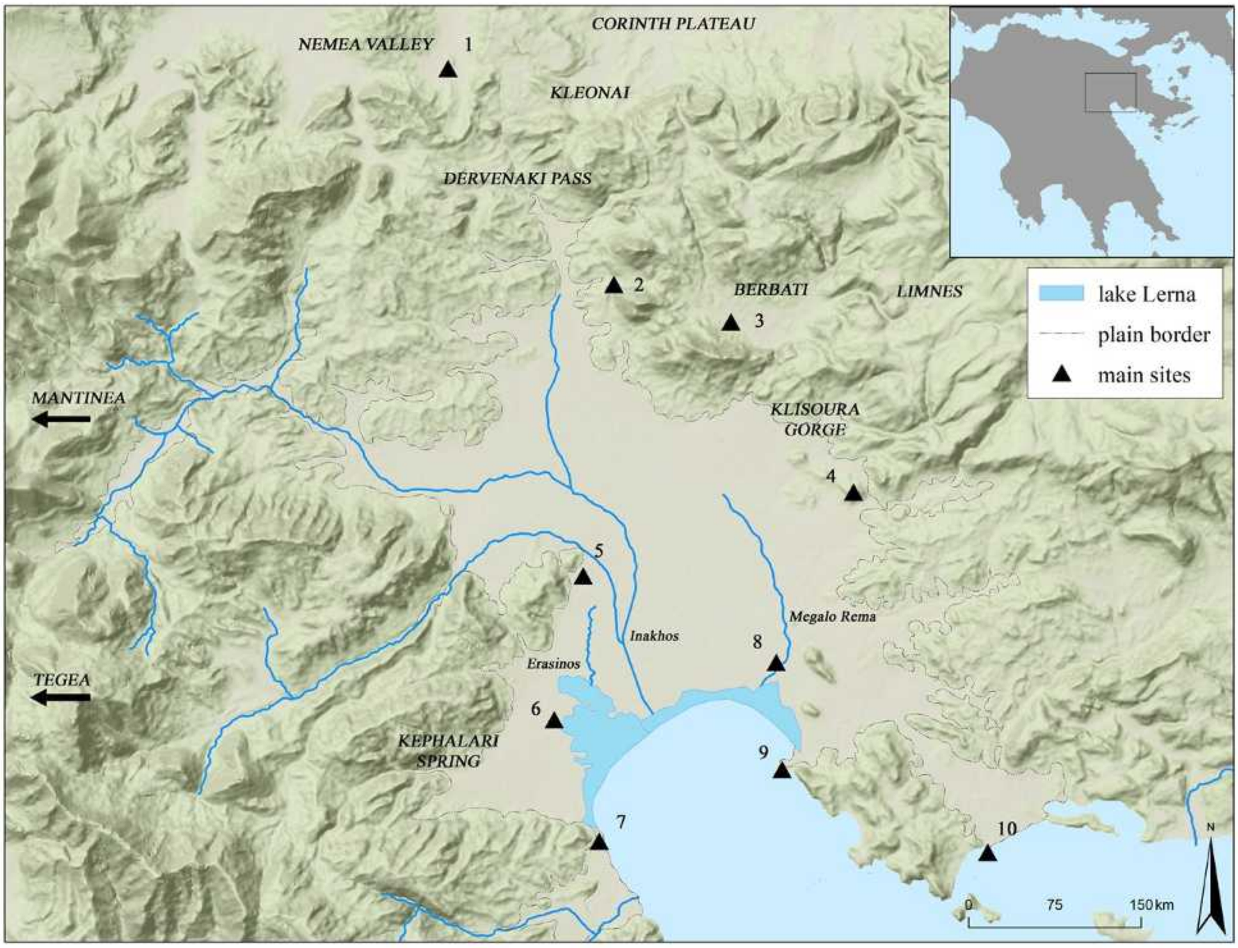

Figure 5.1. The geography of the Argive Plain. The map shows the three main streams, Lake Lerna, and other geographical landmarks mentioned in the text. The EH and LH coastline are after Zangger 1991 and 1993, as is the maximum extension of Lake Lerna. The triangles represent the main sites and are in numeric order: 1) Tsoungiza, 2) Mycenae, 3) Mastos, 4) Midea, 5) Argos, 6) Magoula, 7) Lerna), 8) Tiryns, 9) Nafplion, and 10) Asine.

affected by variables such as climate, diet, agricultural methods, species variability, crop specialization, and the organization of landownership.

The following chapter presents geography and soil characteristics of the Argive Plain that are vital for agricultural land use, including elements such as relief, drainage, soil types and water resources. The chapter is divided into three larger sections: pages 63-65 describe the general aspects of the Argive Plain geography, the second section (pp.65-74) examines some of the notable landscape changes that took place in the area during the Bronze Age, and the final section (p.74) investigates the fertility of the common soil types of the area and compares this information to the previous knowledge of Bronze Age soils.

Geography

The Argive Plain consists of *c.* 250km2 of alluvial terrain, which is surrounded by mountains to the north, east and west, and bordered by the Argolid Gulf to the south (Figure 5.1.). The surrounding mountains reach altitudes of 400-700 metres (Zangger 1993: 17). The mountain range has an average slope of 30 percent (Fallu 2017: 47-48), making much of it too steep for terracing or other agricultural activities apart from grazing (see pp.69-74).

The plain is easily defined by its landscape characteristics, since only narrow corridors connect it to neighbouring regions (Figure 5.1). Dervenaki in the north joins the plain to the areas of Nemea and the wider Corinth plateau. It was used as a route already in the Late Bronze Age (Jansen 2002: 43-47). Klisoura Gorge in the east connects the plain with the neighbouring Berbati Valley and the uplands of the Limnes region. In the north-west, the flat plateau changes into a narrow valley, following the Inakhos River and finally reaching to the territory of ancient Mantineia in Arcadia. In the south-east, a Mycenaean road originating in Nafplion crossed the mountainous Southern Argolid peninsula and connected the plain to Epidavros. Finally, in south-west, Pausanias describes an ancient route from the Argive Plain to Tegea (in Arcadia) past Mount Parthenion (Pausanias 19038.6.4.). However, the territory here is mountainous and hard to reach, and there is no concrete evidence of this route being used in the Late Bronze Age.

The plain is located at the meeting point of two tectonic zones, the Pindos zone in the west, and the Pelagonian zone to the east. The eastern side of the plain is mainly bordered by Cretaceous limestones. The western side consists of more varied sedimentary rocks such as flysch, carbonate rocks, and limestones. Sediments and soils derive from bedrock, and therefore its type has a significant impact on the soil fertility. Soils that form over limestone, for example, usually contain good amounts of organic matter and can provide fertile soils for cultivation. Soils on flysch can have a sandy or loamy texture which is better for water infiltration than the often-clayey limestones (Yassoglou *et al.* 2017: 13). Sufficient movement of water through soil, as well as water retention, is essential in plant growth. The suitability of these soil types for crop cultivation is discussed in the following sections.

Three major watercourses run through the plain (Figure 5.1). Mégalo Rema (also called Manessi) on the eastern side is ephemeral, as is Inakhos with its two main branches, Kephissos and Charassos. Erasinos, originating in Kephalari on the western side of the plain, is the only perennial watercourse (Fallu 2017: 47-48; Smith 1995: 24-25). Karst formations, with visible or underground water channels, are typical to the region's landscape. They bring water to numerous natural springs (Smith 1995: 25).

The southern limit of the plain consists of sandy shore. In the Early Bronze Age (EBA), *c.* 2500 BCE, the shoreline was located about 1.5 kilometres further inland, only about 300 meters from Tiryns. By the LBA, the coast had moved closer to its current location, and was *c.* one kilometre away from the Tiryns citadel (fig 5.1, and Zangger 1994a: 194-95). During this time, most of the current old town of Nafplion was under the sea, forming a well-protected bay ideal for harbour use. The Acronauplia Hill formed a long ridge surrounded by water and connected to the mainland only by a narrow land passage (Piteros 2015: 25). On the western side of the gulf, parts of the freshwater lake of Lerna were still open. The last traveller who reported standing water in the lake was Lehmann in the 1930s (Lehmann 1937). The lake extended to its maximum size during the Late Neolithic (*c.* 4600 BCE) and reached almost 5 kilometres inland, close to the sites of Argos and Magoula (Figure 5.1). During the EBA, the deposits of the river Inakhos filled large parts of the lake, and by the LBA, the lake had turned into a marsh (Zangger 1991: 12-13). Today, the coastline between Lake Lerna and the outskirts of Nafplion is partially covered by salt marshes (Shay *et al.*: 1998). There are some indications that this salt marsh area was larger and wetter until the beginning of the 20th century (Finke 1988: 39). The surroundings of the lake and the coastal zone were likely marshy and wet in the LBA.

The geology of the Argive Plain is formed by parent materials which enable the formation of alluvial and colluvial deposits on the flat plain area and the surrounding foothills (Figure 5.2). Of these, alluvial deposits are generally considered high quality cultivation land, whereas colluvial deposits, gathering at the foots of hillslopes, can provide a productive platform for plant growth due to their significant depth. However, colluvial deposits also suffer from erosion, and they can have drainage problems, which make them less suitable for cultivation (Shiel 1999: 75; Yassoglou *et al*. 2017: 53). The rivers and natural springs, which are found in good numbers around the plain, are adequate water sources for small-scale irrigation and for drinking water. The geography with a flat plateau surrounded by a wide area of gentle sloping hills would already have been suitable for cereal cultivation in the LBA. Only the marshy areas of the coastline, the foothills with significant colluvial deposits, and the surroundings of Lake Lerna would likely have been less useful for crops. Instead, they would have formed ideal pasture lands.

Adjacent to the plain are smaller valleys and plains. Of these, it can be assumed that the small plain associated with Asine in the south, amounting to some 1355ha, was closely linked to the Argive Plain in the LH III period (Figure 5.1). According to Tomlinson (1972: 13), the plain resembles the Argive Plain with its high-quality soils. Berbati Valley, some 5 kilometres east of Mycenae, consists of a protected flat valley of *c*. 544ha (figs. 5.1 and 5.2), surrounded by steep slopes. Seventy-five percent of the valley bottom is covered by limestone, while flysh and marl formations appear at the northern and western sides of the valley (Wells *et al*. 1990: 212). The uplands of Limnes, east of Berbati, have traditionally been used for sheep and goat pasture, since their climate is too cold for cereal cultivation (Schallin 1996: 172). The two valleys of Nemea and Kleonai consist of *c*. 85km2 land area, 10 km north of Mycenae (figs. 5.1 and 5.2). Cherry and Davis (2001: 155) suggest that the area under cultivation in the LBA resembled that of today, totalling *c*. 5000ha (50km2). However, this figure includes sloping landscape far beyond the valley bottoms, and therefore might be overestimated. Limiting the space to include only surfaces under 6

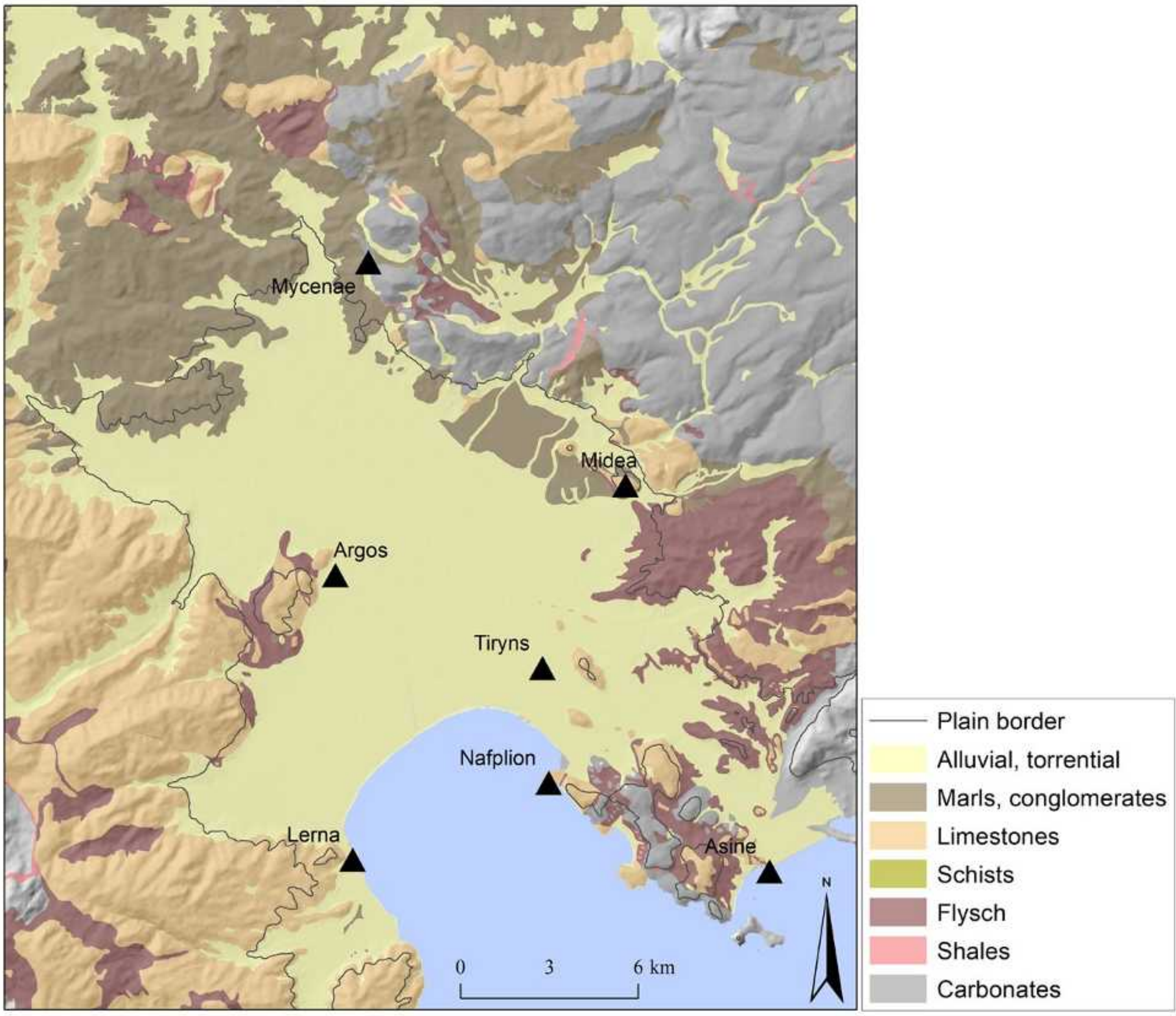

Figure 5.2. Parent materials on and surrounding the Argive Plain. The map was adapted from IGME Geological maps, sheets Nafplion (1964), Argos (1970), Nemea (1970) and Korinthos (1970) by the author.

degrees slope, the size of the two valleys totals *c.* 900ha. In this study, the latter figure is used, since most slopes surrounding the valleys are between 10 and 25 degrees, and therefore should have been terraced if used for cultivation (see the following section pp.69-74).

Late Bronze Age landscape changes

To analyse the suitability of the Bronze Age Argive Plain for cultivation, some of the major landscape changes of the period should be considered. This section aims at evaluating whether the soil cover we see today is comparable to that of the past, and whether sediment accumulation has taken place. The complexity of the Argive Plain geomorphology with the drastic landscape changes in the area has resulted in opposing views on its Bronze Age fertility. Geographical and geomorphological analyses in the region have been conducted in the area ever since the 1930s, with various revisions (Bintliff 1977, 2016; Fallu 2017; Finke 1988; Lehmann 1937; van Andel *et al.* 1986; Wagstaff 1981). However, in relation to the past landscape changes, the western side of the plain remains poorly known compared to the eastern side which has attracted landscape studies due to the archaeological projects at Mycenae and Tiryns.

Major landscape changes took place in the immediate surroundings of Tiryns during the LH IIIB and C (Figure 5.3). Most of them were caused by the flooding of the river Manessi (also called Megalo Rema). Until the LH IIIB, it ran on the southern side of Tiryns, but by LH IIIB2/C the river had diverted north of the settlement. There, gradually accumulating stream and floodplain deposits buried major parts of the Tiryns Lower Town (Fallu 2017: 54-65; Maran 2009: 242). The accumulation of deposits was put to an end in LH IIIB/C by the construction of a large dam (*c.* 100 meters long) and an artificial canal, which diverted the stream away from the citadel (Zangger 1994a: 209, Figure 13). Although the sediment accumulation continued in the settlement area on a smaller scale after the abandonment of the site in LH IIIC (Fallu 2017: 84), the event generally marks the beginning of a stable period that lasted until modern times. During the LH IIIC, only about one metre of deposits accumulated (Zangger 1994a: 198–99). For the LH IIIB2/C, Maran (2009: 243) refers to 'periodic flooding events', which could suggest flooding after the winter rains. Fallu (2017: 88-89) cautiously considers that reduced vegetation (likely referring to the clearing of forests on the surrounding hillslopes) might have resulted in increased erosion, and the deposition of torrential materials. Climate change, such as a sudden increase in the rainfall, does not seem a likely cause for such gradual depositional processes alone.

Fallu (2017: 130-31 and 252) further suggested that similar landscape changes took place on the northern part of the plain. He demonstrates at least two distinct events of major colluvium burying parts of the Lower Town of Mycenae during LH III B/C (Fallu 2017: 131). These sediments originated most likely in the neighbouring mountain of Zara, to the north-east of the citadel. Similar deposits were found at the settlement of Chania, located in the middle of the plain, *c.* three kilometres south of Mycenae (Figure 5.3). Here, they buried a tumulus built over a destroyed settlement in LH IIIC (Fallu 2017: 32-33; Palaiologou 2014). Again, Fallu (2017: 154-55) suggests that the accumulation took place due to an instability of the slope materials, caused by a combination of precipitation changes, decreased slope vegetation, likely due to drought rather than human activities, and seismic activity. The evidence of a drought period is, however, marginal, and derives from other areas in the Peloponnese (see pp.76-78). Pollen evidence from this region indicates land clearing for agricultural use in general throughout the Bronze Age but cannot be applied to this particular period (see pp.88-90). In general, the evidence above seems to point to a similar, long-term instability of the landscape in the south-east and north-east during LH III B and C.

Coring data shows that in the Argive Plain areas, the surroundings of the settlement of Lerna were not notably affected by sediment accumulation during the Bronze Age. Instead, Pleistocene paleosols are found close to the surface along the western edges of the plain from Lerna towards Argos (Finke 1988: 72-73; Zangger 1991: 9-11). However, the plain around the modern town of Argos, as well as the coastal plain north of Lerna and Myloi, was again filled with a thick layer of stream and floodplain deposits from the Inakhos river (Finke 1988: 73-79; Zangger 1991: 9-11). Pleistocene soils further emerge as a narrow strip along the eastern borders of the plain (Fallu 2017: 49 Fig. 9; Finke 1988: 72, Fig. 18).

In summary, sudden changes to the soil landscape of the Argive Plain took place at the end of the LH III period. Nevertheless, the concurrently accumulating fresh alluvial deposits could have formed a fertile basis for agriculture, despite not having developed into soil horizons. However, the increased accumulation of sediments in the surroundings of Mycenae and Tiryns could have caused harvest failures.

Modern and Bronze Age soils

Soil fertility denotes its potential to produce a good yield without exhausting soil (Hansen and Allen 2011: 884; Shiel 1999: 67; Zangger 1992: 15). Besides

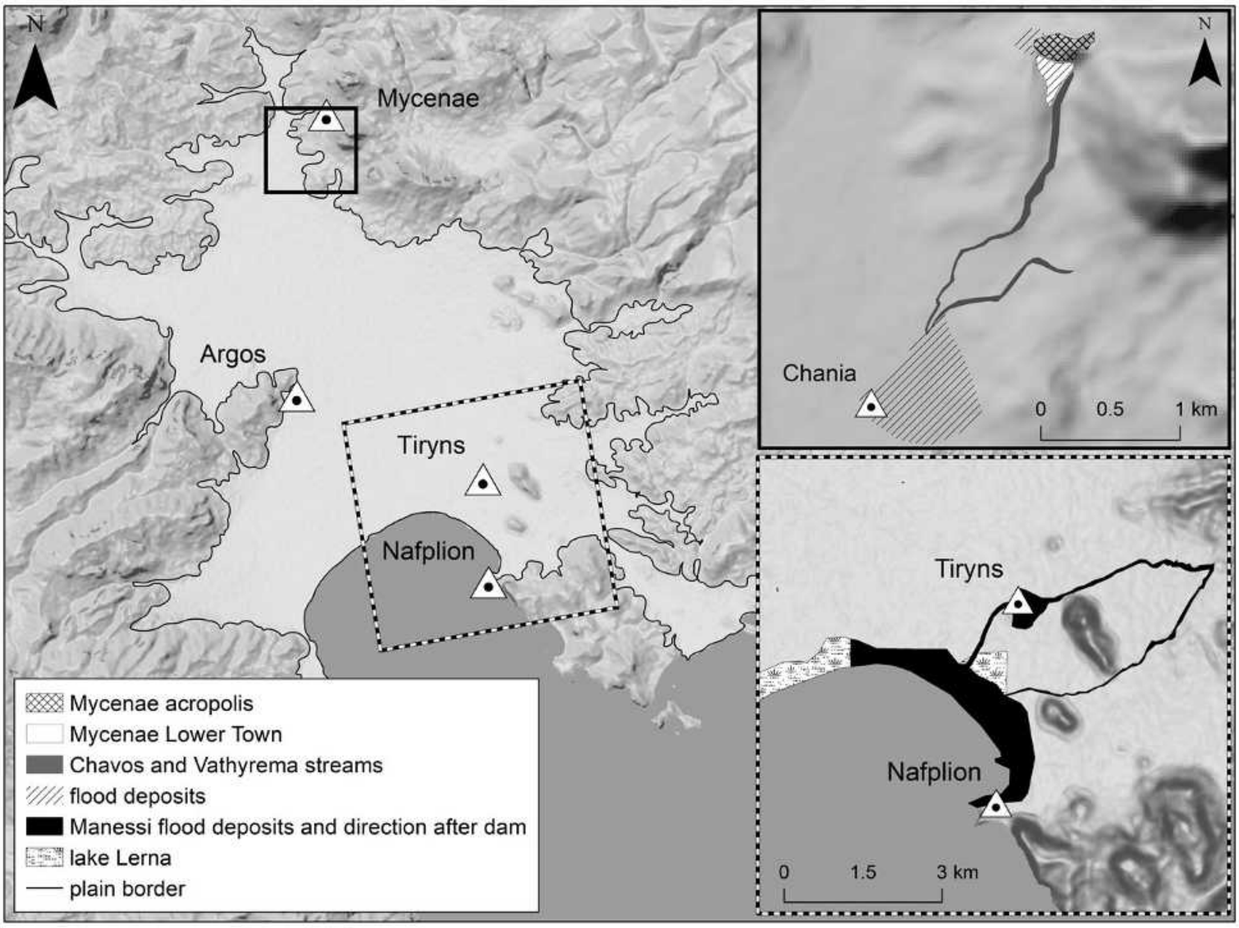

Figure 5.3. Landscape changes around Mycenae and Tiryns, adapted from Finke (1988), Zangger (1993) and Fallu (2017: 30-34 and 211-219). The illustration of the extent of the flood deposits caused by the streams Chavos and Vathyrema around Mycenae and Chania is an interpretation by the current author. To the best knowledge of the current author, there are no previous published visualizations of these flooding events.

external factors, such as climate or active preparation by humans (e.g. tillage, weeding), soil (or sediment) properties are key factors for agricultural productivity. These characteristics include soil properties, depth, texture, drainage and granulometry. Coastal floodplains, such as the Argive Plain, often contain ideal soils for agriculture. Common properties of the floodplain soils are good drainage, minimal stone content, and silty (between clay and sand) granulometry, which enables adequate water and air circulation through the upper layers of the soil (Shiel 1999: 74; Zangger 1992: 15). In such semi-coarse sediments, a larger amount of water can drain through the surface layers and is safe from surface evaporation. Therefore, more water is available for the use of plant roots (Shiel 1999: 68). In the Mediterranean, most of the annual rainfall occurs during the winter season. Because evaporation is less than in the summer, this is the only time moisture is stored in the soils, (Shiel 1999: 69). On the other hand, excessive saturation can limit plant growth by depleting important nutrients, such as nitrogen (Shiel 1999: 74; Zangger 1992: 15).

The most prevalent characteristic of the Argive Plain geomorphology is the thick layer of alluvium, which covers large parts of the plain. It has been produced by a variety of depositional processes, of which debris flows, stream-flood deposits, and sandy overbank loam are the most common (Finke 1988: 34; van Andel *et al.* 1986: 111). These are transported by water. The Argive Plain landscape also includes some local colluvial deposits, which accumulate at the bases of slopes due to weathering (Goldberg and Macphail 2006: 46–47; van Andel *et al.* 1986: 111). Because the alluvial (and colluvial) deposits are formed through a process of erosion, the eroding parent material (bedrock) defines the basic consistency and characteristics of these sediments (Zangger 1992: 14).

Soils and sediments should be separated from each other. Soil develops into distinguishable horizons with different structural and chemical properties over an extended period of time, with stable deposits. During this lengthy process the parent material interacts with climate, topography, and living organisms, such as flora and fauna (Goldberg and Macphail 2006: 52; Zangger 1992: 14-15). Sediments consist of weathered loose material which is transported and deposited. If the landscape remains stable over an extended period of time (thousands of years), soil formation processes can occur (Goldberg and Macphail 2006: 46-51).

In the Argive Plain, Finke (1988) examined the Holocene soil surfaces from several auger cores taken in the plain surroundings, mostly in the south, but a few also in the central and northern sides of the plain. He recognizes four main units of Holocene alluviation (Figure 5.4). The first, 'old brown soil', consists of Pleistocene deposits of more than 10,000 years old. The second one, 'old alluvium' was deposited in *c.* 2500 BCE,[1] before a maximum in the sea transgression 1.5km inland took place. This alluvium overlaid a Middle Neolithic site in the area of Magoula, south-west of the plain. Thus, this phase occurred during the Late/Final Neolithic – Early Helladic (EH). Another large-scale alluvial event took place in the EH period, causing the sea to regress back to the south side of Tiryns. This BA alluvium covers major parts of the plain, including the inner plain in the north, and forms a layer of at least 1-3 metres thick, characterized by red colour and thick clay films. This event also filled major parts of the Lake Lerna, where its surface contained sherds from the Neolithic, LH III and Archaic periods. (Finke 1988: 105-22, Figs. 26, 27, 29). In relation to the immediate surroundings of Tiryns, Finke (1988: 90, Fig. 23) describes this alluvium

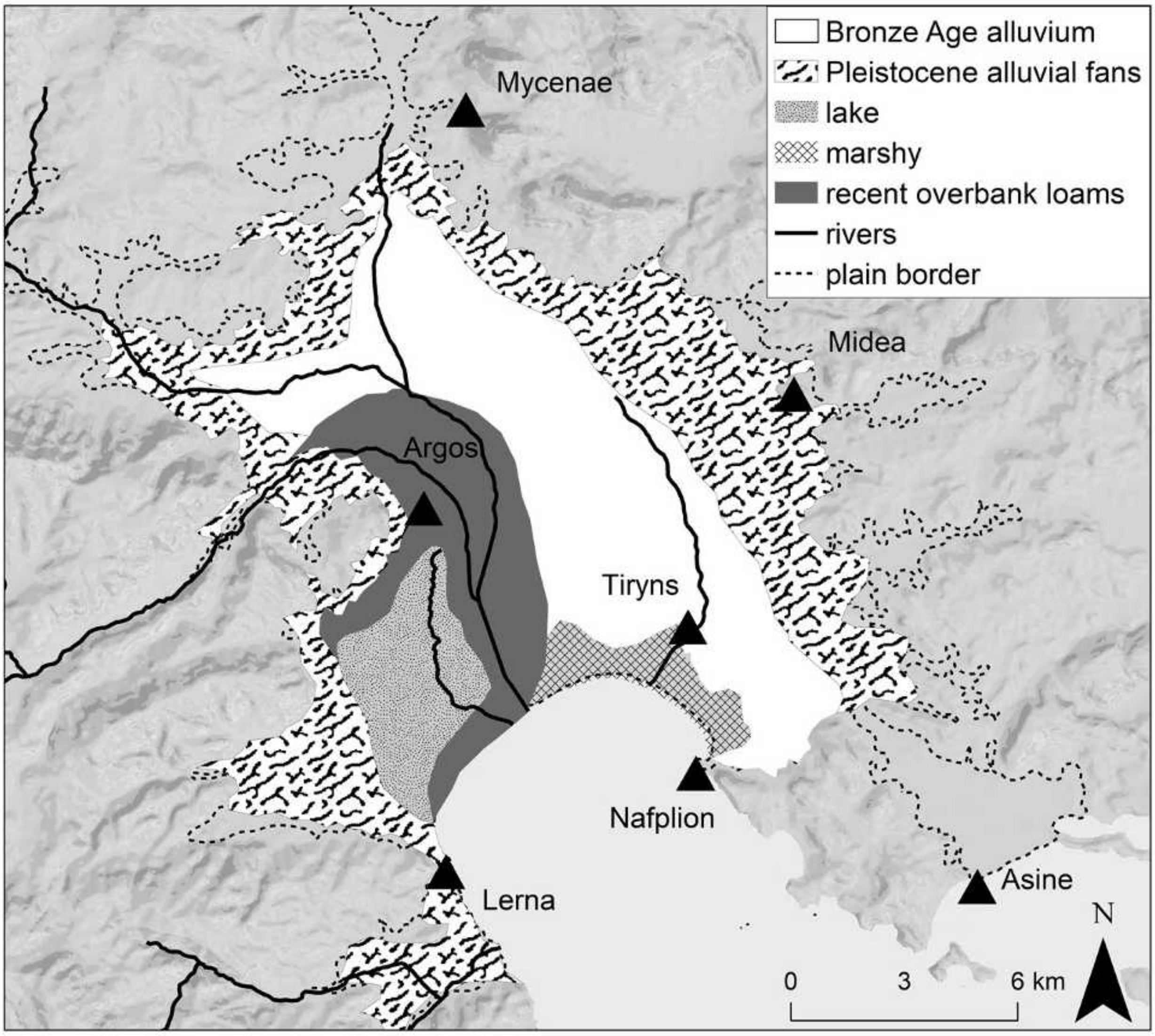

Figure 5.4. Adaptation from Finke (1988: 71, Figure 18). The marsh and lake deposits in the south of the plain, as well as the recent overbank loams surrounding Argos are more recent developments in the Argive Plain landscape. The LH III surface likely consisted of the Pleistocene alluvial fans of the plain edges, and the Bronze Age alluvial deposits, mostly deposited during the EH, almost entirely covering the inner plain.

[1] A piece of charcoal recovered in the cross-section of the A-horizon of this old alluvium gives a dating of 2564 ± 220 BC, placing the sea transgression after this date.

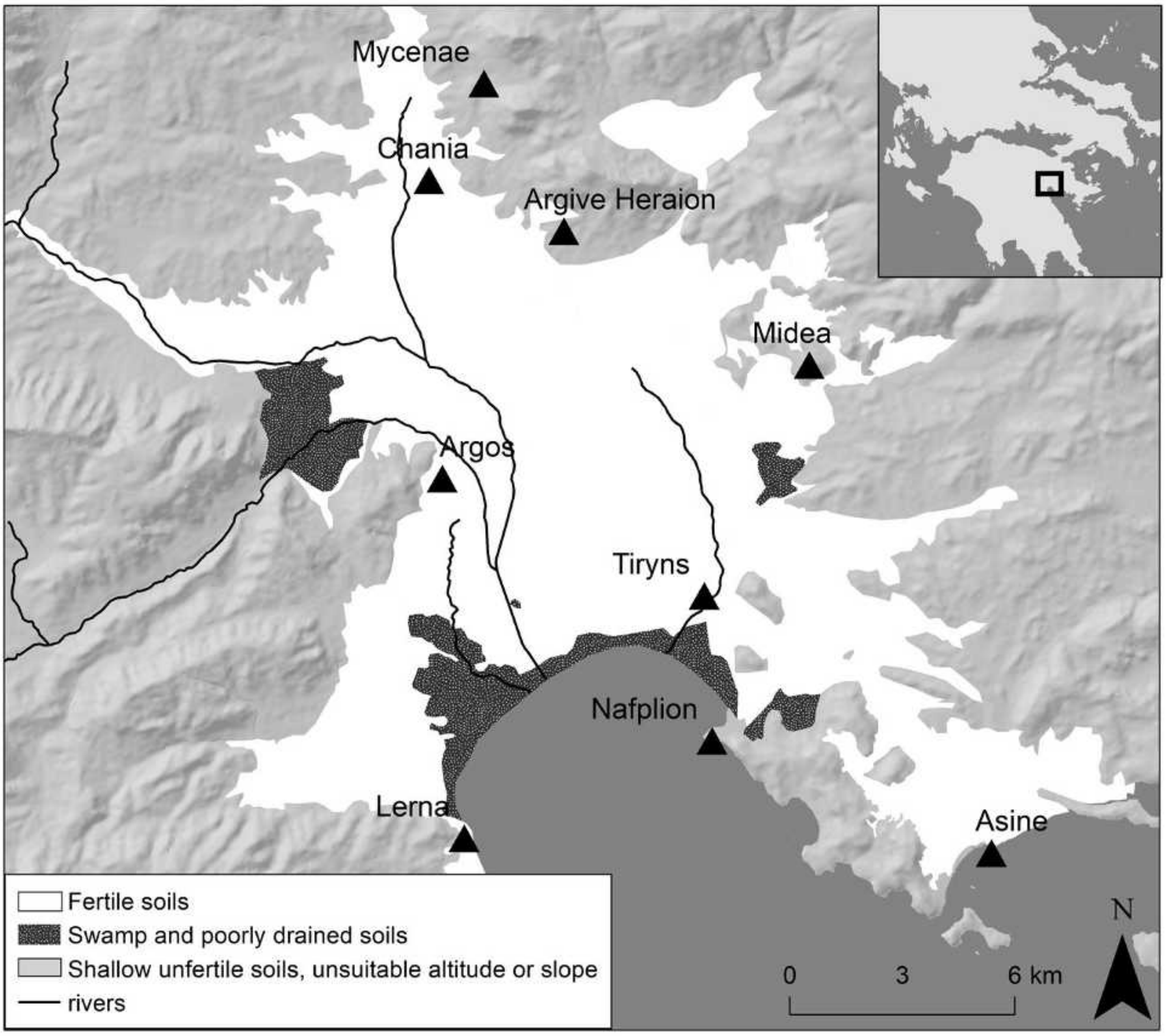

Figure 5.5. Land use potential of the Argive Plain and Berbati Valley. Fertile soils (see also Appendix 3) are marked in white. The map is adapted from Ritzou (2013: 66, Fig 2.17) and Drakaki and Sideri (2014: 30, Fig. 2.17).

as having 'remarkably mature soil development'. The final alluvium phase was deposited during the LH III period in the surroundings of Tiryns, before the large dam was built (Finke 1988: 105-11 and 121-22, Fig. 29). As discussed above (p. 65), similar wider deposition took place more or less simultaneously in the northern part of the plain, in Chania and Mycenae. These events are depicted in Figure 5.3.

Based on the analysis of Finke, before the alluvial event that took place at the end of the period, the LH III surface consisted of older Pleistocene alluvial deposits, and more recent EH alluvial fans. Some local deposits of diverse types may have been found in the surroundings of Lake Lerna and Argos due to the river Inakhos, but the marshy coastal area is reported to have developed only after the Hellenistic period (Finke 1988: 120, Fig. 28). The coastline between Tiryns and the sea was narrow, *c.* one kilometre in length, a likely formed a floodplain suitable for a shallow harbour and fishing, but not for agriculture (Zangger 1994a: 196).

Zangger (1992: 15) estimates that in Greece, one metre of soil on marl, a type of carbonate rock, would take a few thousand years to generate. Yassoglou *et al.* (2017: 68) describe the soil formation processes of alluvial deposits (Fluvisols) on carbonate rocks as 'quick'. Nevertheless, the *c.* 1000 to 1500 years between the EH alluvial event and the LH III period would have likely been too short to enable the formation of soil horizons.

Soils that are formed on Holocene alluvium are classified as Fluvisols (Fluvents) (Yassoglou *et al.* 2017: 69-71). As described above, the majority of the LBA Argive Plain deposits belonged to this category, and Fluvisols remain the most common in the plain landscape today (see Appendix 3 for detailed soil categorization). Fluvisols without developed soil horizons are sub-categorized as Entisols, or slightly more developed Inceptisols (Yassoglou *et al.* 2017: 69). Despite the weak soil horizon formation, both Entisols and Inceptisols are fertile and suitable for the production of cereals, pulses, and tree crops (Ritzou 2013: 31; Yassoglou *et al.* 2017: 71). The higher elevations on the edges of the plain with Late Pleistocene deposits contain shallow, less fertile Alfisols, and indigenous deposits (Fallu 2017: 93; Finke 1988: 34). Alfisols on gentle slopes can, however, have medium fertility and they can be used for cereal and pulse cultivation or tree cropping (Yassoglou *et al.* 2017, 2016: 31). The overall area suitable for crop growth is indicated in Figure 5.5. Since the plain is currently used mainly for citrus cultivation, the fertility variables, such as the amount of groundwater, groundwater depth, soil texture and granulometry may vary slightly, but this would not essentially change its suitability for cereal cultivation.

Terracing

Terracing was a known land modification method in the Greek mainland (Iakovidis and French 2003) and on the Aegean islands (Krahtopoulou and Frederick 2008; Orengo *et al.* 2018) in the LBA. Although there is some evidence of terraces being constructed as early as the Early Bronze Age (Krahtopoulou and Frederick 2008: 567-78), the identification of Bronze Age terraces remains problematic. Terraces could have been constructed to support road systems and building complexes, or to prevent slope erosion, and they could have been used for crop cultivation. Terrace construction and management is labour-intensive, and it is assumed that in the LBA terraces would have not been built unless their benefits (i.e. increased harvest, or the prevention of erosion) surpassed the labour costs (Kvapil 2012: 220; Sitjes 2016: 201). Thus, terraced fields could have had potential to produce yields for the LH III Argive Plain population, and to provide a means for the local palatial centres to produce specific items such as wheat, figs or olive oil for food rations (pp.10-14). Therefore, terracing as a cultivation method must be considered in the reconstruction of the Argive Plain agricultural potential. The following section introduces the available data related to Bronze Age terrace construction and use and discusses this evidence in relation to ethnoarchaeological studies in the Aegean. These data are used to model potential terrace use in the LH III Argive Plain.

Dating of the LBA terraces

The dating of terraces is often difficult because of the scarcity of material evidence, and because old terrace walls are maintained and reused regularly over time. Terraces constructed millennia ago can still be in use (Bevan *et al.* 2013: 265-70). The assumed LBA terraces in Greece have rarely undergone systematic excavations or surveys in which, for example, archaeological or archaeobotanical material is retrieved from the terrace stratigraphy. These methods could enable better dating and analysis of their use. In the eastern Peloponnese, potential Bronze Age terraces have been identified through survey and reconnaissance projects in the close surroundings of Mycenae (Iakovidis and French 2003), in the Berbati Valley (Wells *et al.* 1990), the Southern Argolid (Jameson *et al.* 1994: 371), and in the north-east of the Argive Plain, in the Korphos-Kalamianos area (Kvapil 2012).

Each of these projects identified the terraces mainly through visual observations or based on their location in the vicinity of the LBA settlements. For example, terraces with complex water management systems were built along, and to support, the LHIII road leading from Mycenae to the Berbati Valley (Wells *et al.* 1990: 223). Whether these terraces also had agricultural use is uncertain. Old terrace walls in the Berbati Valley were identified in the vicinity of LBA findspots, mostly interpreted as farmsteads. The dating of the terrace walls was based on the (large) size and shape of stone blocks, and dating of sherds and other finds surface finds located in close vicinity (Wells *et al.* 1990: 227-28). Similarly, the Mycenaean Survey projects dated 48 terrace walls as 'Mycenaean' based on block size and style (Iakovidis and French 2003). Fallu (2017: 115) identified additional 278 terraces in the same area from aerial photographs. In the Southern Argolid, the SARG-project team argued that expansion of settlements and land use in the LBA period resulted in new innovations in land management. One of them was the introduction of terraced fields, which was combined with water management systems to slow down slope erosion. No dating of terraces took place during the project, however (Jameson *et al.* 1994: 371). The evidence of rapid slope erosion in the central northern Argive Plain, where it buried the settlement of Chania and parts of Mycenae in LH IIIB/C (p. 65) could, in this light, suggest that terracing was not extensively used in the area. In south-eastern Corinth (Korphos-Kalamianos area), Kvapil (2012: 183, appendix 1) identified *c.* 100 pre-LBA and LBA terraces in the surroundings of two Mycenaean settlements, Kalamianos and Stiri (surveyed area *c.* 4.26km2). The identification was based on the size and cut of the blocks, the style and construction methods of the walls, and the surface finds of LBA dating across the terraced areas (Kvapil 2012: 124-29).

Since no excavations have been conducted on the Argive Plain slopes, the dating (and, thus, presence) of LBA terraces here remains inconclusive. Other studies in the Aegean have, however, been able to date Bronze Age terraces more firmly. Krahtopoulou and Frederick

(2008) based the dating of terrace walls located in the vicinity of Bronze Age sites on the island of Kythera on the stratigraphy of the soil fill behind the terrace wall, radiocarbon dating of the charcoal recovered in this fill, and on the distribution of sherds within the fill. These factors together produced an Early Bronze Age II (*c.* 2700-2200 BCE) dating for the two investigated terrace systems in separate locations. In both cases, the terraces seemed to have been used for a few centuries until the Middle Bronze Age I-II, after which they ran out of use. In both locations, later, Classical, Venetian, and modern terrace structures had been added on top and in the vicinity of the original ones (Krahtopoulou and Frederick 2008: 567-78).

When terraces are abandoned, vegetation rapidly takes over the walls and platforms. Plant roots often help to hold the walls in place (Whitelaw 1990), whereas grazing and trampling on abandoned terraces reduces vegetation and effectively increases erosion rate. This can result in rapid sheet wash, mud flows and valley alluviation (Foxhall 1996; Krahtopoulou and Frederick 2008). These events can influence the recovery of archaeological records on slope sites and terrace walls (French and Whitelaw 1999; Whitelaw 1990). If a terrace is not reused after its initial construction and abandonment, Krahtopoulou and Frederick (2008: 60) estimate that it takes *c.* 100-200 years for a terraced slope to turn back into a 'normal' slope. Thus, those potential Argive Plain terraces that were not reused after their abandonment in the LH III period would have disappeared. Therefore, it is important to consider whether LBA terraces could be mapped through landscape characteristics such as slope, soils or closeness to settlements instead.

Location of Late Bronze Age terraces

Various landscape characteristics such as geology and soil consistency, slope, aspect (the direction of the face of the slope), and the vicinity to settlements can influence the preferred locations of terrace construction.

Of the locations mentioned above, in the Berbati Valley, ancient and modern terraces are located on the local flysh, marl and alluvial surfaces, while in the adjacent Limnes area, terraces are found mainly on limestone. The Berbati terraces reach high altitudes of 600-900 meters above sea level (henceforth masl). Many of the terraces with a suggested Mycenaean dating are located close to LBA sites and activity areas, which in turn seem to cluster in the vicinity of the Mycenaean 'highway' leading to Mycenae (Wells *et al.* 1990: 227-33). Similar connection between terraces and transportation routes could perhaps be seen in the eastern edge of the Argive Plain where a smaller Mycenaean road (m5) ran from Argive Heraion towards Tiryns (Brysbaert 2021; Brysbaert *et al.* 2020; Jansen 2002; Lavery 1995). Other Mycenaean roads, including the Highway M4, passed along this route as well, but most likely served other economic purposes such as transporting heavy materials, rather than terrace agriculture (Brysbaert 2021). Terraces identified in the Mycenae Survey were mainly located on limestone and the lower Pleistocene alluvial deposits (IGME; Fallu 2017: 117-120). Fallu (2017: 117-120) found no specific relation between the LBA terrace location and slope aspect. Most terraces were located at relatively low altitudes between 178 and 195masl. Very few were identified above 300masl, in contrast to the Berbati and Limnes areas. The majority of the LBA terraces were located in the vicinity of the Mycenaean citadel, but a few of them also extended along the slopes towards the south. Terraced slopes of Korphos-Kalamianos area lie on Mezozoic limestone (Kvapil 2012: 52-54). The surveyed area is located at no more than 200masl, and therefore terraces were not identified at high altitudes. As in the Mycenae and Berbati areas, the terraces were located in the close vicinity of sites, but this is likely due to an observational bias as the survey area that focused on the immediate surroundings of the settlements.

Recent examples from the islands of Antikythera and Kythera suggest that modern and historical terraces concentrate on softer stone materials, and rather on gentle than steep slopes. Softer bedrock includes marls, conglomerates and flysch (Bevan *et al.* 2013: 257-59; Krahtopoulou and Frederick 2008: 559). In Kythera, softer materials were preferred over other factors such as slope or aspect (Krahtopoulou and Frederick 2008: 559). In the case studies discussed, terraces are normally found in the vicinity of settlements. In Antikythera, for example, terraced fields were always located less than three kilometres from villages. Threshing floors, field houses and other agricultural installations were often constructed in the vicinity (within 1.5km) of terraces to make processing and temporary storing of the products easier (Bevan *et al.* 2013: 259, Fig. 5).

Slope is more likely to have importance in terrace location than bedrock or soils. The maximum slope for unterraced fields in the Mediterranean environment has often been defined as 10 degrees (10°) (Bevan and Conolly 2011: 1308; Bevan *et al.* 2003: 220-223; Kvapil 2012: 196; Whitelaw 2000: 234). Whitelaw (2000) suggests that slopes of 10°-15° could have been cultivated without terracing, but with a risk of heavy soil erosion. However, LBA terraces have often been identified on more gentle slopes. Orengo and Knappett (2018: 499) suggest the Minoans of Palaikastro, Crete, preferred terracing on slopes above 7°, and that the majority of the local Minoan terraces clustered on slopes of 7°-15°. Fallu (2017: 117–18, Fig. 42 B) found LBA terraces near Mycenae on slopes below 6°, while most of the terraces around Mycenae are found on slopes below 25°, with none recovered on slopes above 30°. In the Korphos-Kalamianos region the LBA terraces were mainly located on slopes between 10°-15° (Kvapil 2012: 196, note 435).

Another parameter related to terrace location is the question of how much of the landscape can be terraced. OIn the Korphos-Kalamianos region, Kvapil (2012: 183, appendix 1) identified *c.* 100 LBA or pre-LBA terraces on a surveyed area of 426ha (4.26km2). This would indicate a rate of four terraces per hectare of land, or about 25 percent of the sloped land being terraced. The Mycenaean Survey covered an area of *c.* 350ha in the close surroundings of Mycenae in the Argive Plain. Within this area, the survey was able to identify 48 'Mycenaean' terraces (Iakovidis and French 2003). Thus, only *c.* 14 percent of the slopes had terracing. If the additional 278 modern terraces identified by Fallu (2017: 115-16, Fig. 41) are added, some 93 percent of the slopes are terraced, however.

The share of terraced slopes in the modern landscape is high. In the Berbati-Limnes region, all gentle slopes below 600masl were terraced. This entailed *c.* 80 percent of the landscape. However, only *c.* 30 percent of these terraced fields were used at the same time (Wells *et al.* 1990: 213). On the island of Keos up to 70-80 percent of the island's landscape was likely terraced at some point in history. Only about 18 percent of the landscape of the survey area (covering *c.* 13km2) was flat valley bottoms with less than 10 degrees slope, indicating that terracing was crucial in maintaining livelihood through cultivation (Whitelaw 1990: 405). In Kythera, 27.7 percent of the surveyed area was terraced at some point in history (Krahtopoulou and Frederick 2008: 555–57, Table 1).

Little is known of the size of the terraced fields. Whitelaw (1990: 405) noted a range of 1.5 to 30 metre terrace widths in Keos, with an average of two to four metres. In Amorgos, modern and historical terraces had a 'lateral extent' from 4 to 20 meters (likely meaning the length of the terrace along the contour) (French and Whitelaw 1999: 163). The platforms may vary greatly in size. The widest Amorgos terraces could be tilled by using animal-drawn ploughs. Abandoned threshing floor on one terraced field suggests that crop processing was conducted on site (French and Whitelaw 1999: 176).

The abovementioned locations mostly represent closed environments, islands, or valleys bordered by steep slopes. Therefore, terracing could have been extremely important for the local sustenance. In environments such as the Argive Plain, where topography includes more flat surfaces and gently sloping hills, the need to create terraced fields might have been smaller. In the LBA Argive Plain, terraces could have been used for additional production of specific crops, such as olives, figs and vines. The following section examines the use of ancient and recent terraces more closely.

Function of the LBA terraces

Moody and Grove (Moody and Grove 1990) recognized four functions for terraces, 1) cultivation on steep slopes, 2) prevention of soil loss, 3) improving water retention by providing deeper soil stratigraphy, and 4) enabling better root penetration. Terracing significantly helps reduce soil run-off during heavy winter rains. Run-off takes place on slopes that have been cleared due to grazing or cultivation. Terraces are, thus, also built for soil management purposes, as well as to increase cultivation space.

Archaeobotanical and textual evidence of the LBA terrace cultivation is practically non-existent. However, based on lipid analysis indicating faecal material, and the homogenous artifact (debris) distribution in the wall stratigraphy, Bull and co-authors (2001: 227–39) suggested that the Middle and Late Bronze Age terraces in Pseira, Crete were manured. The fertlizer applied to the terrace was a combination of manure, household waste, and human excrements (Bull *et al.* 2001: 239). This strongly suggests the use of terraces for crop cultivation. The argument of evenly distributed artifact 'carpets' as evidence of ancient manuring practices was first presented by Wilkinson (1982) in Near-Eastern contexts, and soon after by Bintliff and Snodgrass during their survey project in Bronze Age Boeotia, Greece (Bintliff and Snodgrass 1985, 1988). Since then, more evidence of such carpets has been found, for example in eastern Corinth in relation to LBA terraces (Kvapil 2012: 240).

According to Classical authors, tree crops such as figs and grapevines were the most common crops placed on terraced fields in the Classical period (Foxhall 1996: 51-53). However, other sources suggest that wealthy landowners were generally not interested in cultivating slopes, and rather let them grow wild, or leased them out to subsistence farmers (Foxhall 1996: 54-55). Today, terraces are cultivated with a variety of crops such as fruit trees, olives and cereals (Bevan *et al.* 2013; Kvapil 2012; Moody and Grove 1990). In particular, intercropping of tree and cereal crops has been favoured (Foxhall 1996). Terraced slopes equipped with functional water management system can also be ideal for grapevine cultivation, which requires very well drained soils (Aschenbrenner 1972: 55). In the Argive Plain and the adjacent Berbati Valley, olive orchards are abundant on the remaining terraced fields (Wells *et al.* 1990: 233, and current author's personal observations).

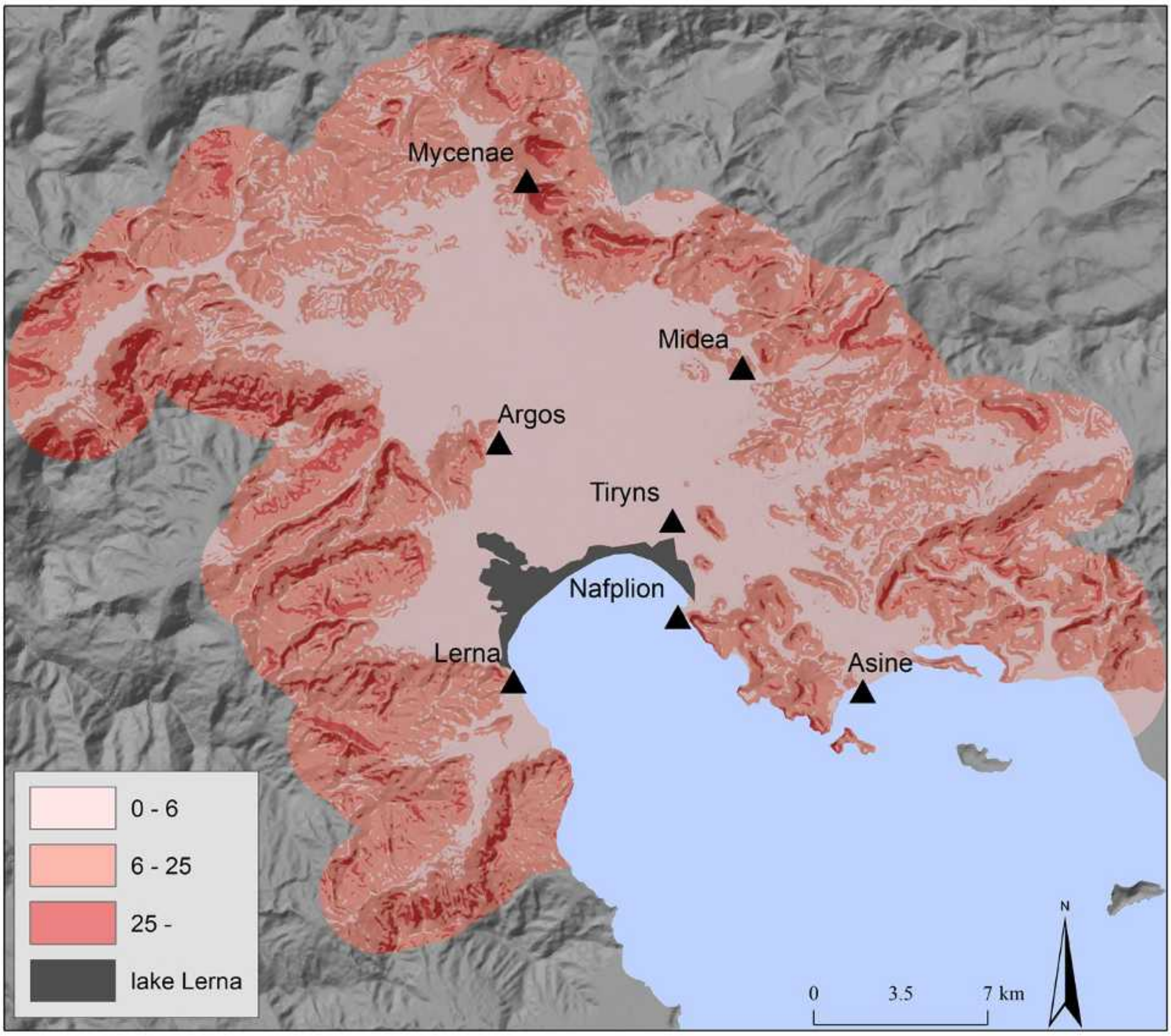

Figure 5.6. Potential slopes (steeper than 6°) suitable for terracing without altitude limitations and within 2.5km buffer from the edge of the flat plain.

However, Wells and co-authors (1990: 233) suggest that in the recent past the Berbati terraces were likely cultivated with wheat and barley. In the Limnes uplands, east of the valley, the colder climate of higher altitudes prevented olive cultivation. However, wheat, barley and oats were grown there successfully (Wells *et al.* 1990: 222). In the Methana peninsula, vetch has been one of the main crops cultivated on terraces. The pulse tolerates the less fertile soils and higher altitudes of the rocky slopes well (Forbes 1982: 248).

Although the evidence is limited, in this study it is assumed that in the LBA, terraces were used for cultivation. Manuring would have enabled the use of terraces for a wide variety of crops (see pp.90-100). Water management systems, such as culverts built within the terraces walls, could have helped to direct water for water-demanding crops (Kvapil 2012: 224). More recent historical and ethnographic sources can be examined for parallels to what has been usually grown on terraces.

The LBA terraces in the Argive Plain

As described above, in the Argive Plain, evidence for LBA terraces is extremely limited and they have only been recovered in the vicinity of Mycenae. Comparisons to Bronze Age terracing patterns elsewhere, together with ethnographic parallels, suggest that terraces could have been located more widely in the landscape. In this section, the potential location of and the additional space provided by terraced platforms for crop cultivation are modelled with a basic GIS slope analysis. The analysis uses the terrace location parameters collected from historical and ethnographic data. These parameters include slope, proximity to settlements and underlying substrate.

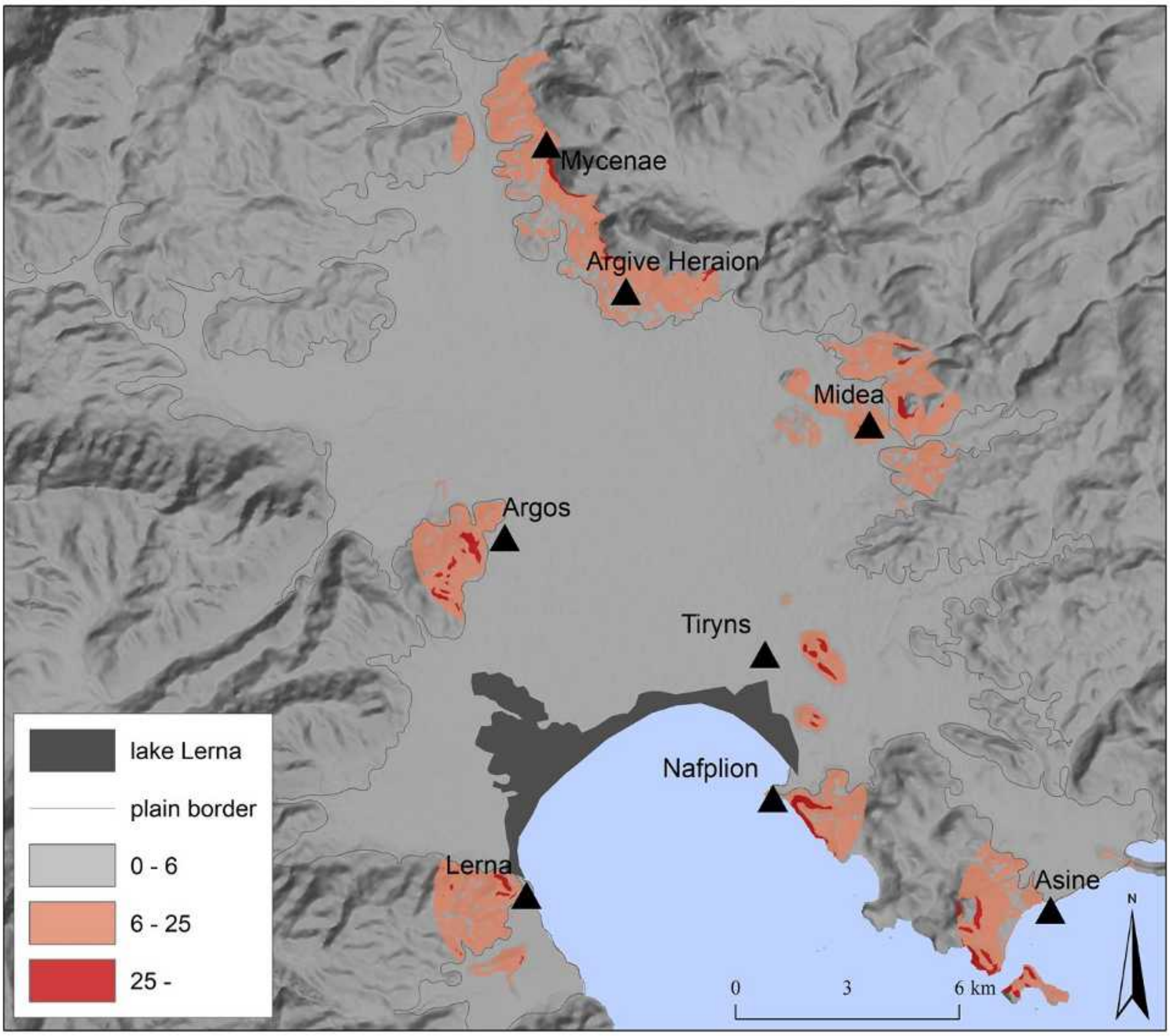

Figure 5.7. Slopes suitable for terracing around the main LBA Argive Plain sites within a 2.5km buffer. The Argive Heraion is included in the sites, since the LBA terraces detected in the Mycenae Survey (Iakovidis and French 2003) are known to continue close to the site.

Soft parent materials were often favoured in terrace construction. These are abundantly available in the Argive Plain landscape (pp.63-64), and as such they would have enabled terrace construction widely across the plain borders. A slope of 6° was used as the lowest threshold between unterraced and terraced land, and the maximum was set to 25°, following the analysis of Fallu (2017: 117-118, Fig. 42).

In Figure 5.6,[2] the potential area for terracing is extracted by using slope categories between 6 and 25 degrees. The area is furthermore limited within 2.5 km from the borders of the flat plain area.

Terraces are usually built in the vicinity of settlements because they need to be regularly maintained. In the absence of conclusive data from the LBA contexts, a maximum distance of 2.5km from the settlement to the furthest terrace is assumed, based on the average distances between current terrace systems and settlements in Antikythera (Bevan *et al.* 2013: 257-59). It is further assumed that the LBA terraces were located mainly around major habitation centres, and thus in Figure 5.7 the potential terraced area is limited inside of a 2.5km buffer around each major settlement of the Argive Plain, and adjacent areas such as the Berbati and Nemea valleys are excluded from the selection.

The maps created are only indicative of the slopes that fall within the parameters chosen here.[3] Table 5.1 shows

[2] Analysis was performed with ESRI ArcMap 10.6.1. CON (Conditional if/else evaluation) Tool by using Copernicus EU-DEM 1.1. (E50N10) with a 25m resolution and vertical accuracy of +/- 7m.

[3] For example, the terrace potential of the area of Asine is exaggerated, since it includes the island of Rómvi, which was very

Table 5.1. Area of land in hectares that could have been terraced in the Argive Plain region. Areas are based on the slope parameters and calculations presented in figures 5.6 and 5.7.

	Slope degree	Total area/ha
All slopes surrounding the Argive Plain (FIGURE 5.6)	6-10	15,012
	10-25	33,194
	25-30	4524
	total	**52,730**
Slopes within 2.5km from major Argive Plain settlements (FIGURE 5.7)	6-10	1282
	10-25	2008
	25-30	139
	total	**3429**

Table 5.2. Terraced area in hectares if 30-90 percent of the potential slope area available was used.

Total area / ha	30%	60%	90%
52,730	15,819	31,638	47,457
3429	1029	2057	3086

how more than 50,000 hectares of land would have been suitable for terracing, about twice the amount of land provided by the flat plain. If terraces were limited to the close surroundings of settlements, about 3400 hectares of suitable land could be added to the Argive Plain. This is still a considerable addition to the total cultivation space. Modern examples presented in the previous section showed how terraces can occupy up to 80-90 percent of the suitable slopes, but that less than half of them might be in use simultaneously, for example 30 percent in the Berbati Valley. In Table 5.2, 30, 60 and 90 percent use rate are provided. These figures are used to examine the potential addition to the LH III Argive Plain agricultural potential by terraced fields in the final analysis (pp.134-138).

Summary: The LH III Argive Plain agricultural landscape

The landscape of the Argive Plain underwent notable changes in the LH IIIB and C period in the areas of Tiryns, Chania, and Mycenae on the south- and north-eastern sides of the plain. However, after these changes, the landscape has remained relatively unchanged until today (Finke 1988: 112; Shay *et al.* 1998: 325). Recent studies have shown that the LH III accumulation took place gradually, likely over a few years or decades (see the LH chronology in introduction), instead of a single event. The south-western and the farthest eastern edges of the plain were not influenced by this activity.

Crop cultivation took place on these Late Bronze Age alluvial deposits (Finke 1988: 109), and on the earlier surfaces beneath them. Before the LH IIIB-C, major alluvial events had taken place during the EBA. Soils would not have had time to develop on these deposits. Rapid events of deposit accumulation could have caused local and temporal destruction to crops. However, the deposited material was generally fertile, since, despite the absence of developed soils, sediments weathering from the calcareous parent material would have contained plenty of nutrients (Fallu 2017: 92). In his PhD dissertation, Bintliff (1977: 336) suggested, that, compared to the plain proper, the gently sloping foothills at the margins of the plain would have provided a superior fertile basis for cereal cultivation in the LBA. However, the results presented here strongly suggest that the plain at large provided a fertile platform for all kind of crop cultivation in the LBA, with only a few exceptions, such as the swampy coastal areas and the surroundings of Lake Lerna. As Finke (1988: 149) concluded, the quality of the LBA soils was similar, or even better than that of today, and in many areas the soils of these two periods are comparable.

People inhabiting the area could have used specific methods to enable better soil fertility as well. In rainfed agricultural systems such as the LH II Argive Plain (pp.100-103 and pp.139-150), the way to secure adequate nutrition levels of the soil is to use fallow and crop rotation and manuring. These cultivation methods are discussed in more detail in the analysis (pp.139-150).

Besides fallowing and manuring, terracing could have offered additional space to agricultural activities. Slope terraces could have been constructed in order to reduce slope erosion that could cause mud flows and sheet erosion, and increase alluviation on valley bottoms (Moody and Grove 1990). Terraced slopes have offered platforms for the cultivation of a variety of crops. In recent decades, tree cropping has become the favoured practice for terraces. Although concrete LBA evidence of terracing is limited (Fallu 2017; Iakovidis and French 2003), terraced slopes could have been commonly found across the Argive Plain landscape, and, thus, may have had an impact on the local agricultural potential. Terraced fields could also have been used for specialized production, for example to provide bulk goods for food rations in the Argive Plain centres, fruit, or olive oil production. These aspects are further discussed on pp.134-138.

Late Bronze Age climate in the Argive Plain and its impact on agriculture

Climate is crucial for agriculture. Therefore, it is essential to consider when reconstructions of past agricultural systems are made. Previous estimates

likely not cultivated in the LBA.

of past agricultural yields have usually assumed that the past climate was similar to that of today (e.g. Jardé 1925: 67; Osborne 1987: 29-31). However, recent paleoclimatic research has yielded new data indicating variable climatic conditions during the Bronze Age. The following section examines these paleoclimatic data and discusses whether these results can be incorporated in the reconstructions of past agricultural systems. In addition, the relationship of agriculture to rainfall and temperature, both of which are known to fluctuate considerably in Greece, is considered. The presented dating follows the individual studies which usually use the (yrs.) BP format.

The term 'climate' refers to a compilation of local weather events over a long (usually several decades) period of time. This compilation consists of mean weather values, such as precipitation and temperature, calculated over a certain time sequence, for example a month or a year. It also includes records of extreme short-term (usually from days to months) weather events, which often occur in sequences or cycles during the given time period (Xoplaki 2002: 1-2). The Eastern Mediterranean enjoys its own climatic regime, influenced by wider global and regional climatic patterns (Moody 2005; Tsonis *et al.* 2010; Xoplaki 2002). In order to understand the relationship of climate and agriculture in this area, information of both the wider global and regional climates as well as the sub-regional climates is required.

Many the studies concerning the Bronze Age climate in the Eastern Mediterranean are focused on the potential relationships of climate change and the so-called Bronze Age collapse around *c.* 1200 BCE (Finné *et al.* 2017; Kaniewski *et al.* 2010, 2013; Weiss 1982, 1997, 2016). However, as Caseldine and Turney (2010: 90) point out:

'Because there has in the past been a tendency to look for 'events' or catastrophes, little attention has been paid to stable periods when humans were able to settle and expand successfully, often on centennial and even millennial time-scales.'

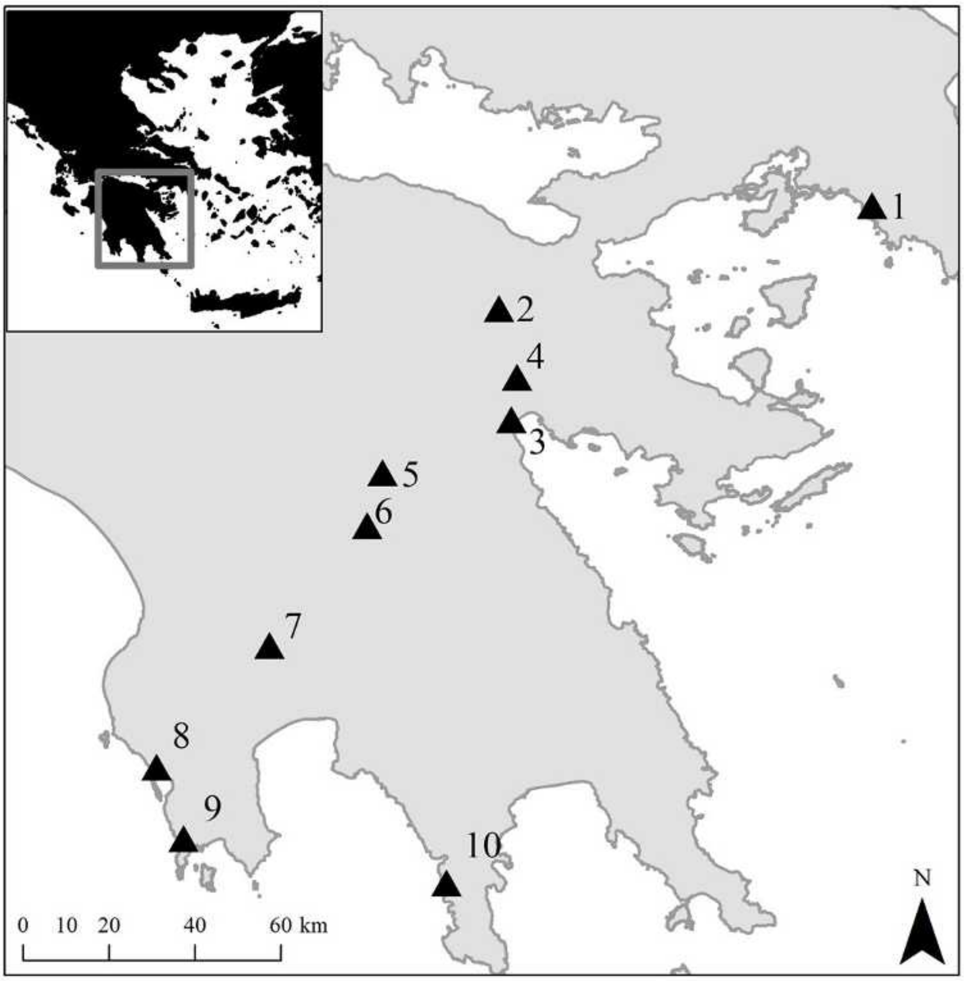

Figure 5.8. Locations of the climate data mentioned in the text. 1) Elliniko, Athens, 2) Kleonai, 3) Lake Lerna 4) Argos 5) Tripoli, 6) Asea valley, 7) Agios Phloros, 8) Gialova Lagoon, 9) Mavri Trypa cave, 10) Alepotrypa cave.

Thus, much less attention has been paid to stable climates in the past. Such reconstructions are, however, essential when climatic conditions are studied in relation to past agriculture. Reconstructing past climatic conditions usually begins with the understanding of the characteristics of the current climate in the study area.

Current climates in the Eastern Mediterranean and the Argive Plain

The climate in the Aegean is characterized by strong seasonality, with warm and arid summers and mild but humid winters. The vast majority of annual precipitation occurs during the winter months (Finné *et al.* 2011: 3154; Xoplaki 2002: 3). The mean annual precipitation in the Argive Plain is *c.* 480mm (average in 1980-2010),[4] November being the rainiest month (Finné *et al.* 2011; Xoplaki 2002). Precipitation can vary notably in different areas of Greece. For example, in the southern mainland, the annual mean values vary from the 366mm of Elliniko, Athens[5] (Figure 5.8) to the 750mm in Tripoli[6] in the central Peloponnese (Anadranistakis *et al.* 2016; Finné *et al.* 2011; Xoplaki 2002). Such variation is influenced greatly by the geographical location of these two regions: Tripoli is located inland and surrounded by high mountains, while Athens is close to the sea, and is surrounded by lower hills, which protect the city from winds (Jahns 1993: 188).

Mean temperatures in mainland Greece are the lowest generally during the winter months, from December to March, and the highest in July and August (Xoplaki 2002: 16). The average temperatures also show regional variability. The mean temperature in Argos (Pyrgela) is *c.* 16.9°C.[7] The mean annual temperature of the flat plain area of the modern Argive Plain is *c.* 18°C (1971-2000), while dropping to *c.* 17°C in the foothills surrounding the plain, and further to 13°C in the mountainous areas encircling the plain. Precipitation varies from 500 to 600mm on the plateau area and increases to 700-800mm in the surrounding mountains (Anadranistakis *et al.* 2016). As becomes evident later (pp.p. 79), such average rainfall is more than adequate for agriculture, and facilitates the cultivation of a large variety of crops. For the Bronze Age agricultural reconstruction, it must be assessed how far these data were comparable in the past.

The LBA climate in the Eastern Mediterranean and the Argolid

A variety of methods have been used to reconstruct past climatic conditions in the Eastern Mediterranean. Most commonly used are pollen data from non-marine sources, sediments from marine or lacustrine environments, and, more recently, isotopic values of minerals in cave speleothems. Pollen is used to examine the presence of and changes in vegetation. From the mid-Holocene onwards, pollen is often considered to mainly reflect human influence on vegetation (Finné *et al.* 2011: 3163; Peyron *et al.* 2017: 259-60). In contrast, isotope values taken from cave speleothems have been considered as less influenced by human activity by some of the more recent studies (Finné *et al.* 2011: 3163; Peyron *et al.* 2017: 259-60).

Climate reconstructions on speleothem evidence are based on oxygen (δ18O) and carbon (δ18C) stable isotope values measured in cave speleothem material. Water dripping into the cave environment reflects the water received by the outside surface. The stable isotope values of carbon and oxygen contained by the cave water can be compared to the values of the surface water (i.e. meteoric water), which, in turn, can reflect the chemical consistency of precipitation. Variation in precipitation can therefore influence the chemistry of the drip water, or the rate of the dripping and therefore the growth rate of the speleothem. Evaporation, cave CO2 levels, contact with karst and soil, outside vegetation cover and many other factors can influence the fractionation rate of the isotopes, thus changing the relationship of cave water, meteoric water and precipitation. Long-term human occupation of the cave can influence its condition, for example through fire use, dung burning, or alteration of the natural ventilation by artificially closing or opening spaces. For the stable isotope signals to be reliably measurable, the conditions of the cave environment must be in equilibrium so that additional fractionation does not occur (Bar-Matthews *et al.* 1997: 156; Boyd 2015: 11-13 and 43-45). In environments where conditions of equilibrium, or near-equilibrium can be demonstrated, speleothem material can provide growing sequences over decades, or even hundreds or thousands of years. The results must be compared with climatic seasonality, regional climates, or other local environmental conditions in order to understand the regional base values with which the isotopic values are compared. The oxygen isotope values have a better correlation with the fluctuation of the rainfall than the carbon isotopes (Bar-Matthews *et al.* 2003; Drăguşin *et al.* 2014; Finné *et al.* 2017). In the Eastern Mediterranean, a more negative oxygen isotope (δ18O) value indicates a higher rainfall (Bar-Matthews *et al.* 2003; Boyd 2015). A diachronic change in precipitation can be thus observed in the fluctuation of the higher and lower oxygen isotope values, and major changes are clearly visible as peaks on the isotope curves. These changes cannot, however, be translated to actual precipitation figures. Climatic interpretations based on carbon isotope values are considerably more complex (Finné *et*

[4] Measured in the weather station in Pyrgela, Argos (Figure 5.8).
[5] Mean precipitation in 1955-2010.
[6] Mean precipitation in 1957-2010.
[7] Varying from the summer average (Apr-Sep) of 22.7 °C to 11.3 °C in the winter (Oct-Mar), measured in 1980–2010.

al. 2017: 6), and the results accomplished so far in the Eastern Mediterranean remain irrelevant for this study.

The combined results of isotope data taken from cave speleothems and sea and lake sediments suggest that towards the end of the LBA, the climate in the Eastern Mediterranean became more unpredictable than before (Finné *et al.* 2011: 3169; Moody 2005: 471). Based on a substantial database,[8] Finné and colleagues (2011: 3166-67) reconstruct a general trend to more arid conditions throughout the latter part of the Holocene from *c.* 4550 BCE (6500 BP) onwards. This trend was frequently interrupted by periods of more humid conditions. During the LBA the Aegean faced more arid and cool conditions, while the Levant and the Adriatic had more humid climatic conditions until *c.* 850 BCE (2800 BP).

In the Peloponnese (see Figure 5.8 for the location of mentioned sites), recent values of sediment and cave stable isotopes show varying results of the precipitation levels of the Bronze Age. The results of these studies are compiled in Figure 5.9, as a simplified illustration. Depending on the location of the source data, the studies seem to yield opposing results for the LH (III) period, which is relevant to the present study.

The two multi-proxy analyses taken in the Gialova lagoon in the western Peloponnese point to dry conditions in the LH period, one from LH IIIA onwards (*c.* 1350 BCE) (Emmanouilidis *et al.* 2018: 59), and the other from LH I to LH IIIC/Submycenaean (*c.* 1650-1050 BCE) (Katrantsiotis *et al.* 2018: 87–88). The latter study also suggests a potential wet/cold spell in LH IIIB (*c.* 1250 BCE) (Katrantsiotis *et al.* 2018: 87-88). Stable isotope values of a sediment core taken in Agios Floros, western Peloponnese, show progressive drying from the EH II until the Geometric period, but indicate a shorter episode of wetter conditions in LH IIIA-LH IIIC (*c.* 1350-1150 BCE) (Norström *et al.* 2018: 569-72). The speleothem isotope values of the Alepotrypa cave in the southern Peloponnese further imply that climatic conditions were dry from EH II onwards and throughout the LH and Geometric periods (Boyd 2015: 43). However, they also indicate a short dry event for the LH IIIB (*c.* 1250 BCE) (Boyd 2015: 43). In contrast, the Mavri Trypa cave speleothem results point to generally wetter conditions around MH II-LH IIIC (*c.* 1850-1150 BCE), except for unusual episodes of aridity around LH I/IIA-LH IIB (*c.* 1600-450 BCE) and LH IIIB (*c.* 1250 BCE) (Finné *et al.* 2017: 7-8). The speleothem isotope data of Asea valley in central Peloponnese only suggest stable and humid conditions in LH IIIB–late Geometric (*c.* 1300-750 BCE) (Unkel *et al.* 2014: 13). Due to its mountainous character, the region still enjoys a high annual rainfall today (see pp.76-78). Finally, the results received from the Lake Lerna sediments in the Argive Plain suggest generally wet climatic conditions throughout the EH I-LH IIIC and after (*c.* 3050-1050 BCE), interrupted by several dry spells, one coinciding with LH IIIA2 (*c.* 1350 BCE) (Katrantsiotis *et al.* 2019: 44-46).

As illustrated above and in figure 5.9, the most notable results from these paleoclimatic studies are the few coinciding indications to a period of unusual dryness around the LH IIIB. Similar dry spells have been visible in other paleoclimatic records around the Eastern Mediterranean, and there have been various efforts to connect them chronologically to the political crisis, 'the collapse', which swept over the Eastern Mediterranean at the very end of the Bronze Age (*c.* 3200 BP/1200 BCE) (Drake 2012; Kaniewski *et al.* 2013; Moody 2005; Tsonis *et al.* 2010). The Mavri Trypa evidence has, for the first time, enabled a high-definition dating[9] of the dry event. Finné and colleagues estimated that it lasted for about 20 years during the LH IIIB period, which in total had a length of about 120 years. The intensity of the event in real climate effects is unknown. However, the dry event took place before the closest Mycenaean palace, the palace in Pylos ('the Palace of Nestor') was destroyed in *c.* 1250-1180 BCE. This suggests that there was no direct link between its destruction and the dry event. It has been suggested, however, that a period of prolonged drought could have led to a subsistence crisis to such a degree that social unrest led to the breaking down of the local political system (Finné *et al.* 2017: 9).

Other climatic trends observed in the studies presented above present longer climatic trends which seem to oppose each other (Figure 5.9). As such, these data cannot reliably describe the climatic conditions of the LH period in the Peloponnese, or more regionally in the Argolid. Reliable past climate proxy data is not yet abundantly available for the Argive Plain. More studies with higher accuracy dating for the eastern Peloponnese are needed to back up the results of the single study of the Lake Lerna sediments by Katrantsiotis and co-authors (2019). As a comparison, pollen data can be examined to see if notable vegetation changes took place during the episodes of drier or wetter climatic conditions.

Microbotanical data from the LBA Argive Plain contexts is discussed in detail in the following section (pp.86-90), where they are used to illustrate the local environment in the LBA. In relation to the Bronze Age climate, it can already be stated, however, that the notable changes in vegetation from the Final Neolithic onwards in the area most likely relate to increased human activities,

[8] The study includes a review of over 80 published climatic datasets over the Eastern Mediterranean. The data derives from a variety of proxy data, such as speleothem isotopes, and deep sea and cave sediments (Finné *et al.* 2011: 3511, table 1).

[9] U-Th (Uranium-Thorium) dating gave an average uncertainty of <±1% for the 24 samples measured (Finné *et al.* 2017: 3).

Figure 5.9. The wetter (blue) and drier (red) climatic conditions, and the shorter dry periods (dark red) in the Peloponnese according to the referenced studies (source). The period of interest to this study is marked yellow. The LBA 'collapse' is currently dated to *c.* 1200 BCE.

rather than changes in precipitation or temperature (Jahns 1993: 197). Furthermore, the dating of the local pollen samples is too wide to allow observations of vegetation changes in the LBA or even the Bronze Age (the zone including BA begins from the Final Neolithic and ends in the Geometric period). Therefore, as of today, paleoclimatic reconstructions concerning the LH III Argive Plain cannot be reliably conducted based on the available data. The past climate can, however, be examined through observations of climate's impact on agriculture. The main questions of the following section are, 1) what kind of climatic conditions would have been optimal for the LH III mixed farming, and 2) what type of climatic change could have caused severe subsistence failures?

The impact of climate on the Bronze Age crop production

Detecting periods of past climate changes can provide a better understanding of the environmental constrains regarding agriculture. However, reconstructing these changes in precise rainfall or temperature figures is not possible. Therefore, it is not known exactly what is meant by a 'drought event' or 'a change to wetter conditions'. One of the crucial issues appears to be that the threshold to which any changes could be compared cannot be established. Thus, if a LBA dry event is reported in the eastern Peloponnese, it remains unclear whether it should be compared to the current levels of annual rainfall. The extent of this drought in millimetres of rain cannot be established, yet such precise numbers are important to estimate potential crop yields in a rain-fed agricultural system. Nevertheless, in the absence of precise figures, it is assumed here that when a dry event is reconstructed from past climatic data, its severity was substantial enough to impact the local subsistence strategies. Furthermore, these events can be approach by examining what kind of changes would have been severe enough to cause subsistence crises.

Mycenaean agriculture was dependent on a predictable annual rainfall (rather than temperature) since it was based on dry-farming. More precisely, the success of yields is strongly influenced by the amount of winter precipitation. Even if the total rainfall of the year reaches the mean values, a failure in the winter rainfall amounts can cause serious problems during the growing season (Xoplaki 2002: 7). Such a system, therefore, included some risks, not only because farmers had to trust in natural precipitation, but because of natural - and human-caused - hazards that would have directly impacted the yield (Halstead 2004: 155). In the past, changes in the annual precipitation (although mainly in areas with already a low mean precipitation) would have eventually led to changes in yields, even though developed storage systems and emergency cultivation strategies for dry periods likely existed (Halstead 1989; 1999a). Since plant species have variable tolerance for arid conditions or changes in temperature, more tolerant plant species, such as barley, would have been preferred in times of reduced rainfall (Riehl 2009: 110-11).

While current paleoclimatic studies are trying to unravel the details of climatic changes in the Bronze Age Peloponnese, rainfall and temperature changes can be approached from another perspective; by asking what kind of change in rainfall would have been harmful for the crop production. In addition, it is important to examine the temporal dimension of such changes. How many years of drought could Mycenaean society tolerate? Some contemporary estimations of the connection of rainfall and main crops exist. Table 5.3 presents the thresholds used often in studies of past agricultural practices. While the analysis of Arnon (1972) of rainfall thresholds are based on modern reference data from multiple (dry) regions around the world, Wilkinson (1997) has intensively studied the region of Upper Mesopotamia, which currently extends to Iran, Syria, Turkey and Iraq. His results are based on a combination of modern data of agronomic conditions and rainfall figures (varying between 150 mm and 700 mm within the study region), and archaeological survey evidence of the regional population changes. Gibbon's (Gibbon 1981) thresholds are based on fieldwork data from the Aleppo province in northern Syria, where two villages practicing rainfed agriculture were studied (see Appendix 2 for background information).

Fluctuation in crop yields in the Mediterranean is connected to rainfall, soil fertility, topography, altitude and multiple other features (pp.62-64 and pp.90-100).

Table 5.3. Average rainfall in millimetres per year needed for diverse types of crop cultivation in the Eastern Mediterranean according to archaeoethnographic studies.

	Gibbon 1981	Arnon 1972	Wilkinson 1997
Wheat cultivation	600	300	350-600
Barley cultivation	300	200-250	250-300
Legumes	-	350-400	-
Cereal cultivation and tree cropping	-	-	600
Sheep and goat husbandry, barley grown as fodder	-	-	200-250

If the BA rainfall in the Argive Plain was similar to that of the present at *c*. 500mm, it would have enabled the cultivation of a large variety of plants. Wheat could have been cultivated as the main crop. Large scale animal husbandry would probably have been secondary to crop production in the plain area. Mixed farming with a small number of animals per household would have likely provided the most secure yields. According to the estimates in Table 5.3, only a rainfall clearly less than 350mm could have endangered this. The archaeobotanical evidence from different Argive Plain sites indicates that a wide variety of plants were indeed cultivated on the plain or collected in the wild. The assemblage includes the seeds of cereal crops and fruits such as figs and olives (pp.90-100). This evidence suggests that the climatic conditions on the plain were adequate for growing such crops in the LBA, meaning that the average rainfall would have needed to be above 300mm.

Poor soil quality can cause crop failures during years of lower precipitation. Good quality soils can, however, enable good yields in drier conditions (Gibbon 1981). A recent study in the current Near East shows that crop losses vary with the mean annual rainfall. The most severe losses likely occur in regions where normal precipitation is regularly low, some 200-300mm. Regions with higher annual precipitation experience less severe losses, even if the volume of the dry event is the same (Riehl *et al*. 2014). Studies from areas that rely on rain-fed agricultural systems show that when the precipitation decline is continuous, the number of years without a yield increase. In northern Syria, where rainfall is normally above 350mm, a 50-100mm decrease in rainfall increases a complete crop loss by 1 percent, a 100mm decrease causes 36 percent crop loss, 100-150mm decrease a 46 percent loss and finally 150mm or higher decrease causes a 64 percent loss (Wilkinson 1997: 75). In Tell Sweyhat, Upper Mesopotamia, where the mean rainfall was as low as 250mm, a 6-year episode of lower than 200mm rainfall was estimated to result in a total crop failure in one year out of five (Wilkinson *et al*. 1994: 499-500).

As noted by Wilkinson (1997: 75), regular major droughts and concurring famines have not been unfamiliar phenomena in the history of the Mediterranean. Nevertheless, even a rainfall decline of 100-150mm would have not caused major crop losses in the LBA Argive Plain if the average rainfall in the area was 500-600mm. If the figures in Table 5.3 are taken as a guideline, the main LBA crops could still be cultivated with a rainfall of 300-350mm. Thus, the decline of precipitation in the LBA Argive Plain would have needed to be some 50 percent in order for major problems to occur in the local subsistence system. Such drops could have entailed changes to the main crops species, for example a switch from bread wheat cultivation to barley, (temporary) abandonment of tree cropping, or an increased focus on animal husbandry, specifically on sheep and goat herding. In the short term (decennial scale), prolonged crop-losses would have quickly worn out the food buffers of the LBA communities (see pp.82-85 and pp.139-150). The diminished yields would also have meant that less stock could be saved for seeding. This, in turn, would have quickly reduced the potential crops for a longer term. Nevertheless, short-term changes and the consequent crop losses may also have been compensated by cultivating barley, which tolerates drier conditions much better. Increased use of animal products would have further ensured the required energy intake.

Summary: Climate as a factor in Late Bronze Age farming

Of the paleoclimatic studies presented in this chapter, a few (Boyd 2015; Finnè *et al*. 2017) point to a short (few decades or less) period of unusually dry conditions in the Peloponnese during the LH III period. If changes towards drier conditions took place over centuries, adaptation to these conditions, for example through changing farming practices, would have prevented subsistence crises. However, a period of drought lasting for some decades, or see-saw between arid, humid, cold and warm climates at a decennial scale, could have created severe food shortages. Since the paleoclimate data concerning the LBA Argive Plain remains inconclusive, it cannot be estimated whether the average rainfall in the region was similar to that of today: 500-600mm, or if the results of the stable isotope studies (e.g. Boyd 2015; Emmanouilidis *et al*. 2018) from elsewhere in the Peloponnese showing 'dry or drying conditions' for the Bronze Age meant that the rainfall was, for example, closer to 400 or 300mm. This latter average has a major influence on the way the area would have been impacted by sudden drops of precipitation.

Based on the large variety of crop species in the archaeobotanical samples from the LH III period (pp.91-92), it seems more likely, however, that the average rainfall in the region was similar to today. The mean rainfall had to be sufficient to grow (bread) wheat, which needs a secure amount of water to thrive (e.g. Wilkinson 1997). There does not seem to be any evidence (e.g. archaeobotanical or osteoarchaeological) of a famine caused by a rapid climate change occurring in the Argive Plain in the LH III period. Nevertheless, episodes of arid conditions could have caused subsistence difficulties and eventually led to social unrest. Such episodes, as discussed earlier, seem to have taken place in the south-western Peloponnese (and more generally in the Eastern Mediterranean around 1200 BCE), lasting for about twenty years (Finné *et al.* 2017: 7-8). Since the potential causes of the LBA 'collapse' are beyond the scope of this book, here it is more fruitful to examine the ways the Mycenaean population of the Argive Plain stored their goods, and whether they were able to import subsistence products from other areas in case of bad crop years. These themes will be touched upon in the next section.

Agriculture in the LBA material evidence

Like in the Linear B dataset, Mycenaean agricultural practices are poorly visible in the material remains of the period. Remains of tools, crop processing installations, or animal pens could help to illustrate how crop cultivation and animal husbandry were conducted. Information on individual and communal storage spaces can be used to investigate past risk management strategies, but also to examine local societal and political systems. The following section presents a concise overview of the structures and tools related to agricultural work. The aim of this section is to see what the material evidence can say about specific LBA practices, such as crop processing and storage, and how those practices may have influenced the amounts of foodstuffs that were available, and to whom they were available. In addition, potential import of food products from regions overseas is discussed, in order to indicate whether the LH III Argive Plain was self-sustainable, or if at least some food items were imported.

Agricultural tools

Bronze Age agricultural tools have only been found in small numbers in the Aegean. Tools were not luxury items and were in part made of perishable materials such as wood. Therefore, they have not preserved well through time. Yet, stone tool technology is well attested in the Bronze Age; for example, obsidian from the island of Melos was a major trade item across the Eastern Mediterranean. However, stone tools have rarely been identified as agricultural tools, and they were often multifunctional.

The most common agricultural tool recovered in Bronze Age Aegean contexts is the sickle, a single-handed tool with a curved blade. Sickles are usually used for cutting cereal crops during harvest (Halstead and Jones 1997: 274). A few sickles made of stone have been recovered in LH III contexts in Tiryns (Blackwell 2011: 46), but for now, they represent the only agricultural tool finds at the Argive Plain sites. Other cutting tools such as axes, chisels, and celts have been recovered in the same Tiryns contexts. These could have been used in agricultural work, but also in carpentry and other craft activities, and thus they cannot be exclusively related to agriculture (Blackwell 2011: 46). Bronze sickles have been recovered, for example at the LH III site of Akrotiri, Thera, and they seem to become more common towards the end of the LBA (Sarpaki 1987: 130).

Bronze and stone sickles and other agricultural tools have been recovered in greater numbers in Bronze Age shipwrecks. It has been suggested (Blackwell 2011: 77) that they were either trade items, or part of the ship's toolkit, and used for subsistence activities on board and on land. Several sickles and a ploughshare were recovered among other tools in the Uluburun shipwreck in western coastal Turkey. The ship was transporting various raw materials and precious objects, containers and more mundane cargo items. The mainland Mycenaean settlements were part of the trade networks in the Eastern Mediterranean, and some of the Uluburun cargo consisted of Mycenaean objects. Although the sickles and the ploughshare cannot be identified as Mycenaean, the tools were, in all likelihood, much like the types used generally in the Eastern Mediterranean in the Bronze Age (Pulak 1998: 208-218).

Bronze hoes and various types of socketed blades were recovered in the Cape Gelidonya shipwreck in western coastal Turkey. These items were likely used for agricultural purposes, as hoes or as ploughshares (Bass *et al.* 1967: 88-93). Among the recovered items were also pruning hooks, likely meant for cutting brushwood or vines, a sickle, a shovel and a mattock, all made of bronze (Bass *et al.* 1967: 94-95). The latter two items could have been used for a variety of agricultural and non-agricultural tasks. Similar to the Uluburun shipwreck, Bass and companions (1967: 165) suggest that the cargo of the Gelidonya wreck gives general indications about the types of materials and objects, including tools, which were used in the Eastern Mediterranean in the 14th and 13th century BCE.

Sickles, as mentioned, are usually used to cut cereals and legumes during harvest. The stone blades recovered in (Late) Bronze Age contexts could also be used for threshing. It has been suggested that these blades could have served as inserts of a threshing sledge (Kardulias and Yerkes 1996: 664). The threshing sledge (*dhoukani*) was commonly used in the Eastern Mediterranean before the development of mechanical threshing devices in the 1950s. It typically consists of one or two thick wooden planks tied together. At the bottom, these planks are inserted with stone objects (from a few dozen to hundreds). A person stands or sits on a rack built on top of the boards and guides the animal who pulls the sledge, usually around a circular threshing floor on which the grain stalks lie. In the process, the flint blades separate the kernels from the stem (Kardulias and Yerkes 1996: 657–58). There is no direct evidence of the use of such sledges in the Mycenaean context. However, these sledges were used in Bronze Age Mesopotamia, thus the technique was known and could have spread to the Aegean. Nevertheless, the sledges are not mentioned in the Greek sources from the Bronze Age or Classical periods or found as such among the material evidence (Kardulias and Yerkes 1996: 658). Several use-wear analyses[10] of prehistoric and Bronze Age flint blades around Europe and the Near East suggest that the sledge was used widely for at least 5000 years (Kardulias and Yerkes 1996: 664; Whittaker 2000: 65).

If sledges were not used, threshing could have been assisted by large domestic animals, whose weight, and the sharpness of the hooves would have separated kernels from stems. This method has been traditionally used in Greece (Murray and Kardulias 1986: 26). Threshing could also have been completed by using some type of flails or rollers to stomp the grain, or by beating the grain with sticks. The sledge, however, is one of the most efficient non-mechanical methods, and would have considerably increased productivity by saving time and workforce (Kardulias and Yerkes 1996: 664).

Of other tools related to agricultural work, one can mention the various types of spindle whorls, loom weights, and needles which indicate the manufacturing of textiles from materials such as wool or flax. Wool was likely plucked from sheep with knives (Andersson Strand 2014: 44), and therefore specific wool plucking tools cannot be identified amongst the LBA tool assemblages. Textile-making tools, however, refer to the processing of wool into thread and fabrics. Remains of wool thread, and several fragments of textiles woven of flax, were also recovered in LH III Akrotiri, Thera (Spantidaki and Moulherat 2012: 187). Although the LH III textual evidence of textile production are related to palatial crafts workshops (pp.15-18), textiles must have been manufactured in regular household contexts as well. From the size of the spindle whorls found in the EH II Tiryns and LH IIIB2/C Thebes, it has been possible to reconstruct different thread sizes, from coarse and thick to light and delicate. Fabrics were, thus, woven to produce both heavy outdoors clothing and delicate, probably folded and possibly embroidered or decorated textiles in palatial contexts (Alberti, 2012: 99; Nosch and Andersson Strand 2003: 201-202).

Special activity sites

Sites in which agricultural activities took place can help to shed light on the ways cultivation and animal husbandry was organized in the landscape, and within farming communities of the past. Agricultural sites discussed in this section include crop processing sites, and sites related to animal husbandry practices. Installations such as milling and pressing devices are introduced further on pp.92-99. As with farming tools, evidence of agricultural sites is limited, and dating of potential sites is challenging. In the future, surveys with a focus on cultivation and pastoral sites could help to better understand how agricultural practices were organized in the landscape.

Threshing floors (*alonia*) are circular floors on which some crop processing activities such as threshing and winnowing take place (see also pp.92-95) (Murray and Kardulias, 1986: 26; Whittaker 2000: 63). Threshing floors were mostly absent in the LH III Argive Plain, and more widely in the Bronze Age Aegean (Pullen 2019a: 143). One potential threshing site was recovered in the Southern Argolid during an ethnoarchaeological survey of ancient and traditional agricultural sites, but it could not be dated. An 'ancient' stone quarry was likely located in connection to the site, however. The identification of the site is based on the diameter of the hilltop above a lithics scatter, which could derive from threshing activities. The size of the hilltop resembles traditional threshing floors, and the scatter of lithics could represent a threshing sledge (Murray and Kadulias 1986: 39). Thus, the identification is rather uncertain. The best evidence of a possible Mycenaean threshing floor has recently been recovered in the Kalamianos area north of the Argive Plain. A semi-circular threshing floor paved with cobbled stones was recovered within a system of terraced slopes. Its retaining wall was constructed with similar masonry to that of the nearby terrace walls, which have been dated to the LH III. More recently, the terraced fields

[10] In the future, usewear analyses conducted on sickle-type stone blades can shed light on their actual use in the past. As van Gijn (2010: 66) points out, in usewear analysis, sickle blades are usually recognized of the distinct gloss of the blade, created by the close contact with cereal plants. If the blades have been used for other purposes than cutting, the pattern of traces is different, even if the gloss remains similar.

have been cultivated with olive trees, and the floor must have preceded this use (Pullen 2019a: 142-43). Threshing floors are also recorded in the Late Bronze Age Hittite texts. In them, plots of land are recorded by their size, use (e.g. for cereal cultivation, pasture, orchard), and connected threshing floor (Uchitel 2007: 481-83). In the Hittite state, threshing floors were connected to the land of large estates (Uchitel 2007: 484). This could refer to their joined use by several small farming communities.

Ethnographic notes from Cyprus suggest that it was common for almost every farming household to own their own circular threshing floor, even if crop processing was done jointly with other village members. Several dozens of threshing floors could be placed on the edges of the village. When crop processing was conducted near the habitation, the processed cereal and chaff could be collected more efficiently for storage (Whittaker 2000: 64). Threshing floors and crop processing facilities have also been located in the vicinity of fields and further away from settlements, as on the islands of Karpathos and Amorgos. Land fragmentation and the consequent challenges of transporting crops to settlements from fields far away created a need for seasonal field houses, which each had their own threshing floors (Halstead and Jones 1997: 271-272). The location of the threshing floor had to be carefully chosen because winnowing which uses the breeze to separate impurities from kernels was conducted on the same site. Thus, the location had to be clearly away from the settlement. in an open space.

Pens, shelters and other special activity sites related to animal husbandry practices are short-lived and even when they are well-preserved, hard to date. Chang (1981) has studied the histories of traditional special activity sites in Didyma, Southern Argolid, where sheep and goat husbandry were the dominant subsistence strategies until recent years. Like other agricultural sites, animal pens undergo constant remodelling, according to the changing subsistence needs, flock sizes, territorial boundaries, and technologies. Such sites have traditionally been located outside habitation, in the vicinity of water resources and pasture sites. They usually include pens for flock management and separation. for example, during milking, herder's huts for overnight stays, and shelters for the animals (Chang 1981: 62-66).

Blitzer (1990) has studied traditional sheep herding sites in the Cretan mountain-landscapes. Based on the distribution of small Minoan sites in these high altitudes, she has suggested that these could represent remains of installations related to summer-grazing in the area. Traditionally, such installations (*mitato*) have included penning facilities, hearths and facilities for cheese making, for example.

Due to the challenges related to the preservation and dating of pasture and other special activity sites, the suggestions of Chang (1992) about examining pasture sites through catchment and other spatial analyses, seem to be the most promising approaches for future research. Defining pasture and cultivation sites in relation to settlement patterns could help to define the potential extent of agricultural activities in past agricultural landscapes.

The limited evidence of the LBA agricultural activity sites does not offer significant help for the LH III Argive Plain agricultural reconstruction. Based on the evidence, harvesting was likely done with sickles, and, although ploughshares have been recovered in shipwrecks, the various types of hoes could indicate that ploughing was still often conducted manually. Hoes are multifunctional tools and may also have been used for weeding, drilling paths for planting seeds, or any type of earth-moving in agricultural contexts. If the two finds of threshing floors could be firmly dated to the LBA, they might suggest that crop processing took place close to fields rather than settlements.

Agricultural storage

Evidence of the Mycenaean storage spaces and practices is fragmentary. In the southern mainland, storage rooms and spaces recovered in LBA context are mostly small in capacity, enough to support a small group of people such as extended households, but not entire communities. Indications of larger storage spaces have been found mainly in Minoan contexts. Their absence has been an indication that the Mycenaean economic system was not based on redistribution (pp.16-18). The following section introduces Mycenaean storage strategies. Storing of goods was an important risk management strategy for the Mycenaean Argive Plain population, and thus an important part of agricultural practices.

A rather unique example of a LH III agricultural storage comes from the settlement of Chania, located in the central northern Argive Plain (p. 30). The excavated part of this small settlement included a building with two storage rooms, separated from the living quarters and the central courtyard by corridors and wooden doors. Both rooms held a large number of storage vessels for foodstuffs, oil, and other liquids (Palaiologou 2014: 518, 2015: 57). The corridor leading to the storage spaces was connected to an ascending ramp, which was likely used to move heavy containers to the upper floor of the building. Thus, the upper floor likely included more storage space. The roofing of the ascending ramp suggests that the storage area upstairs was also covered (Palaiologou 2015: 59). Downstairs, a variety of containers, including two large, one-metre-tall pithoi, suggests that foodstuff were separated in specific types of containers (e.g. liquids and grain). The storage in Chania could represent a larger storage space used by all inhabitants of the hamlet (the settlement included three houses).

Other LBA Argive Plain storage evidence comes from Mycenae. The storage spaces at Mycenae are small and dispersed over various buildings, such as the House of Oil Merchants, the House of Columns (Nagle 2015: 261-65), the West House (Nagle 2015: 298, but see Tournavitou 2006 for different opinion), and the rooms above the North Gate (Iakovidis 1983). The House of Oil Merchants and the West House were part of a house complex which likely had a commercial function. Besides charred legume and grain seeds, their storage spaces yielded a collection of Linear B tablets (Tournavitou 1995). It seems that storage rooms could be multifunctional. Overall, most of the buildings at Mycenae and other Argive Plain settlements contained one or more storage rooms which could hold moderate number of foodstuffs and other items (see detailed analysis of house spaces by Nagle 2015). Although the capacities of the spaces are mostly unknown, it seems that these individual storage rooms were meant to support a small number of people, either as household storages, or storages for specialized workers for their craft and workshop activities. However, the houses uncovered at Mycenae (and other large Mycenaean sites) are usually elaborate, containing multiple rooms and stories, and separate spaces for various activities (Shear 1969: 459). Simpler Mycenaean house types, often found outside the Mycenaean core areas, contain only one or two rooms and held storage containers in the living space (e.g. Shear 1969: 331-338; description of the houses at Malthi-Dorion).

Outside the Argive Plain, LBA storage spaces resemble those of Chania and Mycenae as they are separate rooms filled with diverse types of ceramic containers for the storage of bulk goods, such as cereals and oil (Jones *et al*. 1986; Margomenou 2008; Palaiologou 2015; Tournavitou 1995). Evidence of containers from Thessaloniki Toumba included pithoi, pits in which pithoi or food could be placed, smaller containers, clay bins, and impressions of baskets (Margomenou 2008: 200). Comparative analysis of vessel types and other objects found in the same storage suggested that smaller containers were related to cooking activities and short-term storage. Pithos containers were mainly used for storing goods in a more stable, long-term manner, but they could also be related to craft activities such as weaving, spinning, stone knapping, and processing of skins instead of keeping food (Margomenou 2008: 205). It is not possible to define whether there were distinct types of storages used more communally by the people living in hamlets or villages, or if storages were meant to kept goods for one year (as usually estimated) or perhaps a shorter or longer period of time.

A storage space discovered at the LBA site of Assiros Toumba in northern Greece is one of the few spaces where volume has been estimated. This storage complex consisted of multiple rooms and had a minimum capacity of 4000-5000 litres (two rooms exclusively used for storing goods). Such volume could have supported *c*. 20 people for a year. This space was not a household storage, nor was it a communal storage, since the population of the site was larger (Jones *et al*. 1986: 98–99). Jones and others (1986: 98–99) describe this storage type as exceptionally large compared to the other contemporaneous storages recovered in the area.

Another well-investigated LBA storage was recovered in Akrotiri on the island of Thera (Santorini). The West House, to which this complex belonged, was recovered in what seemed to be a wealthy part of the settlement (Sarpaki 1987: 110). The house had three floors, and it could have housed 8-14 inhabitants, although Sarpaki (1987: 117) suggests it was occupied by one nuclear family (5-6 people) only. The storage in Akrotiri had a minimum capacity of 3300 litres (based on the volumes of large pithoi recovered in the storerooms) (Sarpaki 1987: 225). With the same food consumption ratio as at Assiros (see above), this storage could have supported 13-17 people for a year. According to Sarpaki (1987: 223-224), the storage spaces at Akrotiri show no implications of communal storage systems, but that each house unit included its own storage units.

In relation to the Assiros storage, Jones *et al*. (1986: 101-102) suggest that individual families stored food in their own dwellings but kept some bulk goods additionally in a communal storage as a security measure. According to them (1986: 101-102), such a storage management system could reflect a system of redistribution, in which a central settlement would collect subsistence products which it would offer to the people in times of trouble, or in exchange for services. In the Chania context, Palaiologou (2015: 73) has suggested that the larger storage complex here could have been used to keep products which were waiting to be transferred to the palatial storages of Mycenae. Assiros was not a palace, but possibly a regional centre (Jones *et al*. 1986). However, another LBA regional centre in the same area, Thessaloniki Toumba, did not have a communal storage, only smaller storage spaces dispersed over several buildings (Margomenou 2008: 194). Furthermore, according to Margomenou (2008: 216), the clustered

Assiros storage was only used in the early LBA, and towards the end of the period the Assiros storage spaces were as dispersed as in other locations. This suggests that communal storage spaces were not typical, even for LBA regional centres and does not fit the idea of a redistributive system. These examples are, however, more reflective of the social and political organization of northern Greece at the time and cannot be directly compared with the Mycenaean areas in the south.

The ways in which goods were kept in storages appear quite similar in each of the example cases. Sarpaki (1987: 223-224) has noted that the storage rooms may have had their own specific functions, potentially related to long-term and short-term keeping of goods, cooking activities, or to the type of goods stored. For example, liquids were potentially kept in a separate place. Similar notions have been put forth in relation to the Chania storage (above). The Assiros storage has yielded the most detailed analysis of storage strategies. It held grain, which was mostly recovered in pure samples. It is likely that different crop species were stored in different ways: bread wheat, which needed less processing, was stored cleaned and ready to be cooked, while the glume wheats that have to be processed were stored without removing the protective spikelets. This would have helped to prevent damage caused by insects and fungi (Jones *et al.* 1986: 100-101). At Akrotiri, different crops were often kept in different rooms, for example, most pulses were kept together in their own space, but lentils were placed in another room (Sarpaki 1987: 218).

Evidence of exceptionally large LBA storage facilities in the Argive Plain derives mainly from Mycenae, where a large house complex was excavated in the vicinity of the Lion Gate (published by Iakovidis 2006). The complex was named a granary, after the charred grain seeds of grain and plant remains found in large jars stored in its basement. While scholars in favour of the redistributive economic theory have interpreted this complex as the 'central storage' of Mycenae, it likely had other functions (Iakovidis 1983: 42). Nevertheless, Privitera (2014: 444 citing Iakovidis 2006) interpreted the complex as a grain silo, and estimated the capacity of this potential storage complex as at least 700,000 litres. Such a large capacity could support some 2800-3500 people for a year, with 200kg grain consumption per person (but see pp.150-166 for the re-estimated consumption in LH III). Thus, comparing this volume to the estimated population numbers for Mycenae (max. 6400, see pp.36-38), it seems that the grain silo was not large enough to support a sizeable portion of the population of the citadel. If used for storing food, it could have supported palatial workers such as craftsmen and -women, or military personnel, for example.

In Midea, the area of the West Gate on the acropolis has been described as a craft and storage space. Demakopoulou (1995: 157) suggests, based on archaeobotanical samples recovered from the floor deposits, that the people living in this area of the settlement were guarding not only the gate, but also a larger storage space. The capacity of this storage was, however, not estimated, and the area in which it was located appears minor compared to the size of the settlement. The use of the storage space was likely multifunctional (Sjöberg 2004: 77).

In Tiryns, multiple rooms attached to a defence wall were added in the Upper Citadel area in LH IIIB2. It has been suggested that these rooms could have been used as a larger central storage (Maran 2009: 248; Shelmerdine 2008b: 122–24). However, Sjöberg (2004: 77) has argued that the capacity of these galleries would have been limited considering the high population of the settlement (see pp.36-38). Thus, the presence of a larger storage space in Tiryns remains unverified.

As a comparison, the presence of large storage spaces is more pronounced in the pre-Palatial and Palatial Crete (LM IA-B). For example, the Magazines of Knossos included 18 storage rooms grouped along a single corridor. They had an estimated capacity of 231,000 litres (Christakis 2004: 300) and could, thus, support less than 1200 people. Even these rooms were not meant to provide goods for all the inhabitants of Knossos. Towards the LM III, the Knossos storage capacity seems to decrease and there is a trend towards the emergence of dispersed local storages located in regional centres.

Based on the data presented above, it seems that the large palatial centres of the LH III Argive Plain did not possess large enough storage capacity to fully support the population of the plain, or even the populations of the settlements themselves. Nonetheless, estimates of storage volumes can be biased, because they can only evaluate the volumes of ceramic and stone storage containers. Grain and other crops were likely also kept in perishable containers, as demonstrated by the fragments of cloth fibres referring to a sack containing barley grain recovered in the LBA Akrotiri, Thera (Spantidaki and Moulherat 2012: 188). Nevertheless, smaller Mycenaean communities had either dispersed, individual storage spaces, or larger storages to support some 15-20 people for a year (e.g. Sarpaki 1987). In the calculations of the agricultural potential the total yield is assumed to sustain a population for one full year, and additional surplus production or stock put away for two years are not considered, due to the uncertainties related to the Mycenaean storage data.

Potential trade of agricultural products

The mainland Mycenaean settlements, including many of those located in the Argive Plain, participated actively in Mediterranean trade. Detailed examinations of these transactions are beyond the scope of this study, but a few aspects of the trade related to the study area might have potential implications for local agricultural practices. Furthermore, examination of trade connections between the Argive Plain and the Eastern Mediterranean reflects the independent role various sites were able to take in trade activities. This section examines trade, with the aim of shedding light on whether some foodstuffs could have been imported instead of produced in the Argive Plain itself, and whether this had an effect on the agricultural potential and self-sustainability of the area.

In the LBA, the Aegean settlements were connected to the Eastern, Central and Western Mediterranean through maritime trade (Burns 2012: 291). Based on the material evidence deriving from LBA shipwrecks, settlements, and burials, trade appears to have focused mostly on raw materials and luxury goods, which were not available regionally (Burns 2012: 291; Cline 1994: 95–96). However, organic goods such as foodstuffs are easily perishable materials, which is why their large-scale exchange may remain mostly unidentified in the archaeological material (Knapp 1991: 21). Recent study by Meiri and co-auhors (2019) has shown that domestic pigs were transported or exchanged across the LBA Mediterranean. This could relate to the mobility of the LBA populations, who were possibly migrating from one location to another, bringing with them subsistence goods such as seeds and animals. It could also suggest that more mundane exchanges of agricultural products occurred in the LBA Mediterranean.

Evidence of the containers used to carry trade items indicates that the most common trade items were liquids, such as wine, oil and unguents (sentenced oils), spices, metals (e.g. gold, copper, tin), textiles and dyes, timber, and precious objects. Additionally, ceramic vessels and luxury tableware were exchanged across the LBA Mediterranean (Burns 2012: 291; Cline 1994: 95-96;). It would be tempting to assume that grain was also traded, but the absence of material or textual evidence for grain exchange prevent further interpretations. Some organic finds have been recovered in the LBA UluBurun shipwreck. The finds include olive stones, pomegranate, grape and fig seeds, and spices and herbs such as coriander and safflower, but not grain (Pulak 1998: 210).

Transport container types provide an idea of the products that were commonly transported (Knapp 1991: 22–23). A common container type was the so-called Canaanite jar, an amphora of Near Eastern origins. These were used to transport various goods, including wine, oil and glass beads, but, according to Cline (1994: 95), likely also grain. These jars have been found at LH III Argive Plain sites such as Mycenae, often in burial contexts. This suggests that the containers themselves were also valued (Cline 1994: 96). Many of these containers have yielded traces of pistachio or other type of pine resin. This has been interpreted as evidence for wine transport. Pine resin could have been used either to seal the container, or to spice-up the wine as in 'retsina' (Knapp 1991: 28).

Another common container was the Transport Stirrup Jar, a round vessel with two handles attached to a false neck and an additional spout. These vessels were exclusively used to transport liquids. Their origins appear to have been in the Aegean, and since many of them were painted with Linear B inscriptions, a relation with the Aegean palatial elites has been suggested. Analysis of the Stirrup Jars found at Tiryns has revealed a close connection between the settlement and Cretan settlements (Ayia Triada, Kommos, Phaistos and Chania) (Kardamaki *et al.* 2016: 146). Similarly, the recovery of trade items at Mycenae suggests intimate relations with Egypt (Cline 1994: 86-87). Objects found at Asine, Midea and Nafplion further suggest that many, if not all, notable Argive Plain settlements were engaged in maritime trade (Cline 1994: 86-87). Such contacts could be seen as indications of the independent participation of these sites in foreign trade, and through that, the acquisition of valuable materials which were important in the competition for power in the LBA core areas. For the Argolid, Voutsaki 2010) has suggested that the leading settlement, Mycenae, was able to permit a level of trade partnerships for the other major settlements of the area, with the purpose of keeping them as close allies and dependants (see also the discussion on pp.31-36).

Ceramics with Aegean origin found across the Mediterranean suggests that these were the items manufactured for export purposes in the mainland Mycenaean regions and the Aegean islands. Textiles could have been other commonly exchanged products (Burns 2012: 297; van Wijngaarden 2002). Linear B tablets have indicated that textile and unguent industries were present at Pylos, but do not clarify whether these products were manufactured specifically for trade (Sarpaki 2001a). In the Argive Plain, some fragmentary records point to wool industry being practiced at Mycenae, and the pottery workshop at Mastos in the Berbati Valley produced ceramics which have been recovered on Cyprus and the Levant (van Wijngaarden 2002; also see p. 29 for site descriptions). Wool textiles and ceramics could have been among major exchange items from the Argive Plain settlements.

Textual evidence from other locations in the Eastern Mediterranean (e.g. Egypt, Assyria) implies a great interest towards unguents and a variety of oils. Perfume industries appear to have been important at Mycenae, as indicated by the names of herbs and spices commonly used to make perfumed oils in the Linear B texts (e.g. Sarpaki 2001a). Knapp (1991) has gathered textual evidence for the exchange of organic materials in the LBA Eastern Mediterranean. According to these (texts of non-Mycenaean origin), grain and cereal exchange took place across the Eastern Mediterranean on rare occasions, for example when states were suffering from famine. As an example, in a fragment from Ugarit, a merchant was given a duty-free status on grain, fermented drink, and oil which he was importing from Crete (Knapp 1991: 37).

In the absence of secure evidence for regular exchange of subsistence-related items such as grain between the Argive Plain settlements and destinations abroad, it has to be assumed that Mycenaean trade focused on luxury items. Thus, the Mycenaean regions remained mostly self-sufficient. However, in the final calculations of the agricultural potential, it is worth considering whether the Argive Plain was able to produce so enough stock of products as olive oil that they could be exported.

Summary: material evidence of Mycenaean agricultural practices

Indications of Mycenaean agricultural activities remain rather scarce in material evidence. It is likely that most tools and special activity sites such as crop-processing areas were made with materials and techniques which were not able to last generations. However, interestingly, bronze as a material used to make sickles and other tools increased towards the LH III period (Blackwell 2011; Sarpaki 1987), leaving us with scarce material record of the type of agricultural tools used at the end of the LBA. Distributing or lending such tools of higher value could have been a way for the palace to create dependency relationships with local communities.

The use of sickles in itself refers to the laborious task of harvesting crops by hand, and likely leaving some length of stubble in the fields, perhaps to be consumed by pasturing animals. Possible evidence of threshing sledges suggests that animals were used in many phases of the agricultural year, again with the opportunity for the palaces to strengthen their relations with the local communities by lending animal power. For the Mycenaeans, the use of the sledge would have required access to the power of large domestic animals such as cows, oxen, donkeys or horses. This may have not been possible for a subsistence farmer. Animals such as oxen could have been rented from wealthier owners such as the Mycenaean palaces, for tillage and other activities (pp.8-10 and pp.111-112).

If confirmed, the threshing floor with a Mycenaean date in Kalamianos (Pullen 2019a) would indicate that crop processing took place near cultivated fields, at least in terrace contexts. It could also indicate that terraced slopes were cultivated with cereals or legumes which required threshing and other type of cleaning after being collected. Adding this to the evidence of manured terraces (see pp.71-72), this could imply the use of terraces solely for cereal or legume cultivation, or mixed cropping of trees and cereals.

Evidence of trade items emphasizes mainly the independent status of various Argive Plain settlements, but there is not enough evidence to confirm whether any of the Argive Plain settlements (except, perhaps, for the pottery production site of Mastos, see van Wijngaarden 2002) were specialized in exporting specific products, or if export was conducted on a notable scale. Similarly, while the import of luxury items and precious raw materials is well evidenced (Burns 2012; Cline 1994), it cannot be confirmed whether bulk goods such as olive oil, wine or grain were brought to the Argive Plain from outside. At this point, the region can be considered as mostly self-sustained. The following two sections examine the agricultural production of the region through the remains of crop plants and domestic animals recovered from the LH III Argive Plain contexts.

Vegetation and food crops of the Late Bronze Age Argive Plain

This section presents an overview of the archaeobotanical finds collected at the LBA sites in the Argive Plain and its close environs and compares these assemblages to finds elsewhere in the Peloponnese and mainland Greece. The finds mainly consist of pollen records and charred seed remains. Among these, pollen is used to make observations about the prevailing characteristics of the LBA vegetation in the Argolid (pp.86-90), while charred seed remains are treated as indicators of locally cultivated and consumed plants (pp.90-100). These data are used in Chapter 6 to reconstruct the LBA diet in the Argive Plain, and to observe the LBA food production methods in order to estimate the local agricultural potential.

Archaeobotanical finds can be divided into two categories: macro- and microbotanical remains. The study of plant macrofossils includes remains such as wood, seeds and fruits visible to the naked eye. Plant microfossils, such as pollen grains and spores, are only visible through a microscope (Lowe and Walker 1997: 162–82). Macroremains, are commonly used for reconstructions of human dietary and agricultural practices. They are often found at archaeological sites in contexts which suggest human plant use (Livarda 2014: 108; Valamoti 2004: 51). While (charred) macroremains preserve well in various depositional environments (Lowe and Walker 1997: 182–85), pollen preserve best in waterlogged conditions. Therefore, the latter are regularly collected from lake, river or swamp environments. Pollen grains and spores can travel long distances by wind or water, and are, therefore, suitable for more general environmental reconstructions. Fluctuation in the pollen counts can in some cases inform about past climatic conditions or land use (Valamoti 2004: 54). Due to the varying characteristics of these two macrofossil types, an overview the LBA Argive Plain macrofossil evidence is presented in two distinct subsections. Of these, the first section (pp.86-90) introduces pollen evidence and compares them to the information received from palaeoclimatic studies, and the second (pp.90-100) focuses on macroremains. The Argive Plain find sites, as well as the locations of the comparative datasets mentioned in the text are presented in Figure 5.10.

Microbotanical evidence

The following section examines the pollen data available from the Argive Plain, and compares these to data received from other Mycenaean contexts. Pollen analysis can shed light on the nature of vegetation of the LBA Argive Plain landscape. Depending on its abundance, tree pollen, for example, can be used to

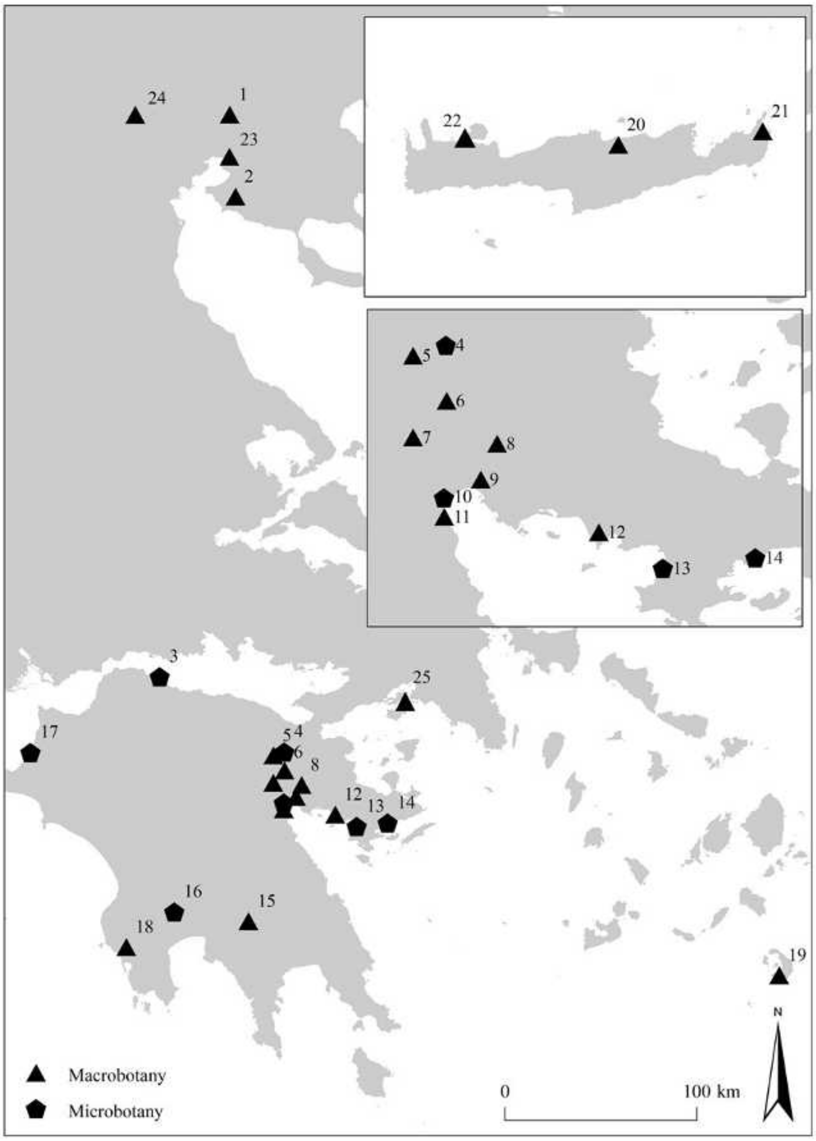

Figure 5.10. Locations of the sources of the micro- and macrobotanical data mentioned in the text. The sites in order are 1) Assiros Toumba, 2) Mesimeriani Toumba, 3) Aliki, 4) Kleonai, 5) Tsoungiza, 6) Mycenae, 7) Synoro, 8) Midea, 9) Tiryns, 10) Lake Lerna, 11) Lerna, 12) Iria, 13) Koiladha bay, 14) Limni Thermisia, 15) Kouphovouno, 16) Agios Phloros, 17) Kotihi lagoon, 18) Pylos, 19) Akrotiri, Thera, 20) Knossos, Crete, 21) Palaikastro, Crete, 22) Chania, Crete, 23) Thessaloniki Toumba, and 24) Archontiko, 25) Salamis.

investigate from the potential cultivation of olive and vine. Such data enables firmer evaluations of the Argive Plain land use.

Pollen are essential for the fertilisation of trees, weeds and grasses. They preserve well in anaerobic conditions like lake sediments, but can also be found in soils, or cave and deep-sea sediments (Lowe and Walker 1997: 164-65). To ensure successful pollination, pollen spores are usually spread across the environment in large numbers.[11] Therefore, counting the number of pollen spores in a microbotanical sample can help to determine the presence, and sometimes abundance, of plant species in past environments. However, different plant species produce variable amounts of pollen, which can result in over- and under-representation of pollen in a sample (Lowe and Walker 1997: 165-69). In southern mainland Greece, further interpretational biases are by dry climatic conditions which obstruct pollen preservation (Jahns 1993: 187, 2003: 127). After being spread in the air, pollen can travel relatively long distances (several kilometres) along river flows or wind, making them a dubious indicator of vegetation in very small and limited areas such as dwelling sites. Nevertheless, due to their ability to travel, pollen are useful for reconstructing wider regional vegetation (Lowe and Walker 1997: 170-73).

The pollen data discussed here derive from sites located in the Peloponnese. The most relevant data are received from cores taken from Lake Lerna (Figure 5.10) in the south-western Argive Plain (Jahns 1993). Other geographically close data are retrieved from Kleonai just beyond the northern borders of the Argive Plain (Atherden *et al.* 1993); and Kiladha Bay (Bottema 1990), and Limni Thermisia (Sheehan 1979) in the Southern Argolid. The common tree and maquis types present at these sites are listed in Appendix 5. In each of the studies, pollen counts have been calibrated by comparing them with modern surface samples. Pollen samples taken from surface soils can be compared to the pollen recovered in past contexts to detect potential over- or underrepresentation of species in the samples, and to recognize intrusion of modern specimen in the excavated material (Pearsall 2016: 213).

The following section presents the dating of samples similarly to the source studies (most often marked as yrs BP). Translation to BCE is made by the author. Since pollen can usually be recognized down to genus but not to species level, the common name of the most probable species (typical for the Mediterranean and Greece) is given, but the Latin genus is indicated as it is presented in the publications.

The Argive Plain pollen data

A pollen core was taken from the dried lake of Lerna in 1987. In the analysis (Jahns 1993), the LBA is included in the Subzone IIIa, extending approximately from the late Neolithic to the beginning of the Archaic period.[12] Concurrently, a comparable pollen analysis was conducted in the nearby Kleonai (Atherden *et al.* 1993), where likewise the entire Bronze Age is in one vegetation zone.[13] Two cores taken in the Southern Argolid show similar chronological division into subzones.[14] Because of the division into chronologically long periods (the length of the Bronze Age is roughly 2000 years), changes in vegetation cannot be easily connected to the societal changes of the LBA. The changes in the amount of pollen, and thus in the amount of different plant species, must, therefore, be observed as long-term, general changes in vegetation in the Argolid area. These slow changes in species representation can be, however, seen as signs of increasing human influence on the environment, or as potential changes in climate.

Of the tree taxa, the dominant species in the Bronze Age Lerna, Kleonai and Limni Thermisia were pine[15] (*Pinus*), olive (*Olea*), and deciduous oak[16] (*Quercus pubences* type) Although abundant, pine decreases throughout the period. Towards the LBA and Archaic periods, deciduous oak increases in all samples. It is a tree which colonises open areas and could indicate clearing of forested mountain slopes (Atherden *et al.* 1993: 354; Jahns 1993: 192–94; Sheehan 1979: 29).

Evergreen oak (*Quercus ilex*) is one of the dominant species in the Neolithic - EBA part of the Limni Thermisia core, but it decreases in the LBA (Sheehan 1979: 29). The pollen of the evergreen trees (including pine) has presumably travelled down to the plain from longer distances and higher altitudes (Jahns 1993: 192-94). This suggests that although slowly decreasing, evergreen woodlands were still present in the mountains surrounding the Argive Plain and its side valleys. In Kleonai, pine and evergreen fir (*Abies*) pollen

[11] Pollination is the transmission of pollen between male and female plants or plant parts in order to produce fertilization.

[12] Zone III beginning in 4720 ± 140 B.P. and subzone IIIb beginning in 2960 (interpolated) B.P. According to Jahns (1993) this indicates a period from 3600 cal B.C. to 800 cal B.C (i.e. Final Neolithic-Geometric).

[13] The time period expands from 3820 ± 50 PB to 3345 ± 70 PB (*c.* 1870 ± 50 BCE-1395 ± 70 BCE). The next period is undated but estimated to begin in *c.* 1295 BCE (i.e. LH IIIB) and expanding until the Hellenistic period (Atherden *et al.* 1993: 355, Table 3).

[14] The Kiladha bay core is divided into Zones I and II, of which Zone I covers a period from the Middle Neolithic to the end of the Bronze Age (*c.* 6700-3200 B.P.), and Zone II the time right after the LH III (*c.* 3200 B.P. onwards) period. The Late Bronze Age is placed roughly at the change of Zones I and II (Bottema 1990: 127). The Zone 4 (depth 444-257cm) of the Limni Thermisia core has been dated to approximately 2610-860 B.C. (3900-2700 B.P.) (Sheehan 1979: 26), which covers periods from EH IIIA to the Geometric.

[15] Atherden *et al.* (1993) assumes the species is the Aleppo pine (*Pinus halepensis).*

[16] Deciduous trees shed their leaves annually, as opposed to coniferous (i.e. evergreen) species.

actually increase throughout the Bronze Age. This could indicate that there was less need for the clearing of forests for agricultural use. The influence of human activities on the woodlands appears to be proven by the drastic increase of tree taxa soon after the BA/IA (Iron Age) shift, simultaneously with a dramatic decline in population numbers (Bottema 1990: 125).

Olive is nearly absent in the Neolithic - BA samples of Kiladha (Bottema 1990: 125), but it increases drastically after the LBA. This indicates that olive cultivation was established in the areas probably at the very end of the BA (Bottema 1990, 125-26). The high amount of olive in the Lerna and Kleonai samples suggests it was actively cultivated in the Argive Plain sometime during the Bronze Age (Atherden *et al.* 1993: 355; Jahns 1993: 197). According to the Thermisia samples, however, olive crops were more abundant during the earlier part of the Bronze Age, and relatively less so towards the Bronze Age - Iron Age shift (Sheehan 1979: 29). This variation could perhaps be explained by regional differences in olive cultivation, or by the potential decline of wild olive growth in the region.

Kermes oak, (*Quercus coccifera*), heath (*Erica*), mock privet (*Phillyrea*), rock rose (*Cistaceae*), strawberry tree (*Arbutus*), hornbeam (*Carpinus orientalis/Ostrya*) and pistachio (*Pistachia*), are typical species of the Greek shrub vegetation, maquis, and are well presented in all of the samples (Atherden *et al.* 1993: 353; Bottema 1990: 123; Jahns 1993: 197; Sheehan 1979: 32–33). The spread of maquis can indicate the clearing of dense woodlands and increased land use for cultivation and pastoral purposes (Atherden *et al.* 1993: 356). Farming in the nearby landscapes is further indicated by the presence of various grasses and flowering plants typical for cultivated fields and pastures (e.g. *Asteroideae*, *Liguliflorae*, *Cruciferae*, *Umbelliferae* and *Chenopodiaceae*) (Atherden *et al.* 1993: 355; Bottema 1990: 123; Jahns 1993: 197; Sheehan 1979: 46). The cutting of woodland from the surrounding mountainous slopes, indicated as a decrease in evergreen tree species could indicate the creation of terraced fields. Nevertheless, the presence of maquis seems to suggest that the previously cleared areas were left to fill out with bushy vegetation, thus, they were not in regular or intensive use at least all the time. However, the chronological scale of the sample does not allow a more detailed analysis. Of other plants, the Limni Thermisia shows small amounts of *Leguminosae* and *Gramineae* families, which include leguminous plants and cereal grasses (Sheehan 1979: 69, table 9b). However, the amounts, and the identification only on family-level do not enable interpretations of the cultivation of cereal and legume crops in the region. *Cerealia*-[17]type of pollen is usually not present in assemblages in substantial amounts, even if cereal cultivation took place in the vicinity. However, the Zone I (*c.* MN-LH IIIB) of the Kiladha Bay core shows higher than usual values for *Cerealia,* strongly emphasizing the amounts of cereal growing in the region already in the Neolithic (Bottema 1990: 123-24). Likewise, the pollen diagram of Nemea Valley shows a notable presence of *Gramineae* pollen in the Bronze Age, suggesting the expansion of cultivation in the area. Small amounts of *Leguminosae* are also present (Atherden *et al.* 1993: 354-55). *Vitis* (vine) is commonly under-represented in pollen samples (Atherden *et al.* 1993: 354-55), and therefore it is no surprise that it is not present in any of the forementioned cores. This does not rule out the possibility of vine cultivation in the area.

Comparative data

Pollen data of the Bronze Age vegetation in other areas in the western and southern Peloponnese (sites listed in Figure 5.10) generally fit with the results of the Argolid. Mixed oak forests with evergreen and deciduous oak, hornbeam and plantain are common in almost all sites. However, the majority of sites, Kotihi (Lazarova *et al.* 2012: 144), Osmanaga (Wright Jr. 1972: 193-95), Agios Phloros[18] (Papazisimou *et al.* 2005: 667), and Lake Lerna, (although only compared to the previous zone dating to the FN) (Jahns 1993: 197), show a decrease of the evergreen forests towards the end of the LBA. This decrease is often accompanied by the increase of maquis species, indicating more open land was available, and that clearing of forests for agricultural purposes likely took place. The notable increase of evergreen oak in Kiladha right after the LBA (Bottema 1990: 125), could indicate the abandonment of the area by people and their cattle after the ‘collapse’ of the palatial society, and the return into a forestry landscape (Zangger *et al.* 1997: 593). The continuous prominent levels of oak trees combined with the low values of maquis plants in Bronze Age-Geometric Aliki could indicate that human activities did not play a significant role in shaping the landscape around that site (Kontopoulos and Avramidis 2003: 85).

All the present oak species prefer warm climates and relatively dry soils (Ellenberg 1979: 90; Polunin and Huxley 1965: 55). However, there is no clear evidence of the general decrease of the tree-type being related to a climatic change from warmer to colder environments, and only some suggestions of it being related to a change from drier conditions into more humid (Bottema 1990: 135, and above). Data of modern Mediterranean oak forests indicate a close relationship with pine, which prefers even drier soil conditions than the oaks: when the annual rainfall is below 400-450mm, a natural

[17] *Cerealia* includes namely cultivated grasses, while *Gramineae* refers to a large family of grasses.

[18] Although not dated, tree-types decrease towards the zone following the Early Bronze Age.

pruning of the mixed woodlands occurs, and the amount of pine and shrubs increase (Terradas 1999: 10). A reversed type of woodland behaviour occurred at Kiladha and Osmanaga during the shift from the Bronze Age to the Iron Age (see below), suggesting, that the rainfall must have remained above 400mm.

Pines practically disappeared from Osmanaga after 1600 BC (Zangger *et al.* 1997: 593). Also, in Aliki the species decreased rapidly during the Bronze Age and shows low values in the Geometric period. Elsewhere pined mostly dominated the pollen throughout the Bronze Age. Pine trees prefer very dry and calcareous environments with nitrogen-poor soils. The disappearance of pine trees from the Osmanaga region is more likely to have been caused by anthropogenic factors than by a climate change from dry conditions to more humid conditions. There are some suggestions that such a change took place around 1200 BC (3200 BP). This is based on the appearance of new species such as plane tree (*Platanus*) and walnut (*Juglans*) (Bottema 1990: 135); however, both are also known to have been introduced to the landscape intentionally by people (Atherden *et al.* 1993: 354).

Other common tree species in the Bronze Age Peloponnesian landscape were alder (*Alnus*), fir (*Abies*), elm (*Ulmus*) and *Tilia*. They are all tree-types which require a good supply of water and prefer higher altitudes and mountainous areas (Bottema 1990: 123-25; Earle 2017), with fir preferring altitudes above 800m above sea level (Polunin and Huxley 1965: 54). The presence of the nut-producing tree-types, such as pistachio (*Pistachia*), chestnut (*Castanea*), hazel (*Corylus*), and walnut (*Juglans*) are interesting, considering that their fruit might have been used for human or animal consumption. Plantain (*Platago lanceolata*), present in most of the samples of the Peloponnese, belongs to the variety of anthropogenic indicators and is specifically related to grazing (Bottema and Woldring 1990: 236).

In summary, the pollen evidence suggests that the evergreen woodlands were actively being cleared during the Bronze Age in the Peloponnese, including the Argive Plain, possibly due to increasing land use for agricultural purposes (Atherden *et al.* 1993; Jahns 1993; Sheehan 1979). The notable increase of maquis species, as well as the tree species requiring mountain slopes and higher altitudes for growing could suggest that slopes were left to grow bushy vegetation at least at times, perhaps because their main use was pastoral. Shrublands and leafy, low woodlands covered the landscape around the Argive Plain, as well as most of the sloping hills in the Peloponnese (Atherden *et al.* 1993; Jahns 1993; Sheehan 1979). Thus, the landscape was notably less bare than today.

Macrobotanical evidence

Knowledge of the find context of the remains is crucial in interpreting how and by whom the plants were used. Fruits, seeds, and wood remains found at human occupation sites can reveal various details of the activities of the specific community in question (Vetters *et al.* 2016). In most cases, macrobotanical remains are charred, which means they have been exposed to fire (Vetters *et al.* 2016: 95). Charring might be the result of food preparation, or be caused by other types of crafting, building or farming activities which required the use of fire (Valamoti 2004: 51; Vetters *et al.* 2016). Not all plants are likely to be exposed to fire, however. Fruit and vegetables, for example, are often consumed fresh. Furthermore, only certain species remain recognizable after fire exposure (Valamoti 2004: 52). This over- and under-representation of plant types and species due to recovery biases can influence interpretations of macro-remains.

Charred seeds found in settlement contexts can also be informative about fuel use instead of human food. Over the past decades, a debate over the ways in which charred plant remains are deposited in archaeological contexts has occurred. This debate originated within Near Eastern archaeology, since it was noted that in this area, where the transportation of macro-remains to habitation sites often took place through dung cakes (Miller 1984). In dry areas, dung has traditionally been the main source of fuel due to the scarcity of wood. Dung of domesticated animals was systematically collected and used as fuel (Wallace and Charles 2013: 18-19). For the Greek Bronze Age, the use of dung fuel remains debated. If the botanical finds presented here mainly derived from animal dung used as fuel, it would imply that these plants tell us more about animal diet rather than that of people. Thus, they would have ended up in the animal digestion system when they grazed on harvested stubble fields or even at natural pasture sites, or these plants were grown and intentionally fed to them as fodder. Fodder plants have commonly been considered as lower status food, used in human diets mainly in times of famine (Valamoti and Charles 2005). If this was the case for the LBA Argive Plain, reconstructing the local diet would become much more complicated. This question is considered further in the discussion (pp.100-103), where the botanical finds and their recovery contexts are further examined.

The following section has three objectives: 1) to provide an overview of the main plant species that were present in the LBA Argive plain; 2) to present data on the conditions these plants were growing in; and 3) to collect information about the ways these plants could have been used for food. These data are used to construct a dietary model for the Late Bronze Age Argive Plain. They will also provide information about past climatic and soil conditions, crop productivity, and land use and vegetation patterns that can be used in the reconstruction of the Argive Plain agricultural potential. The recovered plant remains in all Argive Plain sites are compiled in Appendix 4.

Find locations and contexts

Published data on macrobotanical remains are available from six Bronze Age sites in the Argive Plain region. The finds of Tiryns (Kroll 1982), Midea (Shay *et al.* 1998) and Mycenae (Hillman 2011; Tournavitou 1995) have been dated to the LH IIIB, while Tsoungiza (Allen and Forste 2020; Hansen and Allen 2011) provides a diachronic overview of human plant use from the late Neolithic to the Late Helladic IIIC. The Lerna finds (Hopf 1961) mainly date to the Early and Middle Helladic periods. The LH III settlements of Iria and Synoro in the vicinity of Tiryns have yielded very few botanical remains (Willerding 1973).

In Tiryns, the sampling took place in the 'rooms' inside the walled citadel (Upper Town). Locations with charcoal remains were picked when possible. The soil samples were water sieved with a 0.2mm mesh, which was effective in retrieving a large variety of species. Kroll (1982: 467) notes, that the plant remains are few compared to other Bronze Age settlements in northern Greece. He postulates that this is because the palatial rooms were used for specialized activities, whereas food processing and storage took place elsewhere. Furthermore, he argues that regular cleaning and effective waste disposal of the housing quarters impeded the preservation of organic residues. Nevertheless, a wide variety of plant remains, including cereals and legumes, fruits, and wild species were recovered at Tiryns (Kroll 1982: 467). A more recent investigation of the LBA ovens and ash deposits in rooms in the Lower Citadel north yielded more charred seeds, and a variety (ten different species) of charred wood remains. (Vetters *et al.* 2016: 107). The samples consisted of hand-collected charred macroremains and sediment samples which were either water sieved or processed by flotation.

In Midea, the majority of the archaeobotanical remains were retrieved from the LH IIIB and C destruction debris and floor deposits inside the walled citadel. The remains were both hand-collected charred seeds, and sediment samples which were processed by air flotation machine (Shay *et al.* 1998). 59 percent of the collection was comprised by legumes, which included species such as grass pea, bitter vetch, and common vetch considered toxic if consumed uncarefully. Wild species comprised only about 1.5 percent of the charred remains, but were considerably more numerous among the uncharred botanical finds. The latter were, however, considered intrusive, reflecting only the modern species variety around the site (Shay *et al.* 1998). The small number of charred seeds of wild species likely indicates that cereal and legume crops were cleaned before they were transported and stored in the citadel (Shay *et al.* 1998).

The Mycenae archaeobotanical finds come from two locations, the House of Sphinxes and the West House located outside the citadel walls (Tournavitou 1995), and the so-called Granary located inside the citadel near its main entrance, the Lion Gate (Hillman 2011). The House of Sphinxes and the West House belong to a complex of houses (the Ivory Houses/The House of Oil Merchant complex/West House complex) which were likely used for multiple purposes such as living, storage and commerce (French 2002: 67-68). The House of Sphinxes material derives from a burned destruction layer (Room 8), while the West House remains were recovered in the same room (4) with a hearth inside a storage vessel (FS 58 in Room 4). Although not directly stated, it is implied that the remains were hand-collected. Tournavitou (1995: 278-79) suggests that both contexts indicate the use of the seeds for cooking purposes.

The botanical remains of the Granary at Mycenae were recovered in the 1920s and stored in local museums until the 1970s when they were studied by Gordon Hillman. His report from 1974 was not published until 2011 as a fascicule in the *Well Built Mycenae* -series. Because of the long timespan between the recovery, examination, and publication, some contextual information on the collection has been lost (see editor E. French's comment in Hillman 2011: 730). Nevertheless, the assemblage can be studied for the presence and absence of species.

The Granary Botanical remains were recovered as three main samples connected with respective storage jars. The function of the Granary building itself has been related to centralized storage, and to guard duties (due to its location by the main gate). The containers were recovered in the refuse deposits of a collapsed first floor dated to the post-palatial (LH IIIC) period (Hillman 2011: 748-750). The grain and seed content of the containers was partially mixed with the floor deposits. Of the three samples, sample 1 represents the bulkiest collection and the largest variety of taxon, including grain seeds and by-products, bitter vetch, other legumes and fruits but hardly any weeds. Sample 2 is dominated by barley grains and bitter vetch but also includes a large number of weed seeds. Sample 3 has the lowest number of remains with its 15 barley grains, two olive pips, and some bitter vetch seeds (Hillman 2011: 769-776). Hillman (2011: 769-776) contributes the clean character of the 'wheat sample' (sample 1) and 'barley sample' (sample 3) to harvesting and crop processing methods, thus grain was cleaned before it was stored.

The Lerna find contexts and retrieval methods are, unfortunately, not described in detail. As with the other sites, however, the Lerna archaeobotanical assemblage includes mostly charred finds of cereals and legumes from Early to Late Helladic periods. Only a few finds of wild weed seeds are found, and Hopf (1961: 246) notes that their small number is surprising. This could, again, refer to the cleaning of the crops before they entered the site.

At Tsoungiza, vigorous sampling and water-sieving of the excavated sediments resulted in a comprehensive collection of macrobotanical remains. These remains are published in two parts, the Neolithic to Middle Helladic III assemblages by Hansen and Allen (2011), and the Mycenaean collection by Allen and Forste (2020). This study is mainly interested in the Mycenaean collection (MH III to LH IIIC), but the chronologically earlier assemblages are mentioned when relevant. The Mycenaean finds were recovered from floor deposits, exterior debris, and refuse pits (Allen and Forste 2020: 1030). The Neolithic to Middle Helladic finds were retrieved from pits which were likely used for storage or refuse disposal (Hansen and Allen 2011). Some charred plant material were also hand-collected (Allen and Forste 2020: 1029; Hansen and Allen 2011: 806). The Mycenaean finds include common wheat and barley taxa, legumes, and fruits, and, interestingly, the first Late Helladic finds of garlic in Greece (Allen and Forste 2020: 1030). The Early to Middle Helladic botanical assemblages vary significantly between find contexts. While some pits are abundant of crop processing by-products, others include mostly weedy taxa. The latter occasionally comprise over 90 percent of the assemblage (for example in EH I Pit 17) (Hansen and Allen 2011: 845). The Tsoungiza finds were mostly preserved through carbonization, likely in accidental fires (Hansen and Allen 2011: 1054). Fig remains and some weed seeds have preserved through mineralization, suggesting either post-depositional contamination or finds from phosphate-rich contexts such as latrines (Hansen and Allen 2011: 1030-1034). Instead of counting the number of seeds in each chronological context, Allen and Forste (2020: 1059-1060) prefer to present the taxa as percentages of each context in which the species is present. According to them, this allows better observations of diachronic changes in domestic plant use throughout the Mycenaean period. This 'ubiquity value', thus, shows how regularly a species is present in each time period and allows more reliable presentation of the increase or decline of this plant through time.

In summary, the botanical assemblages recovered in the Argive Plain sites include relatively similar representations of plant species. This variety is dominated by cereal and legume crops. In many of the sites, the assemblages appear to be notably clean from wild species such as weeds. This could refer to the cleaning of food crops before they were stored in the settlement. However, retrieval methods vary between the sites, and can, to some extent, contribute to species representational biases. At each find site, botanical remains were recovered within living or commercial quarters, some within debris layers, some within storage containers. The find context seem to suggest the use of these plants for cooking or other domestic purposes.

Cereals

Macrobotanical evidence recovered in the Bronze Age sites in the Argive Plain and elsewhere in the mainland Greece suggests that the Late Bronze Age (mainland) plant cultivation was dominated by four cereal types. Of these, three, emmer, einkorn and bread wheat, are wheat species, and the fourth is (hulled) barley. Cereals have been favoured staple crops through time because they are relatively simple to grow, produce high yields, and contain high levels of carbohydrates which translate into energy in the human nutritional system (Heinrich 2018: 101).

Based on the number of finds, hulled[19] emmer (*Triticum dicoccum*), and hulled barley (*Hordeum vulgare*) were the most common cereal types recovered, and thus presumably regularly used by the inhabitants of LH III Tiryns (Kroll 1982: 468; Vetters *et al.* 2016: 94). Hulled barley was also the most regularly present crop at Late Helladic Tsoungiza (Allen and Forste 2020: 1059). Emmer is present in high numbers (of grain and by-products such as spikelet forks) at the Granary of Mycenae (Hillman 2011: 751, Table C). At the LH IIIC Tsoungiza it is common, but not amongst the two abundant cereals, barley and einkorn, and seems to decline in regularity toward the end of the period (Allen and Forste 2020: 1059). Einkorn (*Triticum monococcum*) exhibits the highest seed counts also in the Early Helladic archaeobotanical sample of Tsoungiza (Hansen and Allen 2011: 863) but declines steadily throughout the Late Helladic. This decline is more generally visible in the Eastern Mediterranean its use seems to decline throughout the Late Bronze Age (Zohary *et al.* 2012).

Bread wheat or free-threshing wheat (*Triticum aestivum/durum*),[20] traditionally considered as one of the crop

[19] Hulled refers to cereal species in which a hard outer layer, the hull or husk, protects the seed. Species which do not contain the hull are referred to as 'naked'.

[20] Bread wheat is sometimes grouped together with 'macaroni' wheat (*Triticum durum*), since both represent free-threshing cereals as opposed to hulled cereal species, and are difficult to recognize from each other in the archaebotanical assemblage (Kroll 2000: 63).

species mention in Linear B texts (e.g. Palmer 1992), is not abundant in the Bronze Age archaeobotanical samples of mainland Greece. It is present at several Early Bronze Age sites in northern Greece but in such low numbers that it could represent an intrusive weed (Valamoti 2002: 5). Bread wheat is also practically absent in the crop assemblage of Tsoungiza from Early to Late Helladic period (Allen and Forste 2020: 1031, Table 15.2; Hansen and Allen 2011: 880–82). In LH III Tiryns (Kroll 1982: 468) and Midea (Shay *et al.* 1998: 320) it is, however, well rpresented. Valamoti (2002: 8, 2009: 27) suggests that the status of wheat as a major crop was not consolidated until the Late Bronze Age. Increasing presence of bread wheat from the Early and Middle Helladic assemblages towards the Late Helladic could also reflect changes in dietary practices (Valamoti 2002: 8), for example towards making bread. Be that as it may, the chaff of bread wheat is more vulnerable to fire than that of einkorn or emmer because of its genetic differences from emmer and einkorn. Unlike the latter, bread wheat does not possess the hard outer layer, husk, which surrounds the grain protecting it from pests, fungi, and other harm (Zohary *et al.* 2012: 47-48). For these reasons, it is possible that it is underrepresented in the LBA archaeobotanical samples.

Besides the four most common cereals, remains of a few other species have been recovered at Late Bronze Age sites in Greek mainland. These are spelt (*Triticum spelta*), broomcorn millet (*Panicum miliaceum*), oat (*Avena sativa*), rye (*Secale cereale)*, and yet-to-be-identified species known as the 'new glume wheat'. Most of them have been recovered more abundantly in northern Greece (Gkotsinas *et al.* 2014; Kroll 2000; Valamoti 2009, 2016). In the southern mainland their representation is limited and it is possible that they were carried to sites as weed contaminants (Kroll 1982: 468; Zohary *et al.* 2012: 69). Due to this uncertainty, here they have been excluded from the final analysis. In addition, besides hulled barley a few scarce finds of naked barley (*Hordeum vulgare var. nudum*) and two-rowed barley (*Hordeum distichum*) have been found in the southern mainland Greece (Hopf 1961: 239-45; Kroll 1982: 468; Allen and Forste 2020: 1029).

Cereal crops underwent a long sequence of processing before they could be consumed. Crop processing included, for example, threshing,[21] winnowing[22] and sieving, as well as dehusking, in which the hard protective glumes around the grain were removed by hand (Kroll 2000: 63; Valamoti 2011a: 22). Besides threshing, bread wheat does not require other types of processing (Vetters *et al.* 2016: 119), and its by-products are 'softer' and easily perishable. Bread wheat can be instantly ground to flour (Kroll 2000: 63), which has been held as one of its most appreciated qualities. Emmer and einkorn finds in northern Greece mainly consist of processing remains rather than grain seeds (Valamoti 2002: 7). In LH III Tiryns, emmer chaff, the debris resulting from dehusking the glume bases, seems to have been used as fuel (Vetters *et al.* 2016: 119). The presence of crop-processing by-products could suggest that their cleaning took place at least partially in the settlement. Kroll (1982: 468) argued that chaff could have been removed right before consumption, as storing grain with its husks attached would have provided better protection against pests and fungi. However, dehusked grain would have required larger storage facilities than cleaned grain. At LH IIIC Tsoungiza, barley and wheat samples are almost completely clean from processing by-products. This means that before they were deposited, grains underwent a second round of threshing which vanquished the last remaining chaff. The purity of the samples could indicate that thorough cleaning of grain crops took place out in the fields (Allen and Forste 2020: 1062). Of the three samples of the Granary at Mycenae, sample 1, abundant with emmer, includes the highest amounts of processing by-products, namely emmer and einkorn spikelet forks which, according to Hillman (2011: 777), can only be removed from the grain by hand-sieving. The sample is notably clean from weed contaminants, which indicates that cleaning of grains took place before they were stored. While sample 3 was also clean from weed contaminants (unless bitter vetch is considered as one, see Hillman 2011: 771), sample 2 included a higher number of weed species. This, however, is more likely due to harvesting methods (pulling the plant by hand off the soil) than a lack of crop-processing (Hillman 2011: 773). The Lerna and Midea assemblages seems to only include whole of full cereal grains and plant seeds. There are no indications of the retrieval or analysis of Bronze Age crop-processing by-products (Hopf 1961; Shay *et al.* 1998).

Besides for cleaning and storing, cereal grains would have further processed for cooking purposes for example by grinding, soaking or boiling. Evidence of the use of these methods can be found amongst the LBA archaeobotanical finds in Greece (Valamoti 2002: 7). In the Bronze Age Mesimeriani Toumba, northern Greece, einkorn seeds were boiled before they were ground to coarse flour (Valamoti 2009: 32). Flour of bread wheat, barley, and pulses has been recovered also in LBA Akrotiri. Of these, barley flour is, perhaps surprisingly, most abundant (Sarpaki 2001b: 32–34). The LBA evidence from northern Greece suggests that

[21] In threshing, the kernels are pounded against a hard surface, such as stone floor, in order to loosen the grain seeds.

[22] In winnowing, air is directed through the threshed grain in order to separate straw and other impurities form the seeds. In traditional agriculture this is usually done by throwing the grain in the air, where the wind blows away the lighter material.

barley was ground and made into lumps with the help of a liquid before storing it.

Different cereal types could have been cooked in similar ways for example by mixing them with a liquid such as water or milk and cooking them into porridge or bulgur-type dishes (Valamoti 2011a: 23–26). While bread wheat was excellent for baked bread due to its high gluten content, all wheat types could be used for this purpose. Barley contains less gluten, which is why it is more difficult to knead into fluffy, well-leavened bread. However, climate and soil nitrogen levels have been noted to affect the gluten content of cereals. Crops growing in manured soils can potentially grow their gluten reserves, and be more efficiently baked into bread as leavening becomes more successful. (Heinrich 2018: 105-106). Thus, it is possible, that in the Late Bronze Age, a variety of cereals were consumed as bread. Nevertheless, Hillman (2011: 754-755) suggests that emmer wheat was superior to be consumed as groats (which could be further cooked soft with a liquid) or even as roasted grain. Recently, Valamoti (2018) has presented the first strong evidence of beer brewing in the Early and Middle Bronze Age Greece. Her study, however, suggest wheat species were preferred over barley in beer making. Hillman (2011: 763) suggests that barley could have been consumed as 'maza', peeled barley pearls, which were well-known in Greece in the Classical period.

The four cereal types have varying growing requirements which may have influenced the LBA cultivation practices. Barley is more tolerant to drought and to poorer soils than wheat. According to Kroll (1984: 219), it can be cultivated in the same field frequently without fallow rotation (see also Osborne 2003, 40 for annual barley cropping in the Classical period). This, however, is not supported by ethnographic evidence (e.g. Hillman 1973). Some barley can be sown on fallow lands to produce additional fodder (Forbes 1982: 223–24). According to Hansen and Allen (2011: 881), in the Neolithic and Bronze Age (in Tsoungiza) barley was a likely famine crop and a preferred cultivar in particular in drought years. However, the abundance of barley in the LBA samples at the Argive Plain sites (see pp.91-92) gives a reason to suggest it was a common dietary crop besides wheat and pulses. Of wheats, the yield of einkorn is generally modest, but the plant adapts well in poorer soils where other wheat types are unsuccessful (Hillman 2011: 759; Zohary *et al.* 2012: 34). It also survives well in dry environments. In Syria, the lowest annual rainfall threshold needed for einkorn cultivation was determined as 200mm (Smith and Munro 2009: 931), whereas the rainfall of the Argive Plain today is around 500mm (Anadranistakis *et al.* 2016). If the Late Bronze Age rainfall came near the current level in the Argive Plain, einkorn and barley could have been successfully cultivated without irrigation. Emmer is considerably more drought-intolerant than einkorn and barley (Hansen and Allen 2011: 881), and bread wheat has high standards for both soil fertility and moisture (Halstead 1995b: 231). Even these crops could have likely been grown without issues with 500mm annual rainfall, however.

Due to these growing requirements, Kroll (1984: 219) and Allen and Forste (2020: 1060) suggested that crop rotation of legumes and wheat was practiced in the LBA to secure a successful wheat harvest and maintain soil fertility. In this system, wheats and legumes would have been grown on the same plot in alternating years (see p.97 about the ability of legumes to produce nitrogen). Hillman (2011: 759) suggested that the low amounts of processed and cleaned einkorn in the Mycenae Granary (sample 1) could point to the mixed cropping of wheats, namely emmer and einkorn. The better tolerance of the latter to poor soils and moisture conditions would have ensured that at least some harvest could be collected even if emmer failed. A few potential storage finds from EH Tsoungiza suggest that barley may have been grown together with wheat as maslin,[23] and that multi-cropping[24] could have been practiced by mixing barley and legumes (Hansen and Allen 2011: 816). This earlier chronological context does not, however, directly indicate the use of similar practices in the LH III period. The storage find of hulled barley and bitter vetch at the LH IIIC Granary of Mycenae could, nevertheless, refer to this same practice (Hillman 2011: 763). However, Hillman (2011: 763) suggested that such mixture could have been used as animal fodder. Instead of mixed cropping of crop rotation, bare fallow as a strategy to maintain soil fertility on crop fields might have been preferred. Cultivation of legumes would have potentially required watering, and therefore placing them on large fields in rotation with cereals would have increased labour costs.

Isotope analysis on archaeobotanical samples has great potential to shed light on the Bronze Age cultivation practices, in particular on manuring and irrigation of various crops. Up to date, there are no studies which have analysed the isotope values of LH III plant remains of the Argive Plain. Isotopic studies of Middle and Late Bronze Age crop remains elsewhere in Greece are, however, increasingly being published. The results of these studies can provide valuable comparative data on prevailing crop husbandry practices in the end of the Bronze Age.

[23] Maslin is a mixture of two or more crop types grown together in the same field.
[24] Multipcropping is when a variety of crops are grown in the same plot in different growing seasons.

Stable isotope values of carbon (δ13C) and nitrogen (δ15N) measured in barley in LH III (*c.* 1350 BCE) Assiros Toumba, northern Greece (Wallace *et al.* 2015) suggest that barley was not irrigated here. Barley and wheat were growing under moderately wet conditions. Wheat may have received low levels of watering, or it alternatively soils with better water retention abilities could have been chosen for the crop. Compared to pulses recovered at the same site, cereals received notably less natural or hand watering (Wallace *et al.* 2015: 14). At Bronze Age Knossos, Crete, the δ13C values of emmer wheat and barley measure high, which seems to suggest irrigation of both crops with an emphasis on the very high figures of emmer (Nitsch *et al.* 2019: 156-160). Emmer wheat is suggested by the authors as the most likely candidate for palatial wheat production at Knossos (see also Halstead 1995a). Thus, it is expected that cereal produced for elite use would have received more attention during the growing season. The δ15N values of the same material show that it is unlikely that manuring was used in emmer cultivation (Nitsch *et al.* 2019: 161). Instead, manuring of barley (and potentially other cereals except emmer) appeared to have been a common practice at Knossos (Nitsch *et al.* 2019: 160), as well as in Bronze Age Archontiko and especially in Thessaloniki Toumba in northern Greece (Nitsch *et al.* 2017: 123). These two sites yielded evidence of 'well-watered' wheats, potentially suggesting irrigation by hand. Barley was grown in drier conditions (Nitsch *et al.* 2017: 123).

The variation in the isotopic values between species in the in Final Palatial (*c.* 1450-1400 BCE) Knossos suggests that barley and pulses, and emmer wheat were grown in different locations and under different cultivation regimes, meaning they were not grown in rotation with each other (Isaakidou *et al.* 2022: 167; Nitch *et al.* 2019: 161). This could indicate the production cereals through a fallow system, and perhaps of the growing of legumes in a more garden type of conditions. In contrast, At MBA Archontiko, northern Greece, similarities between the growing conditions of bread wheat and spelt, and millet and barley, suggest that these crop pairs were like grown in rotation. Millet can ripen quickly, and could potentially be sown after the first barley production was harvested in late spring. At Archontiko and Thessaloniki Toumba, cereals may have been rotated with pulses, or grown together as maslin (Nitsch *et al.* 2017: 123).

Finally, some indications for the use and cultivation of cereals can be sought in the LBA Linear B evidence. Two cereal types, commonly interpreted as wheat (ideogram commonly marked as *120) and barley (*121), are regularly mentioned in Linear B texts.[25] Additionally, sign *65 has been seen to indicate either flour or bread wheat (Palmer 1992: 481). Specific wheat species such as emmer, einkorn, or the 'new glume wheat' are unrecognizable in the Linear B. Sign *120 which is the most common, is traditionally interpreted as bread wheat because the species is considered higher in value than barley, and thus it would have been of greater interest to the palaces whose economic activities are the main content of the Linear B tablets (Halstead 1995a: 232). As an opposing view, Palmer (1992: 484) pointed out the peculiarity of paying the dependent (low-level) personnel of Pylos and Knossos with rations of the more valuable grain, while religious (high-level) personnel would receive less valuable staple, barley (Halstead 1995b: 232; Kroll 2000: 62). However, Halstead has argued that due to its abundance in the archaeobotanical finds at Mycenaean centres such as Knossos, Mycenae and Tiryns, emmer is, in fact, the most probably candidate for palatial production and use (Halstead 1995a: 232; Nitsch *et al.* 2019: 161). The high value of bread wheat is usually connected to its bread making qualities, but recent studies show that in sufficient environmental conditions, for example manured, other wheat types can possess this quality too (Heinrich 2018: 114). As mentioned in in Chapter 2 (pp.12-13), wheat is regularly mentioned in the Linear B texts in relation to plot sizes. The practice of measuring plot sizes by the amount of seed corn needed for their sowing seems to suggest that some level of standardized seed-corn ratio system existed for the Mycenaean palaces. In accordance to this, less seed was sown into land of poor quality, and more into soils that were considered fertile (Palmer 1992: 481-82). According to Halstead (1995a: 232-233), if the species in question was emmer, its poor bread-making quality made it a suitable crop to be used to measure plots, and to be doled out to dependent workers and other officials (Halstead 1995a: 232-233). The most valuable bread wheat could have been restricted to elite production and use only, which is why it is only rarely mentioned in the surviving texts.

While the research involving Linear B signs *120, *121, and *65 continues, archaeobotanical records clearly indicate that a much higher number of cereal (and legume) crops were consumed by the Mycenaean people in- and outside palaces. Since the Mycenaean palatial administrations were likely not interested in the production process but mainly of volume of the end product of few limited crop species, any other informative references about cereal cultivation methods are absent in the records. Therefore, more comprehensive information about crop cultivation methods can be sought for example from

[25] There are numerous references to these in Pylos and Knossos tablets. According to Palmer (1992: 476) the original interpretation of wheat and barley derives from the Pylos tablet PY An 128.

ethnoarchaeological and historical statements (pp.54-58).

Legumes

Together with cereals, legumes are abundant in the archaeobotanical samples in the LBA Greek sites. Although legumes do not occur in the Linear B texts (Halstead 1995b; Valamoti *et al.* 2011), they seem to have been regularly cultivated and consumed. Various species of legumes have been recovered in the LBA Argive Plain contexts, at the same sites as the cereal finds (pp.91-92). Legumes include 'pulses' which are considered as the more edible (by humans) group of plants, while other legumes are traditionally considered as wild plants, and fodder. In the Mycenaean assemblages, both types of legumes are present (Heinrich and Hansen 2018: 117).

Some of the legume species can be toxic to human if consumed in large amounts, or uncooked. Commonly non-toxic species inlude lentil (*Lens culinaris*), fava bean (*Vicia faba*), chickpea (*Cicer arietinum*) and common pea (*Pisum sativum*), while the naturally toxic species include bitter vetch (*Vicia ervilia,* also commonly known as wild pea), common vetch (*Vicia sativa*) and grass pea (*Lathyrus sativus*). Of these, bitter vetch is the most regularly occurring species in the Bronze Age assemblages in Greece (Valamoti *et al.* 2011). It is present in all of the Argive Plain archaeobotanical collections. In LH IIIC Tsoungiza, bitter vetch is the second most common legume after lentil throughout the Mycenaean period (Allen and Forste 2020: 1059). Bitter vetch is abundantly present in the three samples of the Granary of Mycenae, although Hillman (2022: 765-767) argues for its use as fodder, especially when it is found mixed with barley. The second legume species retrieved at the Granary, fava bean, is only present as four seeds in total (Hillman 2022: 751, Table C). At the Ivory Houses of Mycenae, however, lentil and grass pea are also present Tournavitou 1995: 279). The Tiryns botanical remains are also abundant with bitter vetch, but include also some of grass pea, fava bean, pea, and lentil (Kroll 1982: 476). Fava bean seems to be most regularly used in the EH-MH Lerna, however, and bitter vetch is present only as few seeds in EH deposits (Hopf 1961).

When toxic legumes are consumed in large amounts, they can cause a neurological condition called neurolathyrism, a neurogenerative disease which in its severest form can lead to paralysis. However, this condition only occurs when at least 30 percent of the diet consist of the toxic pulse for a prolonged period of time, and can therefore be (normally) easily prevented by adding cereals and fruits to the regular diet to improve their amino-acid and nutrient scores (Heinrich and Hansen 2018: 126; Lambein *et al.* 2019: 824). In addition, commonly non-toxic fava bean can be lethally dangerous if it is consumed by individuals with a deficiency in a specific enzyme (glucose-6-phosphate dehydrogenase, G6PD) which helps red blood cells to function efficiently. This genetic deficiency is common in Greece. Fava beans contain substances which trigger heamolytic anemia if there is not enough G6PD enzymes to protect red blood cells (Howes *et al.* 2013: 135-136). It is probable, that Bronze Age were aware of the toxic qualities of these species and took necessary precautions, such as limiting their consumption.[26] Cooking and fermentation have been noted to partially remove the toxicity of these plants as well (Lambein *et al.* 2019: 824-825; Valamoti *et al.* 2011), although consumed in large quantities for example in times of famine, they can still pose a health risk (Heinrich and Hansen 2018: 126). The topic is, thus, interesting in relation to the evidence of anemia in Bronze Age skeletal samples across mainland Greece (pp.119-125). Although all toxic legumes could have been used as fodder (Valamoti *et al.* 2011; Zohary *et al.* 2012), there is strong evidence to suggest they were part of the everyday human diet in the LBA. Bitter vetch is even depicted in fresco fragments in Late Minoan Palaikastro, Crete (McGillivray *et al.* 1992: 128), reflecting its importance as an exploited plant in the LBA. In Greece today, grass pea is occasionally served at restaurants as a delicacy (Valamoti *et al.* 2011), and bitter vetch is still used in soups, or ground to flour (Shay *et al.* 1998: 319).

Similar methods for growing, cleaning, storing and consuming can be applied to all legume species. Usewear analyses have revealed that sickles were used to cut leguminous crops (pp.80-81) In the LBA. This suggests that legumes were purposefully collected, processed and stored for human or animal use. Additionally, those grown in larger fields, perhaps in rotation with cereals, could have been purposefully left in situ to provide additional fodder, as has been accustomed to rural Greek communities in recent history (Forbes 1976a: 131; 1982: 243–46; Halstead and Jones 1997: 271-73). Sample 3 of the Mycenaean Granary includes bitter vetch seeds that are notably clean from weeds. Such purity could refer to a harvesting method in which the plant is uprooted by hand-pulling and then cleaned and processed, or the bitter vetch of the sample could represent the cleaning by-products of cereals stored separately to be used as fodder (Hillman 2011: 771). Other samples show some evidence of mixed cropping of legumes, mainly bitter vetch, and barley and emmer wheat (although in this sample the seed size could

[26] Before consumption the poisonous would have been detoxified by removing the testa (the outer layers around the seeds) by pounding or grinding, and boiling the seeds while changing the water several times. Other precautions could have been to regulate their consumption, or only use them mixed with cereals (Valamoti *et al.* 2011).

refer to bitter vetch as a weed contaminant (Hillman 2011: 772-774). Classical Roman authors report the intentional mixing of cereals and pulses as a regular culinary practice as well (Heinrich and Hansen 2018: 119).

Legume processing could have included for example sun-drying, washing, soaking, boiling, grinding and splitting (Valamoti *et al.* 2011). In addition, the pods of some species (e.g. fava bean) could be consumed fresh or cooked, seeds still attached. In northern Greece, traces of soaking and boiling toxic vetches have been recovered in BA contexts (Valamoti *et al.* 2011). Legume flour, and a coarser mass of pounded and grinded legumes called fava, have been recovered in LBA contexts in Akrotiri on the island of Thera (Sarpaki 2001b 32-33), and in LH I context in Thebes (Jones and Halstead 1993: 103). Due to their high protein content, legumes could have served as a substitute for meat in the non-elite Mycenaean cuisine (Zohary *et al.* 2012: 77).

Compared to cereals, legumes usually give slightly lower yields, and require better watered conditions to grow compared to cereals, for example (Zohary *et al.* 2012: 82-87). However, bitter vetch can adapt to dry and unfertile conditions (Zohary *et al.* 2012: 95), which might explain its popularity in the LBA. Aided by rhizobia bacteria attached to their roots, leguminous plants have the ability to fix nitrogen directly from the atmosphere for their own use (Kislev 2010: 2479; Lambein *et al.* 2019: 823). Since they do not deplete nitrogen stored in soil, they could have been cultivated in rotation with cereals (Hansen and Allen 2011; Valamoti *et al.* 2011). In contrast, legumes have a shorter self-life than cereals, as they are more vulnerable to species-specific pests (Heinrich and Hansen 2018: 120).

Recent evidence of the cultivation methods of legumes has been received from the nitrogen (δ15N) and carbon (δ13C) stable isotope measures taken from Bronze Age samples. In LH III (*c.* 1350 BCE) Assiros Toumba, northern Greece, the carbon isotope values for bitter vetch and lentil suggest that legumes were growing in wetter conditions than the cereal crops of the same site. The values indicate possible supplementary irrigation for at least some of the legume crops (Wallace *et al.* 2015: 10). For such a method to be labor effective, pulses should have been grown in garden plots close to the settlements (Vaiglova *et al.* 2014; Wallace *et al.* 2015). Legumes recovered in MBA Thessaloniki Toumba and LBA Archontiko, located in northern Greece, were also grown in well-watered soils (Nitch *et al.* 2017: 121-123). This could signal manual irrigation but could also refer to generally wetter climatic conditions of the region. In addition, in LBA Knossos, Crete, the isotopic values of pulses suggest fluctuating watering conditions, also consistent with hand-watering (Nitch *et al.* 2019, 161; Wallace *et al.* 2013: 403).

Nitrogen isotope values measured in pulses at two northern sites of Thessalonki Toumba and Archontiko exhibit varying manuring practices. While the MBA pulses at Thessaloniki Toumba were regularly manured, in LBA Archontiko pulses received considerably lower levels of fertilization (Nitsch *et al.* 2017: 123). The isotope values of the LBA legumes recovered at Knossos map onto the practice of manuring as well. However, some moderate differences can be observed between species (e.g. Celtic bean was more intensively manured than vetchling), possibly suggesting different status of these crops in the local economy (Nitsch *et al.* 2019: 161).

Comparison of the values of legume samples and cereal grains recovered at the same northern sites, Thessaloniki Toumba and Archontiko, implies that these two crop types grew in similar conditions and were likely cultivated in rotation (Nitsch *et al.* 2017: 123). In contrast, varying values of cereal and legume crops at LBA Knossos seem to indicate that these two crop-types were cultivated separately, under different management practices (Nitsch *et al.* 2019: 161).

Tree crops

The most common tree crop finds of the LBA are fig (*Figus carica*), olive (*Olive europaea*) and grapevine (*Vitis vinifera*). These crops are present in the LBA archaeobotanical samples and in Linear B records. In particular, charred fig remains are very common in the Bronze Age samples across mainland Greece (Hansen and Allen 2011: 816). Grapevine and olive are presented by macroremains and pollen across the Peloponnese. Such abundance of finds suggests they were broadly cultivated in the LBA (Hansen and Allen 2011; 881; Kroll 2000: 66). Fig, olive and grapevine remains have been recovered in the same Argive Plain contexts as cereals and legumes (pp.91-92).

Figs are mentioned in the Linear B tablets of Pylos and Knossos. In Pylos, fig and wheat rations were given to female and male workers (Chadwick 1972; Gregersen 1997). As mentioned earlier in this work (pp.8-10), the estimated fixed monthly ration of figs to the female textile workers in Pylos was 20 litres (Palmer 1992). As an example, for the *c.* 750 dependent female workers in the palace of Pylos (Nosch 2003: 15), this would amount to 15,000 litres of figs a month, thus some 180,000 litres (*c.* 115,000kg)[27] a year. Such production targets would require a considerable amount of investment

[27] Fresh figs are available only in the harvest season in late summer. Therefore, here, the volume is calculated by the weight of dried figs. A litre of dried figs weighs c. 0.63kg, and so 180,000l would amount to 115,000kg.

and space. Modern examples show that a large, mature fig tree would produce on average 25kg of fruit a year (Aschenbrenner 1972: 56). Thus, some 4600 trees would have been required to provide the rations for the female workers of Pylos. While fig seeds appear regularly in the Bronze Age Argive Plain assemblages in Tiryns (Kroll 1982: 479), Midea (Shay *et al* 1998: 320, Table 8), and Lerna in the Neolithic and early Bronze Age (Hopf 1961: 246), they are absent Late Helladic Tsoungiza. Fig (wild) remains are, however, abundant in the Early Helladic archaeobotanical collection of Tsoungiza (Hansen and Allen 2011: 805). Fig seeds are also very few among the archaeobotanical samples of the Granary (Hillman, 2011: 751, Table C), nor are they mentioned in the botanical samples of the Ivory Houses of Mycenae (Tournavitou 1995). The absence at Mycenae may be caused by post-depositional or recovery biases, but the Late Helladic assemblage of Tsoungiza was collected namely with a strategy to avoid these.

Domesticated fig trees must be fertilized with a caprifig, the 'male' tree. Traditionally, to ensure that this takes place, caprifig fruits were collected and displayed on tree branches to attract insects, particularly female wasps, who crawl into the male fruit. Such method of fertilization guarantees a maximum amount of fruit per tree. Wild figs produce much less (Aschenbrenner 1972: 56; Forbes 1982a: 267). There is no evidence of the practice of germination of fig trees by farmers in the LBA. However, the presence of 'fig-overseers' in the Linear B texts (p. 10) suggests that fig cultivation was carefully planned and monitored by the Mycenaean palaces. Perhaps their germination was enabled by the fig-overseers, at least if they were cultivated in orchards. The use of figs as a standard commodity of the palatial ration system in itself indicates that there was a reliable source of fig trees available for the palatial use. A fig tree is mentioned in Homeric epic (Od. XII.103) by the name *erinos* [ἐρινεὸς], which is a masculine form of a wild fig-tree (Athenaeus 2022) as opposed to the neuter *sykon* [σῦκον], the ancient Greek name for fig fruit (hence the fig-overseers are *opisūkoi*) The use of the masculine form could be interpreted as the indentification of male and female fig trees, i.e. the knowledge which type of tree needed germination, already in 'Homeric' times. However, the use of gendered terms could also to a wild species as opposed to domesticated, or for a tree type specific to the region. Could it be, that the underrepresentation of fig in the archaebotanical assemblage of Tsoungiza reflects the non-palatial status of the settlement in the Late Bronze Age? If the Mycenaean palaces controlled the production of certain products, such as figs, which were used for the food rations of their own employees, then there may have been a restricted access to these supplies by other settlements and communities.

Compared to other tree crops, numbers of olive remains are quite limited in the mainland Bronze Age macrobotanical assemblages. Margaritis (2013: 751) has, therefore, questioned its importance in the LBA subsistence. Charred olive stones have, nevertheless, been recovered widely in the Greek mainland, the Cyclades and Crete (Kroll 1982: 476). In addition, harvest records of olive (and grain) are found in the Knossos Linear B tablets (E-series) (Palmer 1994: 173). In LH III Tiryns olive is present as olive stones (Kroll 1982: 476), and as charred wood, which indicates its secondary use as fuel and timber (Vetters *et al.* 2016: 107-10). Kroll (1982: 479) suggests that since the Tiryns olive kernels exhibit a large variety of shapes and sizes, they likely represent both cultivated and wild species. At Midea olive is present as stones and fragments (Shay *et al.* 1998: 320, Table 8). At the Granary of Mycenae, olive is only present as five stones, thus reflecting the more general pattern of mainland Greece (Hillman 2011: 769-774). Olive remains are not reportedly recovered in the Ivory Houses of Mycenae (Tournavitou 1995) nor Early Bronze Age Lerna (Hopf 1961). At Tsoungiza, olive, however, increases in ubiquity towards the Late Helladic period, possibly reflecting the palatial interest towards acquiring it for its use (Allen and Forste 202: 1060). Olive (*Olea* fam.) is also present in the pollen sample of Lake Lerna (p.88), further suggesting its cultivation in the region in the Bronze Age (Jahns 1993: 197).

Figs and grapes could have been consumed fresh after harvesting, or dried during the rest of the year (Hansen and Allen 2011: 816; Zohary *et al.* 2012: 124). A large deposit of grape seeds recovered in late Middle Helladic-early Late Helladic 1 context at Tsoungiza refers to the intentional cultivation and processing of the plant, but the seeds show signs of fermentation rather than pressing (Allen and Forste 2020: 1054-1058). Besides the Early Mycenaean hoard, grape is ubiquitous in the Late Helladic Tsougiza deposits (Allen and Forste 2020: 1060). It is also abundant in Late Helladic Tiryns (Kroll 1982: 479). To contrast this, at the Granary of Mycenae grape is present as one seed only (Hillman 2011: 751, Table C), and at the Ivory Houses not at all (Tournavitou 1995). At Lerna, grape emerges only after EH III period, simultaneously with the decline of fig (Hopf 1961: 247).

Substantial evidence of charred crushed grape seeds with traces of pressing has been found in a Bronze Age context in Crete. Pressing refers to juice extraction, which could have been consumed as such, or used for wine-making (Valamoti 2009; Valamoti *et al.* 2007). It has been suggested, that mechanical pressing devices used for olive oil extraction could have been used for grapes as well (Palmer 1994: 16; Pratt 2014: 24). Stone presses for olive oil extraction, as well as clay spouted tubs used for extracting oil from the water that was used in the pressing process, have been recovered in Minoan contexts in Crete (Riley 2002: 66-67). In the LBA mainland contexts they are absent. However, only minor evidence (one small broken stone in Crete) of crushed olive stones has been found. Since oil can be extracted from the fruits manually, the absence of crushed stones or mechanical installations in the Greek mainland do not prove against the making of olive oil (Valamoti 2009: 31). Nevertheless, the physical evidence of olive oil making, or olive consumption for that matter, is oddly scarce, and contradicts the abundance of oil in the Linear B evidence (see below).

Olive oil is regularly mentioned in the Linear B texts. The Pylos tablets indicate that some of the oil was perfumed with different kinds of herbs and spices. Perfumed oils and ointments are often connected to religious occasions (Chadwick 1972: 115). Oil (although not necessarily olive oil) was also stored in large quantities at the 'House of the Oil Merchant' at Mycenae, and it is mentioned in the Linear B tablets found in the same building complex. One tablet (Fo 101) recovered there mentions that oil was distributed to women. Shermeldine (1997: 390) suggests this oil was meant for professional use in the textile industry, which was mainly operated by women. Olive oil appears to have been important to the Mycenaean industries, and therefore olive was likely cultivated in large quantities.

Wine in the Linear B records is indicated with two ideographs, *131 and *131b (Palmer 1994: 16). In one Pylos tablet (PY Er 880), the size of a plot of land is measured in grain (see p.13 for further details), but the land is partially planted with grapes (vine) and figs. Perhaps orchards, where vine and figs were grown together, were a land management strategy in the Pylian territory. The detail could also refer to a system in which tree and cereal crops are cultivated together.

When cultivated, all three trees require long-term investment, since they provide a full harvest only some ten years after planting. Once in operation, the trees require relatively little care between the harvests, and if well maintained they can bear fruit for decades or even hundreds of years (Aschenbrenner 1972: 53-56). Olive has a strong tendency for bi-annual bearing, which means that they produce a higher yield only every second year (Aschenbrenner 1972: 56). While all three tree crops adapt well to the Mediterranean climate, grapevine and fig are more tolerant than olive towards cool temperatures and humidity (Zohary *et al.* 2012: 121). Olive, on the other hand, adapts well in various environments and soils, and tolerates drought extremely well (Aschenbrenner 1972: 53). Vine cultivation takes place in lower altitudes in humid but well drained valley slopes and plain (Aschenbrenner 1972: 55; Hansen and Allen 2011: 883). Today, olives are often grown on terraced fields, and this could also have been the case in the LH III, as terracing technology was well-known (see pp.69-74). On them, tree crops could have been intercropped with cereals or pulses. Due to their intertwining schedules, intercropping of olive or vine and cereals has been a successful practice in the Classical and Roman (White 1970: 288), as well as modern Greek agriculture (Aschenbrenner 1972: 53; Osborne 1987: 45). Fertilization of mixed cereal and tree crop cultivations has taken place regularly in recent history too (Aschenbrenner 1972: 53-54). However, in recent history, olives have also been abundantly collected from trees that spread to unused areas outside orchards (e.g. Aschenbrenner 1972: 53). The land chosen for olive trees has commonly been of lower quality than that chosen for cereals, partially because olive can produce well in poorer conditions. Fragments from the Classical period suggest that olive trees were often planted on the fringes of fields, alongside roads, and in spaces available due to their unsuitability to other crops (Foxhall 2007: 115-116). Only the wealthy might have cultivated tree crops in orchard conditions in a systematic pattern (Foxhall 2007: 115).

In the Mycenaean period, textual fragments from Knossos indicate that the palatial administration was keeping records of the location and numbers of fig and vine trees. The same could have been done for olive too (Melena 1983: 100-105). In his exercise of comparing the Knossos tree records, Melena (1983: 106) suggests that the palace could have been in control of at least 4000 olive trees, and most likely a much higher number. Such control and detailed recording of tree crops could indicate that orchards, or at least carefully managed and monitored croplands with high density of olive trees and other tree crops were sporadically present in the Mycenaean landscapes. Perhaps these fields resembled poorly the systematically curated orchards of the Greek landscapes of today, but the records give some expectations of Late Bronze Age olive yields, at least in the palatial farming context.

All tree crops could have also been grown on terraces, similar to modern practices. Especially for palatial centres such as Mycenae, which had less flat land in its surroundings for any type of cultivation, tree cropping on terraces could have been crucial for the fulfilment of its needs for paid rations and subsistence. Later on (pp.166-174) these different growing strategies will be considered in the calculations of the agricultural potential.

Other plants

In addition to cereals, legumes, and the main tree crops, a wide variety of fruits, vegetables, nuts, and wild plants are present in the LBA assemblages from the Argive Plain and beyond. Since these species are present in lesser amounts, it is difficult to estimate their importance in the human and animal diet. Vegetables and wild plants are likely suffering from recovery and taphonomic biases, and thus their share in local diets can be best observed through ethnographic analogies.

Of the fruits and vegetables, melon and acorns deserve a special note. Seeds resembling melon (*Cucumis melo)* have been recovered from the LH III Tiryns. Kroll (2000: 66) proposes they could be the seeds of the Greek pumpkin, κολοκύθι. Melon (or κολοκύθι) requires plenty of water for growing, and thus it would have likely been cultivated close to the settlement (Kroll 2000: 66). Due to this water need, the melon finds cannot represent wild species. In the EH Tsoungiza, acorns were recovered in a context together with grinding stones and storage vessels, which indicates that they were part of the human diet (Hansen and Allen 2011: 876-80). Acorns have traditionally been a part of the pig diet in the Mediterranean (see pp.109-111).

In addition, flax seeds (*Linum usitatissimum*) were recovered at EH Lerna (Hopf 1961: 241) and LH III Tiryns (Kroll 1984: 212, Table 1). Flax can be used for many purposes. Its seeds are edible and nutritious, but also contain oil which can be extracted by crushing (Valamoti 2009: 27). Fibres of the stem can be used to make thread and woven into a cloth, a practice that was presumably conducted in the Mycenaean palaces during the Late Bronze Age (Valamoti 2011b: 558). The Na-series of the Pylos Linear B tablets lists up to 80 flax producing areas within the region controlled by the palatial centre (Chadwick 1972: 112; Halstead 2001: 44-46). Due to its oil content, flax remains burn quickly, leaving hardly any archaeological traces. This could partially explain the small role of flax in archaeological finds (Valamoti 2011b: 555). On the surface of two daggers and a bronze spearhead recovered in the Grave Circle B at Mycenae, were textile fragments made of linen (flax-based textile). Linen fragments have also been found in burial and storage contexts elsewhere in the LBA Greece, for example in the LH III Akrotiri, Thera, the island of Salamis, and Chania, Crete (Spantidaki and Moulherat 2012). Nevertheless, because flax finds are close to absent in the Argive Plain archaeobotanical and textual evidence, and the origin of the textile fragments attached to the weapons cannot be identified (they may have been imported), the plant is not included in the main agricultural crops in this study.

Summary: The Argive plain macrobotanical remains as indicators of farming and food consumption

The micro and macro remains of plant species recovered in the Argive Plain shed light on the nature of agriculture in the LBA. While pollen data are less informative about which species were cultivated, they suggest the clearing of forests for fields and pasture (Atherden *et al.* 1993; Jahns 1993; Sheehan 1979). Timber was needed in the construction of settlements especially in the LH III period (see Boswinkel 2021 for LH III construction materials), and may also have been used in ship building (e.g. Aloupi *et al.* 2001; see also Tartaron 2013). The fluctuation of maquis species and tree taxa on higher slopes in the Argive Plain territory could reflect a cycle of terrace construction and abandonment (Atherden *et al.* 1993; Jahns 1993; Sheehan 1979). However, the dating of these forestation cycles is too insecure to allow any further conclusions about the dating of human-induced landscape changes at this point.

Combined macrobotanical and textual evidence the latter mostly from other regions) provides information on the plants cultivated in the LBA Argive Plain. The vast majority of the recovered plants consist of domestic species. Cereal and legume species dominate. This could also point to recovery biases, since weed seeds are smaller than grain seeds, for example, and therefore more difficult to retrieve. However, the presence of these charred remains does not by definition indicate that these were used as human food. Miller (1984: 74-76) suggested in the Near Eastern context, that the majority of the archaeological charred seed finds became in contact with fire mixed in dung fuel rather than during cooking activities. This is because food is meant to be consumed instead of being burned in a fire. Charred seeds become deposited also when harvested crops or food is processed near fireplaces, or when debris is intentionally or accidentally discarded in a hearth. In general, charred food residues should accumulate in much lower densities than those resulting from debris or dung fuel.

Does Miller's argument work for the LBA Argive Plain? Dung was used as fuel in environments where dung producing animals were commonly present, and wood was scarce. Dung (fuel) can be observed in archaeobotanical contexts if there is a notable mixture of food plants and weeds in the same assemblage, and weeds form a considerable part of the collection. Weeds are more likely consumed by grazing animals than by people (Miller 1984: 74). They can also travel to the site as crop contaminants, but in this case a high presence of charred seeds would indicate that the cleaning of crops took place in the settlement close to fire in which the weed seeds were deposited accidentally or because they were discarded. Such processes are irregular, and thus appear more unlikely than the transfer through fuel (Miller 1984: 73-74). Furthermore, in Greece, most of the crop processing has traditionally taken place outside the settlements (Halstead and Jones 1997). Jones's (1998: 95-96) report of traditional farming in the island of Amorgos shows that fodder cereals were cleaned and stored as carefully as the ones meant for human consumption. Grain and processing by-products were desired fodder components and fed to animals throughout the year. In order for them to preserve longer in the storage, sufficient cleaning was necessary. Crops meant for fodder were placed in the same storage as food grain.

Of the Argive Plain archaeobotanical assemblages, only that of Tiryns includes a notable variety of weeds and wild plants (Kroll 1982), although some wild species are included in the samples of Midea (Shay *et al.* 1998) and Tsoungiza (Allen and Forste 2020). The Tiryns composition could indicate the deposition of the seeds mixed in dung. At Midea, the botanical assemblage (of mostly charred seeds) is notably clean from weed taxa (Shay *et al.* 1998), implying that crops underwent cleaning before arriving at the sites.

Nevertheless, experimental studies have revealed another type of bias related to the survival of seed remains in the digestion system of different animal species. Experiments in which goats (Valamoti and Charles 2005) and sheep (Wallace and Charles 2013) were fed einkorn spikelets, figs (only goats), einkorn, barley and tubers (only sheep) showed that cereal material preserves poorly in the ovicaprid digestion system. While crop processing products such as glume bases and rachis, were slightly better exhibited in animal dung than cleaned grain, both types of material are still severely affected by digestion. The tubers fed to sheep in the study of Wallace and co-authors (2013: 23) disappeared completely, while fig seeds survived well in the goat digestion system (Valamoti and Charles 2005: 530). In both studies, wild seeds persisted well through the digestion system of sheep and goats.

In Greece, dung has been traditionally collected for manure for example during crop-processing activities. Although manuring has been commonly practiced, the availability of dung in subsistence farming has been limited due to the low number of domestic animals kept by households (Halstead and Jones 1997: 273-75). Dung use as fuel is not described in the ethnoarchaeological works used in this study (Forbes 1982a; Gavrielides 1976b; Halstead and Jones 1997; Jones 1998; Koster 1977), likely because there was enough maquis and forests to collect wood for fuel. Some indications exist of the use of dung cakes as fuel in the Neolithic and Early Bronze Age northern Greece (Valamoti 2004, 118-119; Valamoti and Jones 2003: 28-29), however. Nevertheless, charred wood remains have also been recovered in the same archaeological deposits with seeds and other botanical remains. One of such examples comes from LH III Tiryns (Vetters *et al.* 2013). This seems to suggests that wood was also used as fuel on a regular basis in Greece. In modern rural communities, firewood has been regularly collected for winter during the other agricultural activities such as herding. Wood collection took place especially on hillslopes growing forests and maquis (Bevan *et al.* 2013, 216; Gavrielides 1976a: 267). Such practices have also been attested for the Classical period, during which rich landowners would prefer to leave hillslopes uncultivated and use them for firewood collection (Foxhall 1996: 54). Pollen data (pp.87-90) show that throughout the Bronze Age the landscape of the Argolid was more forested than today. Arboreal forests and maquis could have offered a sufficient resource for firewood.

The presence of forested landscapes in the Late Bronze Age Argive Plain surroundings, the storage finds of cereal and legume crops, the cleanness of the (albeit) charred macrobotanical finds, and the scarcity of evidence indicating regular dung fuel use in Greece in the ancient and more recent past, all indicate that macrobotanical finds in this context mostly reflect human dietary choices. Therefore, in this study it is assumed that the essential LBA diet consisted of cereal and legume crops, figs, olive and olive oil, wine or grapes consumed fresh or dried, and likely a mixture of wild plants such as nuts, fruit, and herbs which were abundantly available in the landscape. Due to their absence in the Linear B records, legumes were only considered an important part of the LBA diet only more recently (Sarpaki 2001b; Valamoti 2009; 2011a; Valamoti *et al.* 2011. Emmer was the most abundant wheat species in the LBA botanical assemblages, and bread wheat likely established a firm position in the Aegean during the LBA. However, barley's abundance in the botanical samples, and its tolerance for drought and poorer likely made it a common crop for human and animal use alike (Shay *et al.* 1998; 320; Zohary *et al.* 2012: 59).

Knowledge of the ratio in which species abundance in archaeobotanical assemblages reflects the abundance of these plants in dietary compositions could notably improve estimations of the agricultural production potential. The abundance of certain species could be further converted into proportions of land use. Unfortunately, there are too many issues related to these assemblages to allow such extrapolations. There are no indications to dietary compositions in Linear B evidence, nor does isotope analysis on human bone material (yet) allow such detailed reconstructions (p. 126). Fortunately, ethnoarchaeological records can be used to a certain extent to model past plant use and their consumption.

Ethnographic data, and isotopic analysis on plant remains can also be used to extract some information on past cultivation practices. Cultivation methods would have further influenced crop productivity in the LBA, and therefore have consequences on the agricultural potential. In rainfed agricultural systems, fallow years are a practical way to maintain adequate soil nutrition levels. In Greek agriculture, short fallow, in which land is left uncultivated for a full year, has been favoured. For example, in Amorgos, cultivation of wheat and barley in rotation with fallow years continued until the 1930s, when it was replaced with bi-annual rotation of cereals and legumes. The latter practice took over because of an emerging need to intensify dairy production and therefore to grow fodder. All fields were still left fallow every few years (Forbes 1982a: 255; Halstead 1987b: 82-83; Halstead and Jones 1997: 273). Halstead (1987b: 82-83; 1995b: 2014), and Nitch and co-authors (2017: 110; 2019;), have argued that the use of bare fallowing, manuring, hand irrigation, crop rotation and other cultivation practices are directly related to the nature, size, and status of the farming community. For example, manuring and irrigation provided high soil fertility and yields, but proportionally lower output due to the high labour input and small cultivation areas it could be applied on. Hastead further argues (1987b: 81) that legumes do not necessarily improve soil quality, but merely help to maintain it. Additionally, they consume water, and in years of low rainfall can end up draining the soil. Therefore, legumes might require manual watering which can result in increased workloads. Of other cultivation strategies, annual cropping without fallow or rotation years would have likely resulted in largest profits in a single year. In this case, other means for improving soil fertility would have been required. According to Boserup (1965: 25–26), population increase would result in fallow rotation and annual cropping being used simultaneously. However, annual cropping has been mostly favoured by modern industrial agriculture which uses significant amounts of chemical fertilizers. Therefore, it is not considered as a Mycenaean cultivation strategy in this study.

The macrobotanical evidence presented in previous sections does not give conclusive evidence of the favouring of fallow rotation versus the rotation of different cereal and pulse species in the Mycenaean period. It is likely that both methods were used, and their adoption depended on the size and type of the settlement, distance to agricultural land, and fluctuating environmental conditions. Available isotope data suggest that hand irrigation and manuring were known and regularly used in the Late Bronze Age Greece (e.g. Nitch *et al.* 2017). These data further indicate that different crop species were cultivated in distinct ways, depending perhaps on production targets, prevailing climatic and environmental conditions, and on the availability of labour and power for agricultural work. For example, barley was irrigated and manured at three of the Bronze Age reference sites, Knossos, Thessaloniki Toumba, and Archontiko (Nitch *et al.* 2017: 123; 2019: 156-160). This is interesting, since the crop is known for its ability to tolerate dry and relatively unfertile conditions, and it would not have needed growing enhancements. Emmer wheat was potentially irrigated at Assiros and definitely so at Knossos (Nitch *et al.* 2017: 123; 2019: 156-160). However, it was not manured, even though one could assume that this wheat was of interest to the palatial elites. Palatial involvement in its production could have meant that the institution has first rights to the highest quality cultivation land, for example areas that have good water retention abilities (Nitsch *et al.* 2017: 123; 2019: 164). This, instead of actual hand watering which would have been labour-intensive as well, could explain the high watering indicators of emmer wheat at several sites, as well as the lack of fertilization (Nitsch *et al.* 2017: 123; 2019: 164). Legume species seem to have been manured often despite of their ability to produce their own nitrogen and not requiring fertilization. Legumes might have been manured because they were grown in garden-like conditions together with fruits and vegetables which received additional fertilization. They could have also been intercropped with olive or other trees on poorer soils that were favoured for manure when it was available.

The sample size of isotope evidence is small, and cannot be directly applied to the LBA Argive Plain context where no such data is currently available. However, bare fallow is also supported by ethnographic evidence (e.g. Halstead and Jones 1997), and the cultivation of cereals and legumes as maslin by macrobotanical evidence deriving from storage contexts (Hillman 2011; pp.91-92 of this publication). According to these models, in the Argive Plain where large central settlements were abundant, a notable share of cereals would have been cultivated in an extensive system, fields locating further away from the settlements on high quality soils. These crops would have been used by the palatial administrations. Legumes could have been grown closer to settlements in garden plots which were hand irrigated and manured. Smaller farming communities living further away from the large population hubs of the plain likely practiced more intensive strategies for cereal cultivation and tree cropping. As previously discussed (pp.69-74), palatial tree crops could have been grown on terraced fields which can be recognized in the vicinity of Mycenae and other LBA sites in Greece, even though the potential discovery of a LBA crop-processing floor within a terraced field system in Kalamianos rather suggests that terraces were used for cereal cropping rather than for trees. Smaller farming communities could have plugged their tree crops from marginal lands such as field and pasture edges.

Many, if not most of the common cultivation methods used until recently were known to the local farmers, and they were able to change cultivation strategies according to the current risk factors, and the changing production targets. It seems that both, the intensive farming methods with higher yields and labour costs, and the extensive, low-labour extensive methods were used by the local Mycenaean communities.

The discussion of the LBA plants continues in Chapter 6 where these data will be incorporated in the reconstruction of the LBA Argive Plain agricultural system (pp.132-150) to the reconstruction of the LBA diet (pp.150-166), and finally to the estimates of land use and agricultural potential (pp.166-178).

Animals and animal husbandry in the LBA Argive Plain

Animal husbandry was an inseparable part of the Late Bronze Age subsistence economy. Animals were exploited not only for their meat, but also for other products such as milk, fibres, and hides, as well as traction power and manure. Large numbers of domesticated sheep, and likely also goats, cattle, and pigs were kept by the palatial centres of the Greek mainland and Crete (Halstead 2003; Isaakidou 2004). Such husbandry systems had an impact on Mycenaean land use and landscapes. The following section discusses the published faunal remains of the LBA Argive Plain sites. Subsequently, it explores the subsistence and environmental requirements of these animals. The aim is to examine the ways these animals were tended, and how they were exploited for human use by the LBA people. This information is important for estimating the agricultural potential of the Argive Plain in two ways. Firstly, through these data it is possible to better define the spatial requirements and limitations for pasture in the Argive Plain area. Secondly, information about the presence and use of animals in the Mycenaean society enables specifications of the role of animal products (e.g. meat and dairy) in human diet. The LBA faunal evidence presented in this chapter derives from two main sources, the Linear B texts (although these archives are mostly found in contexts located outside the Argive Plain), and the faunal material recovered at the Argive Plain sites. For comparison, data from the Peloponnese, northern Greece, and Crete are presented. The locations of the sites are presented in Figure 5.11.

Textual and zooarchaeological evidence on animal husbandry in Mycenaean agriculture correlate rather well. However, similar to plant management, textual archives only mention specific species that were

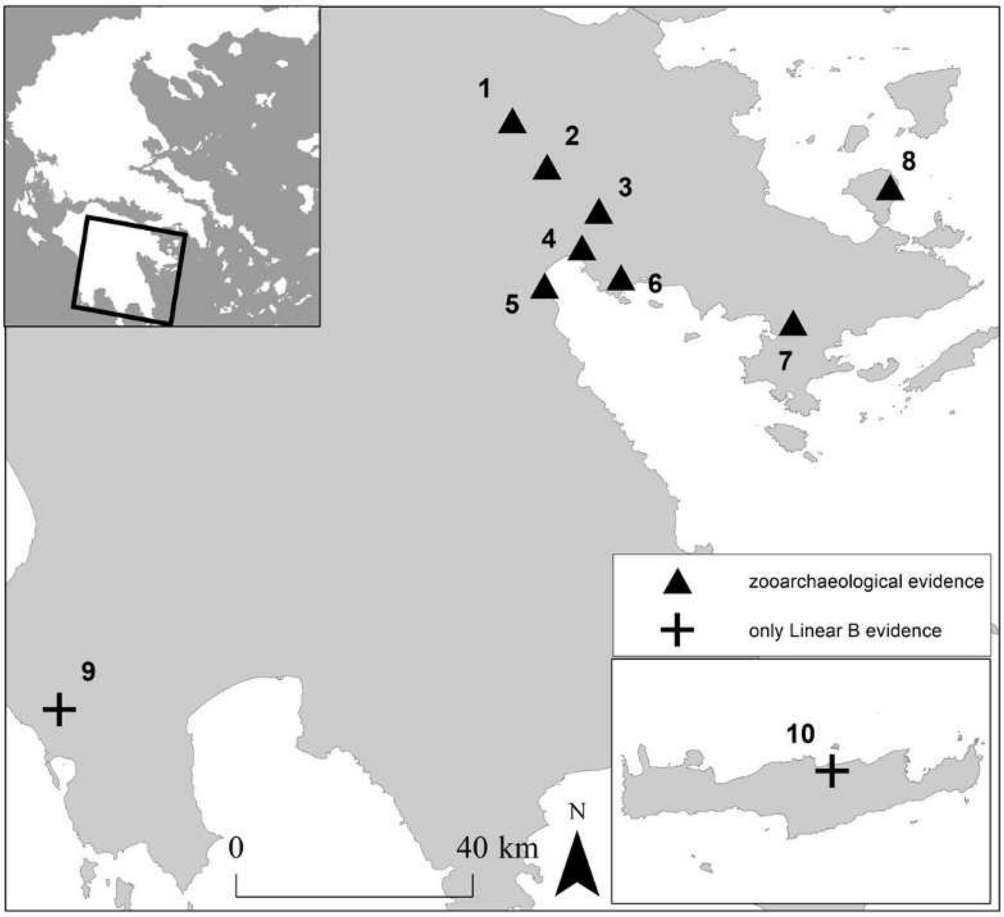

Figure 5.11. The find locations of the zooarchaeological data mentioned in the text. The sites in order are: 1) Tsoungiza, 2) Mycenae, 3) Midea, 4) Tiryns, 5) Lerna, 6) Asine, 7) Fourni, 8) Kosona, 9) Pylos, and 10) Knossos, Crete.

important for palatial centres. Therefore, a more realistic image of the variety of animal species present in LBA Greece can be based on the faunal evidence recovered in excavations beyond the palatial contexts (Halstead 1999b: 150).

Animal bone material discovered from LBA excavations in Greece is subject to various biases that are often related to the settings of past excavation projects. Past excavation publications might provide insufficient or no context data for the deposits from where faunal material was retrieved, or retrieval methods very likely influenced species presentation and bone preservation.

Many aspects of retrieval and storing affect species presentation in zooarchaeological material. Larger bones are easier to detect than smaller ones. The breakability of bones varies among species, and the number of bones is not equal among all taxa. Human activities, such as extracting the bone marrow from the bone or cooking with fire can cause the fragmentation of the bones into unidentifiable splinters. Bones may be consumed by dogs, rodents and other scavengers during the depositional process, leaving gnawing marks, and missing and fragmentary bones (Peres 2010: 25-26). Zooarchaeological material is best recovered by sieving, although depending on the mesh size, smaller bone fragments can still escape detection. Additionally, individuals with an older age may be better represented, since the bone material of young individuals is more vulnerable to breakage. Wet sieving is known to enable the recovery of neonatal specimens (Halstead 2011b: 753-71).

The recovered animal bone remains are examined to define the species, sex, age, shape, and size of the animal. Faunal collections can be used to determine population sizes and age and sex distributions. Marks on the bones can shed light on the exploitation, processing and consumption of animals by humans. Animal diet, measured in the stable isotope values of bone material, can be used in environmental reconstructions and it can help to determine animal husbandry practices, for example, whether fodder was grown as a supplementary food resource (Albarella 2017).

To observe the relationship of different animal species at the archaeological site, the number of animals is usually calculated. The determination of the number of individuals is based on the calculation of bone fragments. There are several ways to express the results, of which specimen count and individual count are the most common (Albarella 2017). Number of Identified Specimens (NISP) expresses the number of each individual bone, tooth, or other 'specimen' recovered. Species identification follows as secondary to this count of the number of faunal 'units'. Minimum Number of Individuals (MNI) calculates the number of individual animals per species. It is estimated from the most diagnostic elements of the bone material after the collection has gone through taxonomic (species) identification, count (NISP), and the recognition of sex and age. A diagnostic element can be, for example, a large bone such as the humerus or pelvis, which is easily recognizable and measurable (Peres 2010).

Textual evidence on LBA animal husbandry

Animals mentioned in Linear B texts are cow, ox, sheep, goat, pig, wild boar, donkey, horse, dog, and deer (Ventris and Chadwick 1956: 129–30). Sheep are most numerous, and the management of sheep flocks, as well as the production of wool, are arguably the best documented industries of the Mycenaean archives (Halstead 1993: 343). These are mostly records of flocks that were owned or controlled by the palatial administration and kept mainly to produce raw materials for the textile industry (Halstead 1993: 343). Sheep and goats were also exploited for their meat and milk, although such information is less visible in the Linear B archives. Only cheese is briefly mentioned in the Pylos tablets (Ventris and Chadwick 1956: 132). The largest records of sheep management practices come from the palatial archives of Knossos and Pylos. The total number of sheep controlled by the Knossos administration has been estimated at 100,000 (Rougemont 2014: 343), with the most important Linear B tablet series Da-Dg alone totalling *c*. 82,000 individuals (Halstead 1999b: 152-54). In Pylos, the estimated number of sheep is considerably smaller, *c*. 10,000 heads (Halstead 1999b: 162).

At Knossos, the sheep belonged to flocks that ranged from 30 to 400 heads, often rounded by multiples of 50 (Halstead 1999b: 154). The Pylos flocks range from 10 to 230 heads (Halstead 1999b: 162–63). In both palatial centres, part of the sheep flocks was outsourced to intermediaries known as 'collectors', who supervised the processing of wool into textiles (Halstead 1993: 344 and 358). Pylos administration practiced a more systematic separation of flocks than that of Knossos. Here, sheep exploited for their wool were exclusively wethers (castrated males), and they were kept separate from other flocks (Chadwick 1963). At Knossos such a division of herds was less notable, and the wool flocks included both sexes (Halstead 1993: 359).

The Argive Plain palatial centres have not yielded as much textual evidence of sheep husbandry practices as the centres in Knossos or Pylos. Linear B texts derive mainly from Mycenae and Tiryns. Many of the tablets of Mycenae record wool, woollen cloths, and workers in the wool production and textile industries (Bennett Jr. and Chadwick 1958; Varias Garcia 2012: 155). A few tablets indicate that numbers of sheep were also recorded in Mycenae, but due to their fragmentary nature, reliable estimates of flock sizes cannot be established (Rougemont 2014: 343). However, some indications of the number of sheep can be estimated based on the amount of wool recorded. Varias-Garcia (2012: 157) has estimated that the total amount of wool mentioned in the Mycenae tablets comprises *c.* 1371kg. Similar estimates have been made for Knossos, where the amount of wool used annually by the palace was 30,000-50,000kg. It is clear that these amounts belong to completely different categories, and the records of Mycenae are probably incomplete. The wool production target marked in the records is *c.* 750 grams[28] per sheep. Nosch (2014: 394) calculated that the 1371kg of Mycenaean raw wool would amount to 1828 sheep. If the wool figures refer to processed wool, the number of sheep needed to produce it could have been double.

Halstead (1981: 328) suggests that a Neolithic village with 100 inhabitants would have needed 200-500kg of wool for their annual clothing requirement – that means up to 1000 sheep. He further argues that the 70,000kg of wool produced in Knossos annually (although note the revised figures above) would clothe some 20-30,000 people. Considering such figures, the amount of wool recorded in the Mycenae tablets seems small. The fragmentary data of the Mycenaean tablets likely give us only a glimpse of the wool production practiced by palace personnel. Wool production probably took place outside the palace too, and but remained unrecorded. The land area of the Argive Plain (*c.* 230 km2) is much smaller than the area controlled by Pylos (*c.* 2500 km2) or Knossos (*c.* 8000 km2), and one could therefore assume that the population of sheep here was much smaller (Aravantinos and Vasilogamvrou 2012: 343-45). In the limited space of the Argive Plain, management of large flocks would have had negative consequences for land use. It is possible, however, that larger wool-producing flocks were taken outside the plain, to regions with more grazing space.

Pigs appear in the texts either in large herds, or as single animals being fattened or 'finished'. This seems to suggest a special purpose for these animals (Chadwick 1972: 116; Halstead and Isaakidou 2011a: 171; Ventris and Chadwick 1956: 132). The Pylos and Knossos tablets record pig herds consisting of dozens, or even hundreds of animals. Halstead and Isaakidou (2011a: 171) suggest two types of pig husbandry based on the Linear B evidence: small-scale, in which local herders looked after a few pigs which were intentionally fattened, and large-scale, in which palatial centres (and their herders) controlled large herds of dozens of animals, which most likely foraged in the landscape instead of being enclosed in pens. Both practices have parallels in modern rural pig husbandry (see pp.109-111).

Cattle appear in the texts in small numbers, although the Pylos tablets mention a herd of 90 heads. More common are indications of cattle herders, who are mentioned in large numbers (i.e. 280, 90, 60) in the Pylos tablets (McInerney 2010: 63-64). References to oxen are also found in the Thebes sealings, which likely recorded contributions to religious (sacrificial) ceremonies (Palaima 1992). In Pylos, herding (and perhaps also the ownership) of cattle was divided between three parties: the palace, communities, and elites (McInerney 2010: 63). The context in which individual cows and oxen (male and female cattle) are represented is usually religious or ritual (Palaima 1992: 469-72).

Oxen had a special status in Knossos, as they were mentioned by name in the local Linear B records (Kajava 2011: 59; McInerney 2010: 50; Ventris and Chadwick 1956: 132). It has been suggested that this naming, which usually happened by describing the physical characteristics of the animal, was meant to keep records of the more valuable animals (Kajava 2011: 60). Oxen name records may also have been kept in Tiryns, although the evidence of this is fragmented (Brysbaert 2013). Textual references (in Pylos tablets) to working oxen pairs or yokes suggest they were used as plough animals in agricultural and building activities. It is possible that these expensive animals were loaned by the palace to the local farming communities (*damoi*) during seasons of heavy labour such as tillage and harvest (Brysbaert 2013: 64–69; Halstead 1995a: 18). Record-keeping ensured that the animals were returned to the palace in pristine condition (Brysbaert 2013: 65). Leasing was a successful means for the palatial administration to hold power over the farming communities and make sure it received part of the harvest in return (see pp.8-10). However, some *damoi* also owned oxen, at least in Pylos. This could mean that many farming communities had access to animal workforce, which would have enabled the cultivation of larger and more faraway areas. Traditional agriculture in Greece was dependent on animals for traction power and transportation. Since people tended to live in nucleated villages, distances to fertile valleys and plateaus were considerable and cultivation became impossible without transport animals (Halstead 1987b: 84).

McInerney (2010: 65) suggests that, at Pylos, the rural communities hired professional herders to take care

[28] One unit of wool in the Linear B records is estimated to have weighed *c.* 3 kg. The Knossos tablets (e.g. Dk/Dl series) indicate different wool production targets for flocks of male and female sheep (the latter including lambs as well). One unit of wool could be produced by four wethers, each of which could produce *c.* 750 grams of wool (Halstead 1999b: 156; Nosch 2014: 373). For breeding ewes, the production target was 600 grams per individual, if it is assumed that lambs are not used for wool production, and 300 grams per individual if lambs were expected to produce as well (Rougemont 2014: 349-350).

of the cattle in areas further away. Ethnographic studies of traditional sheep and goat herding point to a system in which one or more individuals took care of large flocks which consisted of the animals owned by multiple individual households (e.g. Koster 1977). Thus, the practice described by McInerney could refer to a small-scale communal system of animal herding. In the Thebes sealings (Wu 53 and F Wu 76), oxen, pigs and sheep are mentioned together with an ideogram *171 and quantities of 30-36 units. Palaima (1992: 464–65) has suggested that the ideogram could indicate fodder, and the quantities may refer to the number of days for which fodder was needed when the animals in question were moved from the island of Euboia to Thebes. The suggestion of fodder use for animals is interesting since the systematic cultivation of fodder crops would have had an impact on the LBA agricultural practices and land use. The Argive Plain palatial centres have not yielded textual evidence that would point to landownership or specific herding practices, but the valleys of Berbati and Nemea would have offered adequate space for remote pasture, especially for Mycenae (Wright 2004). Fodder cultivation besides food crops may have been a common practice, as it has traditionally been in the Argolid (Forbes 1982; Koster 1977).

References to horses and donkeys are rare in the texts, even though iconographic evidence commonly depicts horses with chariots in battle scenes (Immerwahr 1990: 124-28). Dogs are only mentioned in relation to hunting (Ventris and Chadwick 1956: 132). There are suggestions of deer being used for a variety of purposes, such as sacrifice and games, or as semi-managed, herded domesticates (Hamilakis 2003: 244; Yannouli and Trantalidou 1999: 254). Finally, boar is mentioned (along with cattle, pig, sheep, goat) in relation to sacrificial feasting (Palaima 2004: 228), although there are arguments according to which the text refers to a male pig instead (Bendall 2007: 84).

Linear B texts have yielded valuable information on the animal husbandry of the palatial centres of Knossos and Pylos, but for the Argive Plain animal husbandry they are less informative. Some of the information, for example the fact that larger herds were managed by Mycenaean palaces (Halstead 1999b) and that large animals such as oxen were used in agricultural work and leased out to communities by those who owned them (Brysbaert 2013; Halstead 1995a), can perhaps be applied to the Argive Plain husbandry system too. However, it would be unwise to draw any further conclusions about the administrative control of herds in the Argive Plain based on these external sources. Textual evidence should be examined together with faunal data to attempt a more comprehensive understanding of the animal husbandry of the LBA societies of the Argive Plain.

The LBA Argive Plain zooarchaeological evidence

The following section gives a summary of the published zooarchaeological assemblages of the Argive Plain. The sites where faunal material has been recovered are Mycenae, Tiryns, Lerna, Asine, and Midea. The latter part of the chapter examines the environmental and dietary requirements, and the husbandry practices of the main animal species present in the LH III faunal assemblages of the Argive Plain. Knowledge of these variables enables a better understanding of the ways cultivation and animal husbandry were integrated into the local farming activities. In particular, observations on animal remains in settlement contexts can help to define the role of animal products (meat and dairy) in the local diets.

Unfortunately, the published archaeozoological data retrieved from the LBA Argive Plain sites do not allow for the quantification of the numbers of animals, and therefore any estimates of land use concerning pasture space remain hypothetical. Pasture size and location, and animal dietary requirements can be examined through ethnographic analogies and recent data on animal spatial needs, although with caution. The sex and age distribution of faunal remains recovered in archaeological contexts can give indications to how these animals were exploited in the past. As Tzevelekidi and co-researchers (2014: 429) summarized it; with cattle, sheep and goats, high numbers of young males slaughtered soon after birth suggests a focus on milk production, as the mother's milk is spared for human consumption, and the males are not kept for wool production. Focus on meat production can be suggested if the sample includes a high number of adolescent males. Younger individuals are preferred for their meat, and males are usually not needed for reproduction in large numbers. High number of adult males who often show signs of castration in sheep suggests a preference to wool production, while the same for cattle indicates their use for traction and other power-related duties. The faunal data of the Argive Plain has been retrieved over decades of excavations, some of which are ongoing (e.g. Tiryns, Midea, Mycenae Lower Town). Lack of detailed descriptions of retrieval methods of these assemblages makes it difficult to analyse and compare them with each other. Due to the lack of sieving, biases towards certain species with larger and less fragile bones may occur (Reitz and Wing 2008: 157). In most of the Argive Plain assemblages, the number of recovered remains is low (from a few to a few dozen specimens) and the quantification of numbers of animals per species, species abundance, or sex and age distribution is not possible. These faunal data enable mainly a descriptive analysis. As with the textual evidence, the overview here focuses on the main domestic species, sheep, goat, cattle, and pig, since these species dominate the LBA Argive Plain assemblages. A list of species recovered is provided in Appendix 6.

The Argive Plain assemblages

Late Helladic and LH III faunal remains from Mycenae, Tiryns, Lerna, Asine, Tsoungiza, and Midea have been recovered and at least partially published. The following section gives a concise overview of these assemblages.

A selected assemblage of faunal remains from Mycenae, collected for an isotope analysis, has been published by Price and co-authors (2017). Table 5.4 presents the number of individuals per species from two different contexts: the Petsas House and the Cult Centre of Mycenae (Price *et al*. 2017: 119-122, Tables 1 and 2). The Petsas House was located outside the citadel walls, and included residential, storage, and industrial elements. The faunal samples chosen for the isotope study were recovered from a well deposit. The Cult Centre was inside the citadel walls, connected to the main palace, and contained remains that have been interpreted as related to offerings and rituals (Price *et al*. 2017a: 117-19). Because the assemblage lacks quantitative information, and information of sex and age, species ubiquity cannot be determined. Furthermore, only the main domestic species, sheep, goats, cattle, and pigs have been examined. Thus, the only conclusion that can be drawn based on these data is that these species were present, and likely consumed at LH III Mycenae.

Of the Argive Plain sites, Tiryns has the most comprehensive collection of published LBA faunal remains: *c*. 60,000 bones or bone fragments have been recorded. The finds were recovered mainly in the area of the Lower Town in waste deposits (von den Driesch and Boessneck 1990: 87-89). Such context could derive from household consumption. According to Halstead (2003: 172), the Tiryns assemblage was collected without systematic sampling. This has likely resulted in significant biases in the recovery of smaller bones, including those from young animals, and from birds and fish. Domestic animals make up 97.8 percent of the total collection (see Appendix 6). The Tiryns faunal remains are expressed as the Number of Identifiable Specimen (NISP). The Minimum Number of Individuals (MNI) is not given. Therefore, the assemblage cannot be directly compared with other collections where only the MNI is given (e.g. Midea).

At Tiryns, sheep/goat[29] numbers were high for the entire LH III period,[30] while the number of cattle increased during the LH IIIC. At the same time, the number of pigs decreased. Of the sheep and goats at Tiryns (including everything from pre-Mycenaean to LH IIIC late), 17.4 percent were less than 1 years old, while 44.3 percent were between 2 and 4 years old, and 20.6 percent were older than 4 years of age (von den Driesch and Boessneck 1990: 97, Table 8). A few castrated males were also detected (Halstead 2003: 177). This age distribution, with adults dominating, but with a relatively low share of neonatals and lambs could potentially reflect a focus on wool and hair production instead of meat or dairy exploitation. Similarly, cattle were represented by a relatively high number of older adults (von den Driesch and Boessneck 1990: 97, Table 8), and an equal distribution of males and females. According to Halstead (2003: 176-177) the adult deaths among cattle suggest they were exploited for secondary products, such as traction. This is also implied by the presence of castrated males. He (ibid.) further points out that piglets and adult females dominate the pig samples, which could refer to an interest in producing larger litter sizes.

The faunal remains of Lerna have been published in three separate publications, by Gejvall (1969), Wiencke (1998), and Reese (2008); the latter combining data from the two previous publications. The finds derive from various deposits, most of which are floor and fill deposits within the rooms of the settlement (Reese 2008). Similar to the other collections, retrieval methods are not discussed. Overall, the numbers of individuals per species remains low. Cattle shows notably lower numbers compared to sheep/goats and pigs. Due to the small numbers, not much can be said about their relative importance to animal husbandry. The published Lerna LH remains do not include age estimations outside the few mentions of 'juveniles' with each species (Gejvall 1969; Reese 2008).

The faunal recoveries of Midea derive from the excavations at the enclosed citadel area, and from various contexts, which mostly include floor deposits, and the debris and fill that resulted from the destruction of the citadel in the end of the LH period (Reese 1998; 2007). Retrieval methods, for example, whether samples were sieved, are not explained in detail. The combined MNI of the Midea faunal remains suggests a relatively equal distribution of the main domestic species at the site (Table 5.4). A small number of faunal remains from the Midea acropolis was additionally recorded by Gejvall in 1983. The results suggest the dominance of cattle (61 percent) over other domestic species during the LH III period.[31] If, however, all fragments

[29] Even though sheep and goat are discussed here together (since a species level identification is not always possible), the sheep-goat ratio remains roughly the same 3:1 over time, sheep being the dominant (von den Driesch and Boessneck 1990: 92-93).

[30] The LBA layers include LH IIIB1, IIIB2, IIIC early, IIIC mature, and III C late, all of which are of interest to this study. Additionally, the early Mycenaean layer (LH I and II) can be included in the analysis, although the total amount of finds in this layer is small (536 specimen) (von den Driesch and Boessneck 1990: 89, table 1).

[31] Gejvall divided the LH III finds chronologically to pre-catastrophe

and splinters are included, the shares are more equal (cattle 45, sheep/goat 44, and pig 11 percent) (Gejvall 1983: 51, Table 4). The number of identified bones (total of 609) and fragments (total of 1880) is, however, too small to make conclusive interpretations of species abundance. The finds of sheep and goats in the LH IIIB and C contexts in Midea suggest a generally young age for the individuals, although there are no references to younglings less than six months old Adulthood is here defined according to Halstead (2003: 174) as 2-3 years old for all domestic species. Specimen of two groups, lambs under 10 months of age, and young adults from 1 to 2 years of age appear to be abundant in the assemblage (Reese 1998: 281-82, Table 2; 2007: 397-98). In the 1998 study (Reese 1998: 284, Table 3) of the Midea remains, the number of adult and pre-adult individuals among cattle appear relatively equal. Age groups 1-1.5 years, and 2-3.5 years seem to be best represented. Specimen representing young (less than 1-year-old) individuals are rare. In the subsequent 2007 study (Reese 2007: 398), more adults of 2 years and older seem to be present. Pig remains appear to represent both fully mature individuals (2 years or older), and young individuals (less than one year) in somewhat similar shares (Reese 1998: 284-285, Table 4; 2007: 398).

The MH III-LH III Tsoungiza faunal material derives from dumps, pits, and external surfaces recovered in the excavated settlement over two seasons in 1984-1986. The material is divided into two chronological groups, the 'pre-palatial' MH III-LH II, and 'palatial' LH III. The Tsoungiza assemblages were retrieved through hand-picking, and dry and wet sieving, which count for a less biased retrieval process than in many other Argive Plain sites (Halstead 2020: 1077-1078). The specimens are expressed as Minimum number of Anatomical Units (MinAU), and the two chronological groups contain between 700 and 900 MinAU each (Halstead 2020: 1078, Table 17.1; 1086).

Majority of the Tsoungiza assemblage consist of the remains of four main domesticates, sheep/goat, cattle, and pig. The MinAU of pig remains relatively high throughout the Mycenaean period but decreases by ten percent from the MH III-LH II to the LH III. Sheep forms the second most common species of the assemblage in the MH III–LH II (29%) but also decreases slightly in the LH III (22%). Similar decline is visible with goat (19% in MH III-LH II, and 17% in LH III). However, the identification of these two species remains mostly at a sheep/goat level, and therefore fluctuation in their numbers cannot be seen as indicative of changes in consumption or management practices. Cattle increases notably from MH III-LH II (14%) to the LH III (33%). The share of wild species (from 4 to 2%) and minor domesticates such as dog, horse, and donkey (from 2 to 5%) remain low throughout the LBA. Of the pig remains, a notable share consists of neonatal specimens, while in cattle, very young specimens are the rarest (Halstead 2020: 1080-1088).

The general trends of the Tsoungiza assemblage suggest that pigs were slaughtered much younger than sheep/goats and cattle. Slaughtering very young pigs refers to their exploitation for meat. Evidence of their measurements could potentially suggest that majority of the adult pigs were females. These data correlate well with LBA Tiryns (see above), where they were suggested to indicate an interest towards producing larger litters (Halstead 2003: 176-177; 2020: 148). In the LH III, the majority of cattle and sheep/goats reached the age of three years or older indicating full maturity. The age of sheep/goats seems to increase in the LH III, suggesting their exploitation for secondary products such as wool and hair. Milk production is less likely due to the low number of neonatals in the assemblage. Sex ratio referring to female dominance in sheep/goats disputes these conclusions, however. The assemblage is less conclusive of cattle exploitation, but could potentially refer to their use as draught animals due to the relatively even sex ratio, high share of adult individuals, and some signs of pathologies (healed fractures and bony growth) (Halstead 2020: 1151-1152).

The Asine Bronze Age faunal material accumulated during several excavation campaigns, and was mostly hand-picked rather than sieved (Macheridis2017a: 163). Thus, small bones (e.g. birds and fish) are likely facing underrepresentation, and due to several decades spent in various storage facilities, the collection has been exposed to additional risk of post-depositional fragmentation (Macheridis 2017: 163; 2018: 78). The data used in this study derives from the publications of Macheridis, who examined the Asine faunal remains in her PhD dissertation (2018), and two related papers (2017a and b)[32] that focus on the Middle Helladic period. Of the identifiable and dated remains, 1530 specimens could be dated to the Late Helladic and 522 to the LH IIIC period. In addition, 488 specimens were dated to MH III-LH I (Macheridis 2018: 63, Table 2).[33] The MH III-LH I faunal remains derive from fill and open-air strata related to two housing quarters, one located in the Asine Lower Town, and one in Barbouna Hill (Macheridis 2018: 97; see also p. 29 for the settlement layout of Asine). Majority of the LH IIB-IIIB remains could not be related

(pre- LH IIIB), catastrophe (LH IIIB), and post-catastrophe (post LH IIIB) groups.

[32] A small collection of the faunal remains was studied by Gejvall in the 1970s, but his study remained unpublished. Moberg Nilsson published her examination of selected faunal material in two papers (1992, Moberg Nilsson 1996).

[33] Of the 17,498 bones dating to Bronze Age (EH I-LH IIIC), 35 percent (some 6000) could be identified by taxon by Macheridis (2018: 62).

Table 5.4. The Minimum Number of Individuals (MIN) in three LH III Argive Plain sites, Mycenae, Lerna, and Midea. The assemblage of Mycenae consists of 99 selected individuals from two separate contexts (Price *et al.* 2017). The Lerna assemblage includes the Lerna V+VII, VII+V, VII and VII+Class[34] layers (Reese 2008). The Midea assemblage includes the LH III[35] period, which was published on two occasions (Reese 1998 and 2007). The numbers of individuals from the sites should not be compared, because the Mycenae assemblage represented only a selected number of individuals, not the complete collection. There are further chronological discrepancies between the studies.

Species	**Latin name**	**Mycenae**			**Lerna**	**Midea**		
		Petsas House	Cult Centre	Total		1998	2007	Total
Sheep	*Ovies aries*	19	13	32	-	-	-	-
Goat	*Capra hircus*	16	6	22	-	-	-	-
Cattle	*Bos taurus*	3	11	14	5	36	177	213
Sheep/goat	*Ovis/Capra*	8	8	16	15	54	198	252
Pig	*Sus scrofa*	9	6	15	15	38	164	202

to a primary context. 123 specimens were recovered from deposits contextualized with the habitation area of Barbouna Hill (Macheridis 2018: 98). The LH IIIC material could not be firmly related to specific areas of the Asine dwellings, but derived from a variety of contexts around the site (Macheridis 2018: 99).

In Asine, sheep and goats increase in numbers notably in the MH-LH shift (Macheridis 2018: 97-98). The share of adult individuals is high, showing a slight dominance of males over females (Macheridis 2017a: 166). Sheep/goat remains abundant in the following LH IIB-LH IIIB periods (38%) (Macheridis 2018: 97-98), and in the LH IIIC (32%), although now with a small decline (Macheridis 2018: 99-100). Pigs are common in the MH I-II, the material mostly representing young adults and juveniles (below 12 months up to 3.5 years). Males are slightly more common than females (Macheridis 2017b: 136). In the LH IIB-LH IIIB, pigs form the second largest exploited domesticate (24%), even though their numbers steadily decrease from the MH/LH shift towards the LH IIIC (14%) (Macheridis 2018: 97-98). The share of less than one-year-old pigs increases in the LH, with a clearer dominance of males (Macheridis 2017a: 166-168). In the LH IIB-LH IIIB, cattle are the third largest group of domesticates (19%) (Macheridis 2018: 97-98). The share of young and juvenile individuals decreases towards the LH while the sexing of cattle shows male dominance throughout MH and LH (Macheridis 2017a: 166). In the LH IIIC, cattle face a significant increase (29%) (Macheridis 2018: 99-100). Alongside cattle, the share of deer in Asine is uniquely high in the LH II-IIIB periods (19%) compared to other Mycenaean contexts in the Argolid. The number of deer specimens grows in the LH IIIC to a startling 25 percent (Macheridis 2018: 99-100).

Differences in retrieval methods, analysis, and research foci between investigations do not allow a detailed, systematic comparison of these assemblages. The small sample size at Lerna (Gejvall 1969; Reese 2008; Wiencke 1998), the context and chronology related biases at Asine (Macheridis 2018: 97-99), and the selective sampling at Mycenae (Price *et al.* 2017) prevent any detailed analysis of flock sizes or other animal management strategies. However, some general observations be made based on the Midea (Reese 1998, 2007), Tsoungiza (Halstead 2020), Asine (Macheridis 2018) and Tiryns (Halstead 2003; von den Driesch and Boessneck 1990) assemblages, according to the age and sex distribution of certain species. The following section attempts to incorporate these limited data into a wider discussion of traditional animal husbandry strategies in the LBA Argolid. The section is divided according to species.

Domestic pig (Sus domesticus)

Pigs are often considered as stable animals that do not require large territories, and which consume mostly human-provided food, such as household waste. Ethnographic evidence on rural pig husbandry in the Mediterranean contradicts this view by showing that management methods of large free-roaming herds have often been favoured. In modern rural Greece, extensive pig herds are kept in mixed agricultural farms. These pigs graze in similar ways to cattle, sheep and goats, moving around several kilometres a day. A pig herder and their dogs keep the herd away from cultivated fields, since these herds can do severe damage to crops (Halstead and Isaakidou 2011a: 161-64). The size of pig pastures varies according to husbandry methods, region, and other variables. In modern Sardinia, pig pastures are rarely located further than a 10 km radius from settlements, and usually herds return to pens for the night (Albarella *et al.* 2011: 155). Usually, a pig farmer has at least one free-ranging herd in their ownership. If a herder manages multiple herds, they might apply distinct methods for different herds – some herds or animals can be kept close to the settlement and (partially) enclosed, while others are left to roam more freely (Albarella *et al.* 2007: 300-301). In modern rural Sardinia and Corsica, pigs are usually kept in herds of up to 50 individuals (Albarella *et al.* 2007: 298). Similar 'semi-free' herding strategies are used in Spain where, however, herd sizes range from 200 to 2700 heads, although most fall between 50 and 150 (Hadjikoumis 2012: 356-58). Water and shelter are particularly important for pigs because of their need to thermoregulate. Pigs lack the ability to sweat and cannot be exposed to direct sun or extremely hot temperatures for too long (Choquenot and Ruscoe 2003: 23-25).

Pigs have a versatile diet, and those who are left to feed freely in the natural environment can sustain themselves quite well. Woodland access provides pigs with acorns (particularly from deciduous oak), which, if the rainfall is favourable, can provide the animals with food from autumn until June-July. Other food items provided by natural foraging are beech mast (fruit), chestnuts, fungi, snails, herbs and various kinds of shrub vegetation, roots, leaves and buds. Most of these items were available in the LBA Argive Plain landscape (pp.86-90 and appendices 4 and 5). During summer, human support might be needed to ensure necessary nutrition, for example in the form of grain fodder (Halstead and Isaakidou 2011a: 166). In Sardinia and Corsica such additional feeding takes place once a day for most of the year, however (Albarella *et al.* 2007: 301). In the fall pigs are often left to feed on the stubble fields (Halstead and Isaakidou 2011a: 166).

In Greece a few pigs are commonly kept as household animals in which case their movement is limited, and they are fed with household waste. Such practices can be uneconomical, since an adult pig is known to eat as much as an adult man (Halstead and Isaakidou 2011a: 167). The enclosing in a pen often takes place when they are purposefully fattened before slaughter. Fattening is important for the production of meat and fat (Albarella *et al.* 2011: 154). In the recent history of Greece, only those who could afford to live as full-time farmers, and/or those who owned a sheep or a goat herd could afford to also keep pigs (Halstead and Isaakidou 2011a: 167).

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As mentioned on p. 105, the Linear B evidence from Pylos describes fattened pigs (Chadwick 1972: 116; Ventris and Chadwick 1956: 132). Such fattening could have taken place because the animals were prepared for feasts or rituals (Halstead and Isaakidou 2011a: 169). Recent isotope evidence of pig bones in Late Helladic III Mycenae points to two types of diets and, perhaps, to two types of husbandry practices. The remains of nine pigs recovered from the Petsas House point to a diet consisting of domestic waste. By contrast, the six individuals found at the Cult Centre located inside the palatial complex, seem to have been fed with grain. Both groups consumed standing water. It seems possible that these Mycenaean pigs were deliberately managed with different husbandry methods: the Petsas House pigs enclosed in pens dependent on human care and perhaps fattened, and the Cult Centre pigs in semi-free ranging herds with an access to stubble fields, or fed with cereal fodder, perhaps to produce better quality meat (Price *et al.* 2017a: 123-24). Feeding with grain could also indicate additional foddering in the dry summer season when pigs need additional nutrition, but since isotope values usually measure diet over extended periods of time (see p. 126), it is more likely that the results represent a regular food intake. Although free-ranging has been a common way to raise pigs in more recent history in the Mediterranean, the scarce evidence of pig diets at Mycenae indicates that they were kept close to the settlements and their feeding was controlled by people.

Of the Argive Plain assemblages, the zooarchaeological data of LH III Tiryns (Halstead 2003: 176-177; von den Driesch and Boessneck 1990) and LH III Tsoungiza (Halstead 2020: 148) show high numbers of young piglets, and female dominance in adult individuals. Number of young individuals is also high in LH Asine, but males dominate the adult assemblage (Macheridis 2018: 97-98). In Midea, both juveniles and mature adults appear to be present in the LH III (Reese 1998: 284-285, Table 4; 2007: 398). Female-dominance with high number of juveniles refers to meat economy and tendency towards producing large litter sizes, since multiple females were kept for reproductive purposes (Halstead 2003: 176-177). It cannot be said, however, if this would have been related to pig management by free-roaming. In general, pig declines steadily compared to ovicaprids towards the end of the Late Helladic period in all of the investigated Argive Plain sites, also, according to Gejvall (1983), in Midea. This seems to point to a shift in animal management and consumption towards more intensive use of secondary products. Only in Asine, pigs appear to decrease less compared to the other main domesticates during the Middle and Late Helladic periods, and remain the second largest animal group in the LH III (Macheridis 2018: 99). In general, Late Helladic pig remains of the Argive Plain provide little conclusive evidence for consumption and management practices.

Domestic cattle (Bos taurus)

While cattle were important for meat production, cows and bulls or oxen were important in different ways in the Late Bronze Age agricultural economy. Oxen, castrated bulls, were vital for ploughing. They were commonly used yoked in pairs to plough cultivated lands (Halstead 1995a: 11; Palaima 1992: 464; Sherratt 1981: 162). Besides agricultural tasks, oxen could be used in other tasks that demanded traction power, such as the construction of the monumental walls of the Argive Plain palatial centres. For example, for the Tiryns 'Unterburg' wall construction, Brysbaert (2013, 82) has estimated a need for five pairs of oxen (with 100 men) over the course of six years. Female cows could have also been used for traction (Halstead 2020: 1152), while they were exploited for their meat and milk, and used to produce offspring. In the LBA, the benefits of secondary products – traction power, milk, dung and perhaps also blood – were well-known and used (Isaakidou 2006; Sherratt 1983).

Of the Argive Plain faunal assemblages, the adult-age profile of cattle at Tiryns (von den Driesch and Boessneck 1990) suggests that they were exploited for secondary products such as milk and traction. The latter is also implied by the presence of castrated bulls, and the relatively low number of young individuals in most of the assemblages. Cattle increases quite notably in LH IIIC at Tiryns (von den Driesch and Boessneck 1990: 93, Table 5) and Asine (Macheridis 2018: 100). It is also abundant in LH III Tsoungiza (Halstead 2020: 1088) and possibly in Midea (Gejvall 1983). The LBA Midea samples (Reese 1998, 2007) do not exhibit such clear indications for specific exploitation strategies, although a larger number of adults (older than two years) and pre-adults (1-2 years old) seem to be present in contrast to very young individuals. The sex ratio shows rather equal numbers of male and female cattle in Tiryns (von den Driesch and Boessneck 1990: 93, Table 5) and Tsoungiza (Halstead 2020: 1156), but in LH Asine, males are more abundant (Macheridis 2017a, 168) Overall, each assemblage suggests the exploitation for secondary products. Based on a low number of neonatals in the assemblages, Halstead argues (2020: 1152) that traction might have been preferred over dairy at least in Tsoungiza. Sheep and goat milk was likely more accessible for regular use in average Mycenaean households. However, when available, cow milk could have been used in human cuisine as well, especially towards the end of the LH III period when cattle increased in many places in the Mycenaean Argive Plain. Therefore, dairy production and cattle pasture requirements are both considered in the reconstruction of the LBA agricultural system (pp.166-168).

As large animals, cattle consume considerable amounts of greens. They might prefer grasses and herbaceous vegetation, but can also consume a versatile variety of leaves, acorns, shrubs and young twigs (Gregg, 1988: 102; Schoenbaum *et al.* 2018: 106). Microbotanical data (pp.86-90) from the Argive Plain suggests that non-arboreal ('non-tree') plant species, particularly grasses and herbs, reportedly increased in the area during the Bronze Age, indicating more open grasslands (Hansen and Allen 2011: 881; Jahns 1993: 201-2).

It was mentioned earlier, that loaning oxen yokes to farming communities during seasons of heavy work was likely a strategy for the Mycenaean palatial centres to establish and maintain power relationships. Oxen would have required additional feeding during the ploughing season in the field or when working on construction sites. In fact, Brysbaert (2013: 72) has suggested that the Linear B evidence indicates that the palaces provided fodder rations of grain to people who had oxen on loan. This means that oxen would have been regularly fed with grain while at work. In modern rural Greek communities, feeding draft animals with additional fodder has been common (Halstead and Jones 1997: 280), although it is often dependent on what is available each year rather than based on systematic fodder crop growing (Halstead 2014: 290-291). If the palace provided the fodder, it means that fodder crops could have been purposefully grown, stored, and distributed. This would have been possible if part of the (palatial) cultivation land was dedicated to fodder crops, for example vetches or barley (although barley is also considered as food crop in this study). Growing legumes on fallowed land could also have provided a means to a fodder stock. Crop-processing by-products have also often been used as animal fodder (p. 100).

Rough estimations on the pasture requirements per individual animal can be produced by estimating the size of the cow or ox. The size of the cow is also related to the amount of milk it can produce. A modern dairy cow weighs roughly 600kg and produces *c.* 3000kg (*c.* 3000 litres) of milk a year (Poncheki *et al.* 2015: 189). Bronze Age cattle were smaller (Gregg 1988: 105; Manning *et al.* 2015: 1). Smaller cattle sizes suggest, in turn, smaller pasture requirements, and, consequently, reduced milk yields.

A compilation of faunal remains from Europe points to a 33 percent reduction in cattle size from Early Neolithic to EBA (Manning *et al.* 2015: 12-14). This reduction suggests an average weight of 335kg for the Bronze Age cow, 402kg for an ox, and 469kg for a bull, a weight range previously known from Classical antiquity

(Raepsaet 1993)[34]and.[35] However, the wither heights of the LBA Tiryns cattle suggest an even smaller size for the animals. The height is comparable to specific cattle breeds of Greece (see Appendix 7) and suggests an average weight of 200-300kg per individual animal. If compared with similarly-sized African Zebu-cows, the milk production of one cow would be *c.* 1000 kg a year (Dahl and Hjort 1976: 144–45, 164–65). It is acknowledged that modern thresholds for cattle pasture sizes might not correlate well with Bronze Age pasture, especially if cattle exploitation in the ancient past was less geared towards milk production. Nevertheless, modern figures, currently best available, are in this study considered to provide a reasonable starting point to pasture size estimates in the LBA Argive Plain, as they can provide an idea of the maximum pasture needed by animals needed for human consumption only.

Sheep (Ovis aries) and goat (Capra hircus)

Sheep and goat are often classified together in zooarchaeological reports, because until recent years distinguishing the two species based on their bone material has been challenging. The pasture and dietary requirements of these two species do, however, vary (Chang 1992: 76). Textual evidence has particularly shed light on the Bronze Age sheep economy in the Aegean (pp.104-105). Bronze Age goat husbandry is less well known from the Linear B tablets, but it can be examined through ethnographic parallels.

Finds of sheep and goats in the Argive Plain samples are usually abundant over other domesticates for most of the LH III period. In Asine, the notable increase of sheep/goats in the MH-LH and towards the LH III coincides with the expansion of habitation to Barbouna Hill and seems to be related to a growing interest in secondary products such as wool and dairy (Macheridis 2017a: 166). Secondary products exploitation is most likely the reason for sheep/goat abundance at the other sites too. In many of the assemblages (i.e. Tiryns, Tsoungiza, Asine), the share of lambs (less than 6 months old) is low compared to the shares of young adults and mature adults (Halstead 2020: 1145-1152; Macheridis 2018: 97-98; von den Driesch and Boessneck 1990: 97, Table 8). In Asine and Midea, juvenile sheep/goat of less than 10 to 12 months are well represented, however (Reese 1998: 281-82, Table 2; 2007: 397-98; Macheridis 2017a: 166). In Asine, sheep/goat show a relatively equal sex ratio perhaps with a mild dominance of males (Macherids 2017a: 166), while in LH III Tsoungiza, there is an emphasis on female rather than male sheep (Halstead 2020: 11451152).

The presence of older adults, females and castrated males (the latter in Tiryns, although the difficulty in distinguishing sheep and goat samples prevents further conclusions; see Halstead 1998: 177; 2003: 177) seems to relate to wool economy, in which sheep are kept until their wool production rate drops at an older age (Halstead 1998: 174-77; Isaakidou 2004: 268-70). Payne (1973: 284, Figure 3) places this moment at 6 years and older. Hadjikoumis (2017) observed even older killing patterns among traditional and current sheep husbandry practices in Cyprus. Also, the scarcity of lambs could refer to the exploitation of sheep/goats for wool and hair rather than milk, as with the latter, lambs would be killed off so that milk could be collected for human use. However, at least in Tsoungiza, the abundance of females over males (who produce more wool and hair) does not fit with such a strict conclusion (Halstead 2020: 1145-1152).

The nature of sheep and goat pastoralism in the LBA is under an ongoing debate, but it needs to be addressed. Management strategies of these small ruminants are relevant to the agricultural potential of the Argive Plain as the potential wool economy practiced by palatial centres such as Mycenae and Tiryns could have affected land use.

It is not certain whether pastoral transhumance was practiced similarly as in recent history, and whether communities or individuals could sustain themselves fully through pastoralism (Halstead 1996: 21). Individuals specialized in animal herding might have been hired by the palatial centres of Knossos and Pylos, and therefore it is possible, that such specialization was also enabled by the Argive Plain centres. However, herders mentioned in Linear B texts are often committed to other tasks in the palatial administration, simultaneously with their herding duties (Nakassis 2015: 286-87). Such multi-tasking could maybe refer to herders being hired as seasonal labour, or that the herders mentioned in the texts were individuals coordinating the management and wool production of palatial herds with local producers. Nevertheless, because the texts only record the activities of the palace, it is likely that outside large-scale sheep or goat husbandry (e.g. the *c.* 100,000 sheep controlled by Knossos, mentioned in on p. 104), rural communities practiced small-scale mixed farming (Halstead 1996: 33-35). There is no firm evidence pointing to specialized herding in the LBA non-elite contexts. In a small region with several settlements with large populations, landownership issues may have restricted the grazing of large herds in the limited amount of pastureland available. Wastelands, field and road sides, river banks,

[34] A rough weight average of 500kg for an adult cow in the European Neolithic, 600kg for an adult castrated male, and 700kg for a bull has been established by Gregg (1998: 105). The BA weights are calculated based on these figures.

[35] As a comparison, an average weight of 450kg for an oxen used as a draught animal has been often used in labour cost calculations related to ancient Greek architecture (Raepsaet 1993).

and other unused areas traditionally used for spaces for free-roaming animals would have only sustained small flocks and herds. Neighbouring areas such as the Nemea and Berbati Valleys or mountains beyond the plain and valley borders could have been utilized as additional pasture areas in the LBA, especially for the large palatial flocks. In addition, to release the pressure caused by spatial limitations, herds put together from the domesticates kept by individual households on a village level could have been taken further away from the plain to pasture. Clearing of tree taxa and the emergence of bushy vegetation, and growing erosion on mountain slopes in the area in the LBA can be interpreted as signs of higher altitudes being used as pastures (Halstead 1996: 27-31). Such evidence is also available in the Argive Plain pollen records, even though the dating of tree clearing and the increasing of pasture-related vegetation can only be dated to widely on the Bronze Age, and not specifically to its latter part (pp.86-90).

Recent pastoralism can be divided into three types, all of which could have been practiced as early as prehistory. Summer pastoral transhumance is characterized by the use of marginal landscapes mostly located in high altitudes (1300-1500masl). These areas are grazed by large flocks of some 150 heads of sheep or goat. Winter pastoral transhumance is usually practiced with smaller flocks, which are additionally fed by fodder. Mixed farming and herding usually includes smaller flocks (e.g. 60 heads) and are typically practiced in settlements located at lower altitudes (below 800masl) (Chang 1992: 80-84, 1994: 363).

Skydsgaard (1988: 77-78) finds evidence of ancient transhumance from literary sources, such as the Homeric epics. He suggests that crop rotation was a later innovation, and that fodder was not systematically grown. Farm animals survived on natural greens and fallow stubble. During summer, grazing moved to upland areas which were not necessarily located at exceedingly long distances from settlements (Skydsgaard 1988: 77-78). Traditional transhumance concerns moving flocks several hundreds of kilometres between seasons (Chang 1992: 69-70). The Linear B archives of Knossos seem to support the idea of short-distance, controlled highland grazing. Since the sheep mentioned in the texts belonged to the palatial centre and not to the herder, they would receive at least a major part of their reward from the palace. In typical transhumance systems the main subsistence comes from the herd itself. Further, it is commonly assumed that palatial centres would have preferred to keep flocks they owned nearby for monitoring (Halstead 1993, 1996, 1999b). Blitzer (1990: 38-41) has argued that the numerous small Minoan sites in the upland areas of Crete are evidence of the BA upland pasture systems. The Knossos archives further suggest that sheep were kept in the Mesara Plain, central Crete, which historically has been a winter pasture area for transhumant flocks (Halstead 1996: 32). As a comparison, the Limnes area in the vicinity of the Argive Plain is a favoured highland pasture area (Schallin 1996: 172), and it could also have been used for such activities in the LBA.

Sheep are more particular about their pasture than goats and prefer areas with grass vegetation (Dahl and Hjort 1976: 251). In the Southern Argolid, the lowland fertile areas provided the sheep at the traditional community of Didyma with a large variety of herbaceous plants, but also cereal stubble for additional food (Koster 1977: 72). Water resources for sheep and goats were less important than, for example, pigs and cattle. However, even goats, who can use the minimum rainfall of the summer in a greatly beneficial way, need access to water once every second day (Koster 1977: 229). Sheep required additional fodder during times of milking and lambing, while goats were easier to maintain for the herders and thus particularly important to the Southern Argolid economy. Despite the dietary flexibility of the animals, goat herders often cultivated some barley and vetchling for the animals to graze (Koster 1977: 193).

As for cattle and pigs, the Argive Plain collections of LBA sheep and goat remains do not reveal much information about the number of heads that might have grazed in the area. If the 1828 sheep established by Nosch (2014: 394) based on the Mycenae Linear B evidence were the total amount of heads controlled by the palace of Mycenae, the animals would have most likely been divided into a few large wool-producing flocks that would have grazed in the mountainous areas bordering the Argive Plain. If the Argive Plain functioned as the only pasture for the Mycenaean flocks, and no transhumance took place, the 1828 sheep of Mycenae would have required *c.* 8000ha of pasture according to Chang's estimations (4.45ha/individual), or *c.* 450-1000ha of pasture by modern standards (0.25-0.58ha/individual – see stocking rates in Appendix 8). In this study, the lower pasture size thresholds have been used, as Chang's study mostly refers to flocks grazing in remote areas, and the LBA Argive Plain flocks were likely kept closer to denser human habitation. As with cattle pasture, it is acknowledged that modern figures have to be used with great caution as thresholds for the ancient pasture needs for sheep and goats.

The majority of the LH III Argive Plain farmers likely practiced small-scale mixed animal husbandry, which was interlinked with crop cultivation. A handful, no more than a few dozen sheep or goats, could have been kept by farming households. As an example, in modern Didyma in the Southern Argolid, sheep were kept either in large flocks or for household use only. Large flocks, usually 130-150 heads, were kept mostly in highland pastures, hours away from the settlement. The further away they were grazing, the harder it was to maintain productive milk production. Some households kept a few sheep for family use only (Koster 1977 :244). The zooarchaeological evidence seems to point towards wool and hair exploitation instead of large-scale systematic dairy production. However, the milk of sheep and goats was most likely used on a moderate scale by regular Argive Plain households.

Bronze Age zooarchaeological evidence points to similar sheep and goat sizes to local breeds of sheep and goats in Greece (Appendix 7; Georgoudis *et al.* 2011). Modern sheep with an average weight of 48kg can produce 60 -100kg of milk per year (Georgoudis *et al.* 2011). With low consumption of 15-20kg of milk annually (pp.150-154), one animal could even support a small household, but only assuming that milk was not provided to newborn lambs. Thus, a handful of sheep could be sufficient to support subsistence requirements for milk.

Other species

Besides the main farm animals, other species were actively exploited for food or other purposes. Hunting, however, does not seem to have been important for subsistence in the LBA, except perhaps in remote villages (Wilkens 2003: 86). Hunting of large game such as wild boar and deer appears to have been more related to power and status, and perhaps to ritual behaviour (Cameron and Meyer 1995; McInerney 2010). The number of remains of wild species at the Argive Plain sites is generally small, although the variety of wild species in these assemblages is substantial, especially in Tiryns (Appendix 6). As an exception, the Asine zooarchaeological assemblage shows a notable increase of deer (dominated by red deer) in the MH and LH III deposits (Macheridis 2017a: 134, 2018: 88). In the MH III-LH III the share of deer is 19 percent of the Asine NISP, while by LH IIIC it increases to 25 percent, becoming the third most common animal exploited in the settlement after cattle and sheep/goats (Macheridis 2018: 99-100). In general, wild animals could have been hunted for fur or skins, and they could have formed a small addition to the everyday diet, or be only restricted to the diet of the elite. In Asine, however, Macheridis (2018: 100) suggests that deer could have been increasingly included to the consumption patterns towards the end of the LBA due to the possible growth of deer populations in the region after the abandonment of several settlements during the LBA crisis (in LH IIIB), and due to the more rural status of the settlement compared to the other Argive Plain sites.

Of other, less popular domesticates, horse may have held an important role in the Mycenaean economy. Horses are familiar from the LBA iconographic and textual sources. However, horse remains in the Argive Plain settlements are considerably less numerous than sheep/goats, cattle or pigs (Appendix 6). The several LH III horse burials recovered at the Dendra cemetery and elsewhere in the Mycenaean mainland suggest the importance of the animal in the Mycenaean societies. Based on the burial finds and art, it seems obvious that horses were associated with elite status (Pappi and Isaakidou 2015). Thus, their role as draft animals, or providers of meat or hides among the non-elite seems minor.

Neither zooarchaeological evidence nor isotopic signatures of the Bronze Age Argive Plain human bone material (see pp.126-129) suggest a significant role for marine-based dietary resources. However, numerous artefacts such as fishhooks and net weights, together with iconographic depictions, and fish bones found at LBA sites across Greece suggest that fishing was a common LBA subsistence strategy (Berg 2013: 2; Mylona 2014, 2020; Rose 1994). Number of fish bones found in excavations around mainland Greece is often low (Mylona 2003: 193). Various taphonomic processes (for example, fish bones are small and brittle) and insufficient recovery methods have probably significantly impacted the identification of marine resource exploitation in the Bronze Age contexts (Reitz and Wing 2008: 140-49). In the Argive Plain, the low usage of wet-sieving in excavation projects has affected the recovery of fish bones and other small bones. In more recent archaeological projects in southern Aegean (e.g. Akrotiri on Thera, Chryssi island, and Mochlos, Palaiokastro, Pseira, and Papadiokambos on Crete), fish bones, marine shells, molluscs, and other zooarchaeological evidence of marine resource use in the Late Bronze Age contexts have been found abundantly (Mylona 2014, 2020). On LC I (*c.* 1600 BCE) Thera, evidence of the preparation of fish for food has been recovered in household contexts. These data consist of a storage *pithos* containing fish bones, including 35 fully intact, unprocessed sea breams (*Pagrus pagrus*) mixed with barley and other cereals, a container of fish paste prepared by cooking several types of small fish, remains of dried fish with signs of processing (removal of vertebra), and a 'frying pan' vessel by a hearth with burned tuna vertebrae on it (Mylona 2020: 185-186). Such details from compelling evidence of fish and marine resources use in LBA human diet, at least in coastal settlements closely connected to the sea.

Based on the material evidence of fishing and fish bones, and the storage and dietary evidence deriving from other LBA contexts that contrast the absence of marine resources in isotope data, it is assumed here that fish and marine resources formed a minor part of the LBA Argive Plain diet, at least for those communities residing close to the Argolid Gulf. Generally, the fish species recovered from the Bronze Age deposits in the Argive Plain, as well as in Crete, Thera, and Chryssi, suggest a variety of habitation areas mostly in shallow waters and lagoon environments (Mylona 2020: 203-205; Rose 1994: 385). The shores of Tiryns would have offered excellent opportunities for various kinds of coastal fishing activities which can be describes relatively easy to complete for skilled and non-skilled groups alike. The rocky coastline of the Nauplion area provided suitable places for line fishing. The occasional deep, open-water fish could have been caught during their seasonal migration towards coastlines. Mylona (2020: 203) points out, that catching such migratory fish would have required a group effort, and most like the use of a boat, as these species do not migrate onto shallow coastlines. Thus, catching bigger fish would have taken special effort, and may have been limited to the most skilful fishers, perhaps also restricted as a dietary source to specific groups only.

Besides fish, marine shells have been recovered in large amounts in Midea (Reese 1998: 278-80, 2007: 400), Mycenae (according to Reese 1998: 279), and in smaller amounts in LH III Lerna (Gejvall 1969, Table 4; Reese 1988) and Tiryns (von den Driesch and Boessneck 1990: 153, Table 48). Marine shells were collected either fresh or deceased from the beach (Reese 1998: 278-80, 2007: 400). This seems to suggest that they could have been part of the human diet, but the shells were also used as a resource. Murex shells could have been additionally used for purple dye production (Burke 1999, 80), which was used as a pigment for wall paintings and other purposes (Aloupi *et al*. 1990; Chryssikopoulou and Sotiropoulou, 2003), and in plaster mixtures (Brysbaert 2007). Marine shells are excluded from Appendix 6, but they have been extensively studied by Reese (1982, 1988, 1998, 2007), and found abundantly also in other LBA contexts in the Southern Aegean (Mylona 2014, 2020).

Summary: animal husbandry in the LBA Argive Plain

The combined evidence of faunal remains and Linear B texts from the Argive Plain seem to confirm that sheep, goats, cattle, and pigs were the species mainly exploited in the LH III period by elites and commoners alike. These animals provided protein to the Bronze Age diet in the form of dairy and meat. However, meat was likely consumed only occasionally (Isaakidou 2007: 14), while zooarchaeological evidence remains inconclusive on the scale of milk production for human use (e.g. Halstead 2020: 1152). Besides dietary protein, these animals offered elites and commoners wool, fiber, dung, and traction power (e.g. Brysbaert 2013; Halstead and Isaakidou 2011b; Sherratt 1983). Unfortunately, the evidence does not provide much information about how these animals were tended, where they were pastured, or how much space they would have taken from the agricultural space of the Argive Plain. Therefore, for now, ethnographic data provides the best proxy to examine animal husbandry methods in rural farming communities.

As mentioned previously, the LH III textual data represent the interest of the Mycenaean elites in specific animals and animal products, and therefore these can be used to examine the animal husbandry taking place in regular farming communities only in a limited way. Adding to this, the excavated faunal material often derives from palatial contexts, in the Argive Plain for example in Midea (Reese 1998, 2007) and Tiryns (von den Driesch and Boessneck 1990), and therefore do not offer the most representative sample of the local animal management (e.g. herd composition). Within these settlements, species representation could reflect household or feasting consumption. Especially in relation to ritual and religious consumption, slaughtered animals could have been brought from further away, and older individuals could have been used on these special occasions (Halstead 2020: 1153). There is a need for zooarchaeological overviews combining data from several LBA sites of varied sizes and statuses, and comparing the characteristics of the LBA animal husbandry in different social contexts.

Nevertheless, it does not seem unreasonable to assume that most LBA households kept a small number of animals for subsistence purposes. I argue that ethnographic models of pre-industrial animal husbandry can be cautiously used to examine the activities of these LBA households. While Neolithic farming in Greece has been described as small-scale and garden-based, with single households forming effective self-sustaining units (e.g. Halstead 1996, 2004, 2006), the Late Bronze Age farming could have involved more tasks performed as communal work. This is suggested based on changes in settlement patterns, in which village-type 'second or third tier' sites with larger populations increase in the Mycenaean core areas (see pp.8-15 and 31-36), of larger storage units within settlements (pp.82-85), and, due to longer commutes to fields and pasture, in which cases laborious tasks such as herd management could have been most labour-effectively performed by households together. Although in traditional farming communities some activities may have been geared towards commercial gain (e.g. Forbes 1982; Koster 1977), most activities, especially in animal management aimed at maintaining a sufficient level of subsistence. Therefore, these activities followed the natural cycle of an agricultural year and aimed at low labour costs. This is why they are considered as relevant parallels to the LBA animal husbandry.

The abundance of adult individuals of cattle and sheep/goats in the LBA Argive Plain assemblages seems to suggest a focus on secondary products exploitation, often at the expense of pigs, whose exploitation focused on the production of large litters probably to be slaughtered for meat. Cattle are abundant notably at Tiryns, Midea, Asine, and (although less visibly) Tsoungiza in the LH III, but the low number of calves suggests traction power was favoured over milk production, as in the latter case, majority of calves would have been culled in order to reserve milk for human use. Power was needed in agricultural endeavours, but also in large-scale construction projects across the Argive Plain, even though most of them were completed before the LH IIIC (Brysbaert 2013). Rebuilding took place in Tiryns during LH IIIC (Maran 2015: 283-85; p. 26 in this book). The presence of these animals could also signal increasing wealth within these settlements, or suggest that cattle were more available to a wider selection of the Argive Plain society.

Sheep and goats were most likely exploited for meat, milk and wool in most of the Argive Plain sites. Together, these two species remain constantly abundant at most sites, however, the dominance of adult females combined with the scarcity of neonates offers contrasting evidence of their exploitation strategies. Extensive milk production would likely be exhibited as a higher number of neonates, as by culling them, milk could be collected for human use. Extensive wool production would likely show as a high number of castrated males, who produce large volumes of wool (Halstead 2003). However, Linear B texts found from Mycenae indicate the existence of a wool industry, perhaps similar to the wool industry at Knossos and Pylos (Nosch 2014; Varias Garcia 2012;). In the faunal assemblage of Tiryns, the presence of few castrated adult males points to wool production. Due to the discrepancies in these data sets, both milk and wool/fiber production for sheep and goats need to be included in the model of the regular Argive Plain agricultural economy. In general, species representation does not suggest that animal husbandry was focused on any one animal, although the exploitation patterns of the four main domesticates fluctuated throughout the Late Bronze Age.

Even though the variety of wild mammals in the assemblages is relatively large (particularly in Tiryns), the dominance of the domestic species in the amounts of bone material recovered is so notable that hunting as a major subsistence strategy can be excluded in the Argive Plain model except for Asine where deer hunting may have provided additional sustenance (see above pp.114-115, and Appendix 6). Similar to hunting, according to the available data, the role of marine foods and fishing in the specific Argive Plain context is difficult to estimate, especially since there are no indications to fish consumption in the local isotopic values (Rose 1994; Vika and Theodoropoulou 2012; see also pp.126-129). The evidence of the use of marine resources in domestic contexts elsewhere in Bronze Age Aegean is, however, considerable. It is possible that fish and seafood were part of the cuisine at least some of the Argive Plain communities, perhaps seasonally. Without further evidence of their consumption and transformation into foods, however, this study maintains with C3 terrestrial diet for the LBA Argive Plain communities.

Besides the palatial interest in animal husbandry, animals were kept for domestic purposes in a mixed farming system. Such a system included small herds, and probably additional feeding with fodder seasonally (Halstead 1981; 1987a; 1996; 1999b). Animals could have roamed on stubble fields after harvesting, and on fallow fields. They could have also been fed the cereal by-products left over from crop-processing. The implications of growing fodder for the agricultural potential will be discussed later in this work (pp.166-178).

Dung is one of the important products gained from domestic animals, and it could have been important to the palaces and local communities alike. Earlier, it was demonstrated (p. 71) how some evidence suggests that terraced fields were manured in the LBA. Additionally, there is some evidence that manuring could have been conducted on rather large land areas too: Bintliff (1985) has argued that the in central Greece was created by the use of manure or midden in the local fields in the Bronze Age. However, Halstead (1987b: 182) has suggested that in the Bronze Age, manuring was used only in small gardens. In Mycenaean palatial societies, larger wool-producing flocks of sheep were grazing far away from the centres, which is why their dung was not available for regular farmers. Ethnographic evidence supports this argument of scarcity, as subsistence farms only kept a small number of animals, or their animals were joined with others and sent further away to graze (Halstead 1987b: 79). The available manure and household waste was collected and used for the poorest soils in order to advance the yields (Halstead and Jones 1997: 273). Alternatively, it could be used for crops that benefited from it the most, such as wheats, vegetables, and tree crops (Forbes 1982: 236).

Halstead and Jones (1997: 273) estimate that a farmer in modern day Amorgos owning a few large working animals and a small number of goats could yield enough manure to fertilise on average 0.1-0.2ha of land. However, dung remains scarcely available as crop cultivation takes place on fragmented fields relatively far away from dwellings. Padgham (2014: 18) uses modern manure production data (Hermanson and Kalita 2004) to estimate the amount of land that could be manured in LBA Cyprus. In his example, an average Cypriot household would have owned 'two oxen, two cows, one to two donkeys, and a few sheep, goats and pigs'. These animals, together with the waste produced by a family of six people would have produced 58,000 kg of manure a year and, as such, could manure *c.* 1.84-3.2 hectares of cultivated land. However, the number of animals owned by a household in Padgham's study seems unreasonably high, and it should not be assumed that every household (or even most households) could afford to own a pair of oxen. In addition, the data used by Padgham of manure production is based on pen-raised animals who are fed with chemically altered fodder, and all of their manure is collected from these confined conditions (Hermanson and Kalita 2004). Thus, the volume of dung produced in such conditions may be much higher than with animals mainly grazing in more natural conditions. More recent statistical data (Statistics Netherlands 2012, 71, Table 6.2), suggest that 13 sheep[36] can produce *c.* 26,000 kg of manure a year. These sheep were grazing on grasslands seasonally, and their dung production was evaluated during these grazing periods as 2000kg a year per animal (Statistics Netherlands 2012: 71, Table 6.2). If all of it was collected (which probably was not possible), some 0.8-1.4has of land could have been manured following Padgham's formula.

Further evidence for flock sizes in mixed subsistence farms can be sought in ethnographic accounts. In Methana, recent flock sizes of sheep or goats varied between 1 and 13 (Forbes 1982: 300, Fig. 33). Here, sheep and goat tending was commonly a task for the females of the households, and due to their commitment to a variety of other tasks, herd sizes remained low (ibid., 298). The animals were usually kept close to the house, and dung and household waste were both collected for fertilization, and transported to fields located further away (Forbes 1982: 236). In Didyma in the Southern Argolid, the mean sheep flock size varied between 24 and 353, and goat flock size between 23 and 1229 in 1940-1975 (Koster 1977: 173, Table 42). Many households in Didyma were focused on sheep and goat raising, which explains the huge variations in flock sizes (Koster 1977: 155). Grazing took place in pastures surrounding the village and mountain sides further away by designated herders. Communal grazing in which the animals of several households were grouped together was practiced commonly. Herders might have collected dung to be, for example, exchanged with land owners for grazing land (Koster 1977: 190). In Karpofora, Messenia, every household had a donkey, a couple of milking goats, one or two pigs and some chicken. Cattle, including oxen or cows and horses, were kept only by a few households and in part shared with the rest of the community during ploughing seasons. It was more common for a household to own one large animal and form yoke pairs with other households seasonally than to own a full pair. Sheep were concentrated in only four households who specialized in their husbandry. The nearby valley bottom offered pasture for the local animal, but also to some transhuman pastoralists (Aschenbrenner 1972: 57–58). Finally, in Fourni in the Southern Argolid, each household kept a few goats for milk and meat. In addition, almost every household had either a horse or a donkey for heavy labour and transport. A few households kept sheep or goats, and the herd sizes varied between 25 and 70 on average. Animals were kept in communal lands near the village, as it is located in a fertile valley. This valley bottom was also used by transhumant herders coming from the mountainous regions in central Peloponnese, and by some households of the nearby village of Didyma (Gavrelides 1976a: 266-267).

Ethnographic accounts exhibit the variety of animal management practices in various regions in pre-mechanized Greece. Foci on crop cultivation or herding affects herd sizes and the variety of animals kept by households. These, in turn, regulate the availability of dung that can be used to manure fields. Thus, based on these data on traditional flock sizes, it seems unlikely that the common LBA farmers were able to keep much higher numbers of animals than the recent historical rural households. While specialization in herding could have been practiced in the LBA by some (but perhaps mostly related to palatial economies), it seems more likely that rural communities either kept a low number of animals in their immediate vicinity, or gathered their animals as a bigger flock to be herded at communal pasture lands, as in the cases of Didyma and Fourni. In both scenarios, this would also indicate that dung was not abundantly available, either due to the low number of dung-producing livestock, or due to the distance to pasture that made it difficult to collect larger amounts of dung. This, if dung and that if it was collected for manuring purposes, the crops that it was used for were carefully selected. Overall, the selected ethnographic data exhibits the intertwines of animal and crop management, and their strong correlation with the environmental and economic characteristics each case study area. Furthemore, modern statistical

[36] Flocks with less than 13 animals per household were kept for example by traditional households in Methana (Forbes 1982: 300, Figure 33).

data of dung production does not correlate well with recent historical or ancient historical dung production due to varying management strategies. Therefore, interpretations based on these data on the amount of dung, the number of animals, or the ways they were managed on Late Bronze Age farming cannot be done without caution.

This chapter has collected data of the management practices, and the spatial and environmental requirements for the main farm animals. These requirements will be used in in the final analysis (Chapter 6) to reconstruct discuss the LBA agricultural practices, and the local agricultural potential of the Argive Plain.

The Argive Plain population through osteoarchaeological evidence

Osteoarchaeological analysis of human remains provides information that can be used to investigate past populations in Greece. Skeletal analyses, and more recently, the study of human remains on a molecular level (e.g. aDNA and stable isotopes) are producing data that can be used to observe the physical activities, health, diet, and kinship, as well as the socio-political relationships of past human societies (Larsen 2015: 1). This section will focus on the diet of the Bronze Age Argive Plain populations, although health-related issues are briefly discussed as well.

Information on diet and health in the LBA Argive Plain can be explored through different types of markers in the human skeletal material: for example, malnutrition can manifest itself as lesions in the human skeletal material, while physical activities such as fighting or prolonged mechanical work can cause damage to the bone tissue (Larsen 2015; Papazoglou-Manioudaki *et al.* 2010). Typical characteristics of diet are indicated by stable isotope values measured in bone material.

Currently, the MH osteoarchaeological records available for the Argive Plain are significantly more abundant than the LH records (Ingvarsson-Sundström *et al.* 2009; Triantaphyllou, 2010; Triantaphyllou *et al.* 2008; Voutsaki, 2018; Voutsaki *et al.* 2013). The MH evidence cannot be directly applied to the LH dietary or health patterns, but in a wider Greek context it

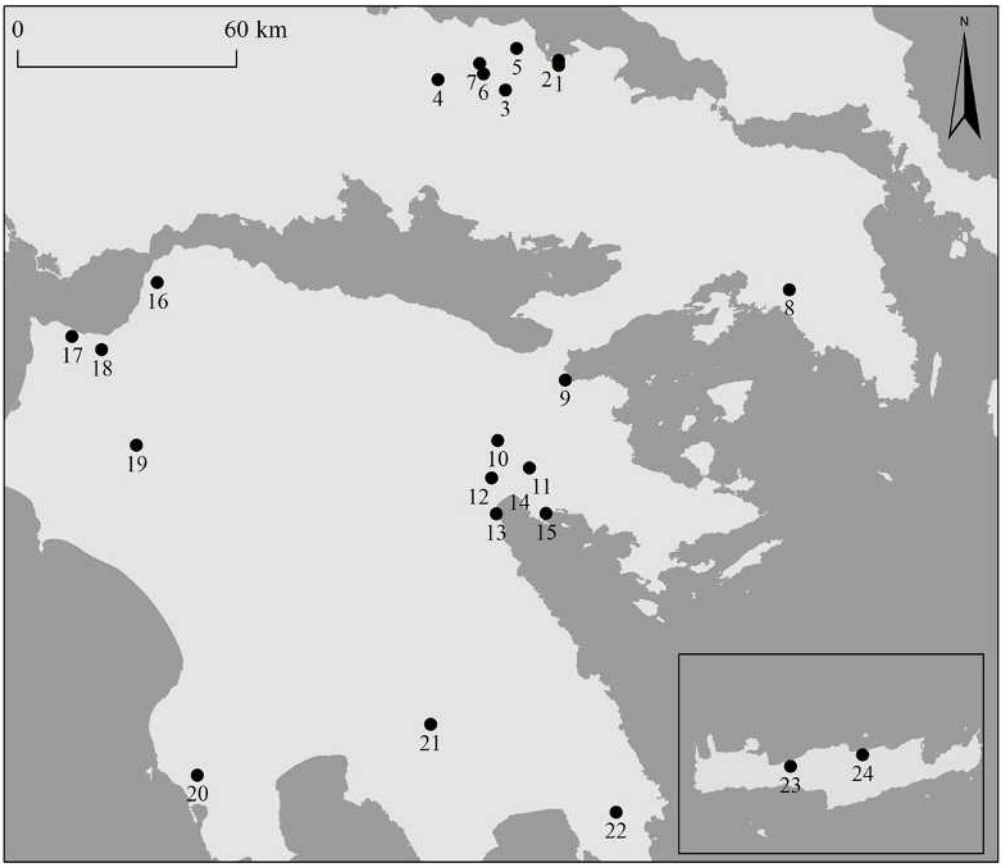

Figure 5.12. Locations of the osteoarchaeological sites mentioned in the section are 1) Tragana Agia Triada, Lokris, 2) Mirou, Lokris, 3) Kolaka, Lokris, 4) Modi, Lokris, 5) Atalanti, Lokris, 6) Kalapodi, Lokris, 7) Zeli, Lokris, 8) Athens, 9) Almyri, 10) Mycenae, 11) Midea, 12) Argos, 13) Lerna, 14) Tiryns, 15) Asine, 16) Voudeni, Achaia, 17) Kalamaki, Achaia, 18) Spaliareika, Achaia, 19) Agia Triada, Achaia, 20) Pylos, 21) Kouphovouno, Laconia, 22) Sykia, Laconia, 23) Armenoi, Crete, and 24) Knossos, Crete.

can be used to examine if there are notable changes through time. Therefore, this chapter will also examine LH osteoarchaeological datasets deriving mainly from southern and central mainland Greece. A few datasets deriving from Crete are touched upon, but northern Greece is not included in this data presentation, because the archaeobotanical evidence points to different crops and dietary patterns for the LH populations of northern and southern mainland Greece. Comparable results have been received through the isotopic analyses, which suggest a difference in diet between the northern and southern BA Greece (Triantaphyllou 2015). The sites mentioned in this chapter are listed in Figure 5.12.

The skeletal analysis of the LBA human remains

Skeletal analysis investigates the age, sex, and health of individuals by making observations based on their bone material (Roberts 2013: 79; see also Triantaphyllou, 1999: 6-7, 2010). While there are several methods to examine osteological material, such as radiography, tomography, isotopic and ancient DNA (aDNA) analyses, macroscopic examination is the most common analytical method (Roberts 2013: 83-85). The recognition of disease or other health-related issues in human bone material is based on the principle that there are a limited number of ways that bones react to disease and injury. These signs can appear for example as porous, or non-smooth surfaces of the bones, or as the abnormal growth of bone, and are usually referred to as 'lesions' (Roberts 2013: 81-83).

Osteoarchaeological examination, like other methods employed to study ancient populations, is subject to numerous caveats. Demographic interpretations of past communities often rely on age and sex data, as becomes evident in the reference studies cited in this study. Health conditions of these communities are inferred through the analysis of injuries and diseases, based on the signs and frequencies observed. However, extrapolations made through such observations on past individuals are contradicted by the so-called osteological paradox. Thus, paradoxically, archaeologists examine deceased individuals to make conclusions about past living communities. In their seminal paper, Wood and co-researchers (1992) defined the three profound issues, demographic nonstationarity, selective mortality, and hidden heterogeneity as the osteological paradox. These definitions have been extensively discussed elsewhere (see DeWitte and Stojanowski 2015 for bibliography). In summary, past populations are rarely stationary, which is why demographic fluctuation occurs through changes in fertility and mortality, but also migration. Age distribution of the deceased is much less informative on the age distribution of the community, as fertility (and mobility) affects the number of young versus old individuals within a community more profoundly (Wood *et al.* 1992: 344). The presence of age, sex, lesions, or other health-related indicators on skeletal material does not necessarily unveil the risk of death or severe illness under which community members lived. While patterns of lesions (or their absence) on individuals may suggest weaknesses contributing to their death and the overall poor health of the community, they can also indicate resilience. Some individuals were able to overcome their conditions until death (Wood *et al.* 1992: 344-345; Wright and Yoder 2003: 45). Additionally, each individual exhibits a unique set of responses to various health threats, shaped by genetic, environmental, and cultural factors. As a result, extrapolating these individual responses to measure communal resilience or frailty becomes problematic (DeWitte and Stojanowski 2015: 405-406).

A few health conditions appear particularly common for the prehistoric bone material recovered in Greece. Porotic hyperostosis and cribra orbitalia are both conditions most often appearing in the cranium, the first in the cranial vault, and the latter in the orbital roof, although arguments have been made of their occurrence in other skeletal parts depending, for example, on the age of the individual (Brickley 2018: 899-900). In both conditions, bone material develops porous lesions (Walker *et al.* 2009: 109). Porotic hyperostosis and cribra orbitalia have been commonly connected to anemia (Brickley 2018: 896; Cole and Waldron 2019: 618-619; Walker *et al.* 2009: 111;). Anemia, the decrease in blood red cells, has several potential causes, including digestion issues due to blood loss caused by trauma or injury, parasitic infection, gastrointestinal problems due to unsanitary conditions, insufficient diet or infectious diseases such as malaria, all of which have been postulated for the BA Argive Plain people (e.g. Angel 1973). Iron deficiency anemia caused by insufficient dietary intake and a combination of the abovementioned factors has been often seen as the most common cause for the porous lesions occurring in ancient skeletal samples (Walker *et al.* 2009: 109-110). Other causes have been searched for hereditary anemic conditions, in the Mediterranean context, especially thalassemia. More recent research has questioned simplistic conclusions about hereditary and iron deficiency-related anemia (or any type of anemia, see Cole and Waldron 2019), however. Arguments have been made for the occurrence of cribra orbitalia only in children and adolescents, in which case the markers of the condition in deceased adults would, in fact, indicate adaptation success instead of decreased health (e.g. McFadden and Oxenham 2020). Walker *et al* (2009) argued that iron deficiency anemia is not capable of causing notable porous lesions related to porotic hyperostosis. Instead, vitamin B12 deficiency (almost exclusively found in meat), in particular, transferred from lactating mothers to their infants causing them to suffer from megaloblastic anemia, is the main contributor to porotic hyperostosis and cribra orbitalia. Due to the increasing amount of new insights into the health of past populations, some of the reference studies used in this study might benefit of a re-examination and interpretation of data. The identification of these lesions, and their aetiology, will therefore follow the identifications given by the original authors.

Of the common activity-related health conditions, osteoarthritis and enthesopathy are problems related to the tendons and ligaments of bones. They both indicate joint pain due to the wearing of cartilages between bones. Joint-related health issues can also appear as the abnormal formation of bone material, for example as pitted or uneven surface of the heads of the bones. They usually occur in legs, arms, or back bones due to long-term mechanical pressure (Roberts 2013: 83).

Potential signs of anemia, whether caused by dietary, or other reasons, and activity-related lesions such as those caused by osteoarthrithis, can be observed as markers of health status and workload, although with caution. Together with demographic data driven from cemetery contexts, the skeletal markers of these conditions can help to examine whether the LBA Argive Plain population enjoyed a sufficient diet, and whether they conducted heavy physical labour related to subsistence activities. However, as many of the Argive Plain reference studies were published before the most recent developments about the osteological paradox and anemic conditions emerged, their conclusions are likely to lack some of the caution related to the representativeness of the assemblages of the living communities. Nevertheless, as a non-specialist, the author of this book remains indebted to the interpretations of the original examinators, and cannot present a reanalysis of the data. The following section presents a concise overview of the health issues of the LBA population in the Argive Plain. Evidence from other sites in mainland Greece and Crete are used as comparisons in the second part of the section (pp.123-124).

The Argive Plain data

In Argos, osteoarchaeological data are available from non-elite individuals of the Middle Helladic settlement on the Aspis hill, and Geometric[37] pit graves recovered in the modern city area. In both assemblages, majority of the studied individuals were 30-50-year-old adults. 28 females and 49 males were included in the Geometric assemblage. Of these, four females and one male were identified as 18-30 years old, eight females and 14 males as 30-40 years old, and four females and nine males as 40-50 years old. The age of 37 adult individuals could not be conclusively defined due to the lack of diagnostic material (Pappi and Triantaphyllou 2011: 722 - 731, Table 7 [the table does not express the exact number of individuals] see also Appendix 9). The Middle Helladic assemblage consists of 13 individuals recovered in intramural burials within the settlement of Aspis, selected for radiocarbon and stable isotope analyses (Voutsaki *et al.* 2006: 615; Triantaphyllou *et al.* 2016: 613). Thus, the sample size for age and sex distribution[38] analysis is rather small. Males are underrepresented, and the majority of the assemblage consists of mature adults around 30 years old (Triantaphyllou *et al.* 2016: 633). In the Geometric assemblage, females seemed to die more frequently at the age of 18 to 30 years than males, possibly due to complications related to pregnancy. There were no individuals older than 50 years among either sex (Pappi and Triantaphyllou 2011: 722). Both chronological groups a show high levels of activity-related lesions in their musculoskeletal systems. Throughout the Early to Late Geometric period, signs of arthirithis, entheseal changes, musculoskeletal markers, and trauma (e.g. healed fractures) remain high in males and females. This seems to suggest both sexes were engaged in heavy physical work. In addition, geometric individuals show signs of disease and infections (Pappi and Triantaphyllou 2011: 723). Anemia, which could be related to diet, is not visible in the Middle Helladic individuals. This may be caused by a recovery bias, since the cranial fragments, in which signs of anemia (i.e. porous lesions) can usually be detected, are not well represented (Triantaphyllou *et al.* 2006: 633). The Geometric individuals show signs (which, however, are not specified by the authors) of anemia especially towards the end of the period (Pappi and Triantaphyllou 2011: 679-80). Due to the selective nature of the Argos analyses, signs of health or activity-related conditions cannot be conclusively connected to the demographic distribution of the Argos population. Furthermore, neither the Middle Helladic, or the Geometric results can be directly applied to the Late Helladic period. Nevertheless, these data can be used to

[37] Pappi and Triantaphyllou (2011: 673) affiliate the Geometric period in Argos to the Early Iron Age (EIA), which they date between 1100 and 700 BCE.

[38] Of the MH individuals, two are 0-6 months old neonatals, one 9-12 months old neonatal, one 14-15 years old adolescent, one a 18-30 years old female, one a 20-30 years old female, two 30-40 years old femlaes, one a 30-40 years old male, one a 30+ years old female, ad one a 40-50 years old male. One individual could not be identified by age or sex, and another one is identified as an adult (Voutsaki *et al.* 2006: 616, Table 1).

examine some of the present health conditions of the Argos populations over time.

Similar to Argos, Asine has yielded skeletal material from the Middle Helladic and Geometric[39] periods. According to Angel (1982: 105), the Mycenaean material is too fragmentary to be properly examined. Of the Middle Helladic individuals, nine were neonatals (0-1 years old), two were infants (1-5 years), five were children (10-15 years), and three were (female) adolescents of around 15 years old.[40] 16 adult males and nine females could be aged. Of these, seven males and seven females were young adults between 20 and 30 years, while one female and six males were aged between 30 and 40 years. One female and three males were aged above 40 years. Of the 19 Iron Age and Protogeometric individuals seven are adults, including three females and four males. Of the subadults, one is an adolescent male (of *c*. 15 years old), two are children (between 5 and 10 years), two are infants (1-5 years old), and seven are neonatals (0-1 years old). Like at Argos, there were no adults older than 50 years identified in either of the assemblages (Angel 1982: 106, Table 1).

The Middle Helladic individuals of Asine were relatively tall. Angel (1982, 107) reports a mean height of 153.6cm for females and 164.6cm for males, although as was common for the time, comment about the even taller appearance of the local royalty a Mycenae. Individuals from both periods exhibit signs of physical stress particularly in the lower limbs. It was likely caused by constant moving over an uneven ground, which appears as platymeria, the flattening of the upper femur shaft, and could be related to subsistence activities (Angerl 1982: 108–11). The Middle Helladic individuals of Asine show particularly high levels of trauma, such as fractures, wounds and depressions to the skull. Additionally, one individual had a healed trepanation hole. Angel (1982: 109–11) related these signs to fighting, in particular efforts to heal after a violent event, but trepanation does not directly indicate violence, only the use of surgical methods.

A considerable number of Middle Helladic and Early Iron Age adults and a few infants exhibit signs of porotic hyperostosis. Angel (1982:109) assumed that this porosity was caused by thalassemia, a genetic anemia common among the modern-day Mediterranean. Since his publication, the presence of thalassemia in prehistoric Greek societies has been questioned as it is considered to be a more recent condition (Kirkpatrick Smith 1998: 4-5; 154; Larsen 2015: 32–34), or to occur too rarely or population-specifically to explain the abundance of porous lesions across ancient skeletal material (Walker *et al*. 2009: 109). While Angel (1982: 107) suggest malaria could be an obvious cause for the slightly poorer than average health among the Bronze Age Asine population, he puts more weight on the consequences of insufficient intake of meat protein and calories. As discussed in the beginning of this section, anemia could be caused by a combination of dietary, gastrointestinal and other issues. Nutritional stress is visible in the young children of Middle Helladic Asine, who remained consistently under the normal growth curve. Such underdevelopment could have been caused by limited or absent breastfeeding, or by a drastic change in the diet of the infants a few months after birth (Ingvarsson-Sundström 2003: 105-10). These issues could potentially relate to the formation of megaloblastic anemia suggested by Walker *et al* (2009) which is sufficient to cause both porotic hyperostosis and cribra orbitalia. However, further examination of the primary data is required to make any conclusions about the type of health condition responsible for the potentially dietary or activity-related lesions in the Asine individuals.

Lerna has one of the best-documented Middle Helladic skeletal assemblages, with 209 recovered individuals. The total number of examined, or aged and sexed individuals is not clarified in the study. More than 25 percent of the Middle Helladic I-II individuals are neonates (0-1 years old), and another 15 percent infants (1-6 years old). In the MH III/LH I, neonates take more than 40 percent of the assemblage with infants remaining at *c*. 15 percent. In the MH I-II, 25+ percent consists of prime adults between 30 and 40 years old. In the MH III/LH I, prime adults have declined slightly to just below 25 percent. The remaining age groups (children 6-12yrs, juveniles 12-18yrs, young adults 18-30yrs, mature adults 40-50yrs, and old adults 50+yrs) fall in the range of 5-10 each, except for the old adults in the MH III/LH I, representing only one percent of the assemblage (Voutsaki *et al*. 2013: 135, Figure 1). Approximately 26 males and 19 females are identified in the MH I-II (Voutsaki *et al*. 2013: 206, Figure 3). 57 individuals are dated to the MH III/LH I shift, with a clear male dominance (37 males versus 20 females) (Voutsaki *et al*. 2013: 141, Table 5).

More infants and children are included in the Lerna assemblage than at Argos and Asine. Unfortunately, the distribution of sex and age is not conclusively provided in the publication. Some diachronic changes in health can be detected: early Middle Helladic females suffered more stress, indicated by metabolic disturbances and enamel hypoplasia (see p. 125) than males. Females also show slightly more signs of activity-related lesions than males in the MH I-II period, while in the MH III/LH I, males suffer from these considerably

[39] Angel (1982: 106) refers to the Protogeometric and Geometric periods as the Early Iron Age, and dates them between 1150 BCE and 650 BCE.
[40] The age categorization used here follows the system used by Voutsaki *et al.* in their 2013 paper and is different from the description of Angel, who counts adulthood from the age of 15, and adolescence between 12 and 15 years.

more. These differences suggest diverse workloads. In general, markers suggesting vertebral arthritis are the most common of all pathological conditions throughout the Middle Helladic (Voutsaki *et al.* 2013: 136, Figure 4). Towards the end of the period, males had a slightly higher number of musculoskeletal stress markers and signs of non-specific infections. According to the authors (Voutsaki *et al.* 2013: 136-141), these differences may have been caused by greater mobility, and thus exposure to external pathogens, for males. Signs of infections and stress factors, such as metabolic disturbances, decline in MH III-LH I in the entire population, perhaps indicating an improvement in living conditions. Cribra orbitalia seems also to decrease from MH I to LH I. It appears among *c.* 30 percent of the MH I-II females, and only some five percent of the MH III-LH I males (Voutsaki *et al.* 2013: 136, Figure 4).

The skeletal material recovered in the shaft graves of the Grave Circles A and B at Mycenae date to the MHIII/LH I transition (see Graziadio 1988)).[41] There were 15 adults in Grave Circle A included 11 males, of which one was 17-20 years old, one 35-40 years old, and the rest from 25 to 35 years old. Of the four females, two were less than 25 years old, and two between 25 and 35 years. In addition, there was one adolescent and one infant in the sample (Papazoglou-Manioudaki *et al.* 2010: 168; see also Appendix 9).

The Grave Circle B yielded only two subadults, a child of around 2 years, and another of some five years old. Six males, one female and one unsexed individual were young adults between 20 and 30 years old. Six males, three females, and three unsexed individuals were mature adults between 30 and 40 years old. Four males, and one unsexed individual reached an age between 40 and 50 years, and one male was older than 50 years (Angel estimates 55 years) at the time of his death (Angel 1973). The number of older adults in this burial context is notable compared to the other Argive Plain assemblages.

Nearly all of the males in the Grave Circle A showed signs of severe mechanical stress to their bodies. This stress was visible in the shoulder and chest areas (pectoral girdle), arms, and, to lesser extent, on the lower limbs. It could have been caused by physical activities such as forward bending while carrying heavy loads or hanging them over the shoulder, or by excessive pulling (Papazoglou-Manioudaki *et al.* 2009: 260-269, 2010: 172-213). Signs of heavy physical stress on the body are intriguing since the burial context would suggest that these men belonged to the elite of Mycenae. Some signs of cribra orbitalia were also detected. The examiners attributed these as indicators of anemia caused by thalassemia or iron-deficiency (Papazoglou-Manioudaki *et al.* 2009: 263). Both conditions as the cause for cribra orbitalia have since been heavily criticized (e.g. Cole and Waldron 2019: 620; Walker *et al.* 2009: 116). The generally good dental health (see p.122) and the robustness of the individuals point to a diet with sufficient protein intake (Papazoglou-Manioudaki *et al.* 2010: 218).

Grave Circle B individuals were notable taller than individuals from other BA burial contexts. Angel (1973: 386) reports male heights of 171.5 centimetres, and male ranges of 160-180 centimetres. According to him (Angel 1973: 386), this was five centimetres more than the local average (166.3cm) which consisted of data from Middle Bronze Age Attica, Argos, Lerna and Mycenae. Several individuals of the Grave Circle B of Mycenae showed arthritic changes in the spinal area (e.g. cervical, lumbar and thoracic vertebras), osteoporosis, but also some signs of healed fractures in upper and lower limbs. In addition, one trepanation hole was discovered. Both sexes suffered from similar health issues (Angel 1973: 379-384; Musgrave *et al.* 1995: 113-122, Appendix 1). Many of the arthritic lesions suggest heavy physical activities (Angel 1973: 379-80), similar to the individuals buried in Grave Circle A. However, many of these individuals were mature and older adults, in which case age-related conditions such as osteoarthritis could be expected.

To summarize, the age range of adults was similar in all investigated groups, young and mature adults of 20-30 and 30-40 years old forming the most common age groups. Individuals older than 50 years were rare, but still present at Mycenae and Lerna. Compared to Argos and Asine, the Lerna sample is much larger, and therefore a larger age variety can be expected. All sexed individuals older than 50 years were males. Neonate and infant deaths appear to have been common in the MH-LH Argive Plain, and in the MH III-LH I they were notably high.

In general, the Middle and early Late Helladic individuals from the three Argive Plain sites seem to have suffered from similar types of stress-related issues. Activity-related lesions, signs of arthritis, and other enthesopathies are common at all three sites and in both sexes. These refer to physical stress caused for example by heavy labour. Trauma is particularly common only in Geometric Argos and Middle Helladic Asine, two chronological contexts that cannot be compared directly with each other, however.

[41] The dating of the Shaft Graves has been revised on several occasions. Under the current knowledge, it seems both of the Grave Circles were constructed during the MH/LH transition (*c.* 17th-16th cent. BCE), Grave Circle B being slightly older and possible dating back to MH IIIA. Further information is provided by Dickinson *et al.* (2012) and an overview of the dating of the Grave Circle B by Graziadio (1988).

Porous lesions in the cranial material are other common health-related issues visible in the Argive Plain skeletal remains. Both pathological conditions are related to anemia in the reference studies. Although there are several types of anemia, iron-deficiency resulted from malnutrition appears to be favoured over anemias resulting from a variety of reasons such as parasitic infections, diarrhea, or blood loss. Another source for anemia in the Bronze Age Argolid is seen in thalassemia, which is frequently occurring in modern Greek populations (Papazoglou-Maniodaki 2010: 263). In the future, re-examinations of the nature of porous lesions in the Argive Plain assemblages, especially cross-examined with infant mortality and malnutrition could have the potential to produce more intricate interpretations of the stress factors, frailty, and resilience of the local populations.

Especially in Mycenae, the individuals' good dental and physical health, robustness, and stature are seen to indicate sufficient diet (Angel 1973; Musgrave 1995). These aspects are further supported by the characterization of the burial context as high-status. However, as suggested by Temple and Goodman (2014: 190), studies attempting to determine health in past societies often end up defining stress indicators instead. Comparing the individuals of Mycenae to other lower-status settlements in the Argive Plain might say more about their potential to overcome and adapt to stressful conditions than the prevailing healthiness of these communities. The relationship between these stress-related data and social status is further discussed in the final discussion of this section (pp.129-131).

Finally, the assemblages presented above all represent communities dating to periods preceding or post-dating the mature Mycenaean period in the LH III. Therefore, unfortunately, the results of these studies cannot be directly applied to the Argive Plain Mycenaean population. They can be used to make observations of the presence of stress-related conditions within settlements that are central to the Mycenaean populations, however. In order to see if similar stress factors were common in the Mycenaean period, comparative data from other locations in Greece is briefly presented in the following section.

Comparative osteoarchaeological data

In contrast to the Middle Helladic and Geometric periods, published LH III skeletal analyses are practically absent in the Argive Plain. Reasons for this may be caused by the disturbed nature of the material (many of the LH III cemeteries and tombs have been looted), permit and funding issues, or research interests. For example, the MH-LH individuals recovered in the Prosymna chamber tombs in the 1930s were only identified to adult/infant level without further analysis of sex or stress factors (Blegen 1937). Two sites, Athens and East Lokris, offer a Late Helladic III comparison to the earlier skeletal data of the Argive Plain.

Kirkpatrick-Smith studied the skeletal material recovered in LH IIB-LH IIIB/C tombs at the Agora of Athens. Based on multiple variables related to the characteristics of the burial, and the burial finds she divided the buried individuals into two groups, high status, and low status individuals. Kirkpatrick-Smith identified 80 adults, of which only one could not be determined by sex. Of these, 38 were females and 41 males (Kirkpatric-Smith 1998: 74, Table 4.5). The adults were divided into two age categories, of which 16-35-year-olds included 13 females and 16 males, and 35+ year-olds included 21 females and 21 males. There were five females and four males whose age could not be determined. In addition, three under three years old infants, eight 3-5 years old children, 13 6-10 years old children, and eight - 15 years old adolescents were identified (Kirkpatric-Smith 1998: 82-87, Table 4.9). Thus, adults represented relatively equal number of males and females. Older adults above 35 years formed a larger age group than young and mature adults, which could possibly indicate a slightly higher age at death compared to the Middle Helladic Argive Plain collections. However, for any further conclusions, standardization of the age groups data between these assemblages would be necessary.

The mean height for adult females was 154.6cm and for males 164.3cm (Kirkpatrick Smith 1998: 105, Table 5.6) Similar to MH-LH I Mycenae and Argos, activity-related lesions in the upper limbs are present in both sexes. This suggests that both males and females were involved with similar type of heavy mechanical activities (Kirkpatrick Smith 1998: 124-125, Tables 6.2 and 6.4; Mountrakis and Manolis 2015: 216). Here, it should be noticed, however, that the majority of the adults consist of individuals above 35 years old. Trauma were notably higher in males and high-status individuals (Kirkpatrick Smith 1998: 130). Signs of anemia (cribra orbitalia and porotic hyperostosis), were relatively rare. According to Kirkpatrick-Smith (1998: 154-157), the most likely cause for anemia was a parasitic infection such as hookworm rather than thalassemia (or other causes). Malarial infections related to thalassemia would have not been high due to the scarcity of swampy areas with disease-spreading mosquitoes around Athens. In addition, few children have porous lesions referring to anemia, which would exclude thalassemia as well (Kirkpatrick-Smith 1998: 154).

The skeletal material recovered in the LH III B-C East Lokris area in Central Greece derived from two different contexts, namely coastal and inland habitation sites (Iezzi 2009: 178, Table 11.1.). The material was recovered from four chamber tomb cemeteries; Tragana and Atalanti in the coastal area, and Kolaka and Modi in the inland (Figure 5.12). The coastal adult females generally lived long lives, the majority of them, 12, reaching an old age of 42-61 years. Three females were 32-41 years old at the time of death, and three others died at 17-21 years. Of the sampled coastal males,four died in the age of 17-21, two died between 22 and 31 years, and five between 46 and 56 years (Iezzi 2009: 179, fig. 11.2.). In the inland group, all females (two at 17-21, three at 22-31, five at 32-41, and two at 42-46 years old) and most of the males (one at 27-31, three at 32-41, and four at 42-46 years old) died before turning 46 years. Two males reached an age of 52-61 (Iezzi 2009: 179, fig. 11.3.).

Iezzi (2005: 187) reports an average height for the East Lokris males as 169.49cm, and for females as 152.99cm. Types of musculoskeletal stress (e.g. osteoarthritis) were distributed differently among the two groups. The coastal group showed more signs of osteoarthritis targeting the upper body, while the inland population suffered the condition in both upper and lower body. These differences were likely caused by different subsistence strategies; crop cultivation in the coastal area versus pastoralism or hunting in inland (Iezzi 2009: 183-87). Osteoporosis was only found in females. Anaemia (cribra orbitalia) was present in both communities, but was particularly common in the inland group and among females. According to Iezzi (2009: 184) the coastal agriculturalists relying heavily on grain which can inhibit iron absorption could have suffered from iron-deficiency anemia. Due to the lack of marshy environments attracting malarious infections, the inland inhabitants more likely suffered from parasitic infection that resulted in anemia (Iezzi 2009: 184-188). The possibility of cribra orbitalia occurring only in childhood is not further discussed. The presence of osteoporosis in females, and the generally poorer heath of females versus males seems to suggest differentiated dietary practices, in which males have a better access to food, especially (meat) protein (Iezzi 2009: 184).

Overall, the results of skeletal analyses of prehistoric sites in Greece suggests that individuals across the mainland suffered from similar health related issues. Osteoarthritis is common from MH to late LH III periods, and it is found in males and females alike. Signs of trauma do not seem to follow a systematic pattern, and their causes remain inconclusive. Finally, anemia is common among all populations from the MH and later periods. It does not seem to be related to sex, but instead to the location of the settlement and potentially different subsistence strategies, as indicated by the results from LH III East Lokris. In general, the most common causes for anemia seem to have been parasitic infection or thalassemia, although the presence of the latter in the Bronze Age is not verified (Kirkpatrick Smith 1998: 4-5 and 154; Larsen 2015: 32-34). Iron-deficiency caused by malnutrition is considered less likely. Each study seems to consider the occurrence of porous lesions in deceased individuals as something that affected them as adults and at the time of their deaths.

Although limited, the evidence of the age distribution seems to show a gradual change from Middle Helladic to Late Helladic. While the Middle Helladic males mostly died in their 30s and 40s, and females before their 35th year, in the Late Helladic period there are more older adults in both sexes, many reaching up to 60 years of age. While the causes of such changes are not clear, and small sample sizes may play a role, it would be tempting to think that a positive development in the subsistence strategies, leading to better availability of food and other resources, could have brought forth these changes.

Oral pathologies

The following section presents the oral pathologies in BA dental material. Caries, dental calculus, and the wear patterns of teeth can point to specific dietary practices. The wear of teeth can be used as an indicator for the texture and hardness of the food: more wear suggests the consumption of hard and less processed foodstuffs (Kirkpatrick Smith 1998: 88). Higher level of caries has been interpreted as a sign of a diet rich in carbohydrates, including starchy and sugar-rich foods (Larsen 2015: 68-69). Dental calculus, instead, refers to a diet that includes more animal protein (Lagia *et al.* 2007: 321; Triantaphyllou *et al.* 2008: 3029). Variation in the amount of caries or calculus on human teeth can also refer to different eating habits: women working in agricultural societies tend to do more tasting and snacking while handling the supplies and preparing the food. Such continuous consumption of foodstuffs could cause more caries (Kirkpatrick Smith 1998: 90). Hormonal and nutritional changes related to pregnancy and weaning can also influence the prevalence of caries. The tendency of males to possess more calculus than caries has been interpreted as better access to meat, for example through feasts (Schepartz *et al.* 2011: 9-10). Finally, enamel hypoplasia, defects on the thickness of the enamel, or even absence of enamel in areas of teeth, can indicate nutritional stress in childhood when enamel is expected to develop (Larsen 2015: 44-46).

The Argive Plain evidence

The most comprehensive records of oral pathologies in the Argive Plain derive from MHI-LHI Lerna. Only limited data exist for other sites: at Argos, enamel hypoplasia, the thinness and deficiency of tooth enamel present in the individuals of MH - LH I and

Geometric periods. The LH III period is not represented in the Argos osteoarchaeological material. Enamel hypoplasia is usually related to nutritional stress in childhood. Additionally, prominent levels of caries in the Geometric individuals could suggest a diet rich in carbohydrates and may have caused the high frequency of antemortem tooth loss and abscesses (Pappi and Triantaphyllou 2007: 679-80).

Two females recovered at Midea and potentially dating to the MH/LH period show signs of dental calculus and caries, and one LH IIIC infant exhibits enamel hypoplasia (Ingvarsson-Sundström 2007). No other details of oral pathologies are presented.

Individuals buried in the Grave Circle A at Mycenae show clear signs of enamel hypoplasia, but low levels of caries and antemortem tooth loss (Papazoglou-Manioudaki *et al.* 2010). Individuals buried in the Grave Circle B seem to have had few oral pathologies, since only some traces of caries were recovered (Angel 1973: 387).

At MH – LH I Lerna, males show slightly higher rates of calculus and lower rates of caries, while females exhibit the opposite results. This suggests that there might have been subtle dietary differences between the two sexes (Triantaphyllou *et al.* 2008: 3029). Females also exhibit higher levels of enamel hypoplasia (Voutsaki *et al.* 2013, 136). No major changes occur in dental lesions towards the LH I period, although some dietary changes can be witnessed in stable isotope values (discussed in pp.126-127). The evidence of dental health at MH-LH I Lerna suggests that the individuals were consuming both plant and animal proteins (Triantaphyllou *et al.* 2008: 3029; Voutsaki *et al.* 2013: 136-141).

In summary, the evidence of oral pathologies of the late MH-early LH Argive Plain individuals does not exhibit major patterns referring to the consumption of specific foodstuffs. Generally, the results indicate the consumption of plant and animal-based foods. Enamel hypoplasia, caries, and calculus are present, although remarkably low in the individuals buried in the Grave Circles A and B at Mycenae, perhaps indicating a better health among the elite. According to this evidence, dietary differences between sexes were not notable.

Comparative material

Comparative material for the Argive Plain oral studies is offered by three LH sites: Athens; Pylos; and East Lokris (Figure 5.12).

At the LH IIB-LH IIIB/C Agora of Athens (see pp.120-123 for more details), caries and antemortem tooth loss were common, and slightly more so among lower status individuals. The wear of the teeth, however, did not vary among low- and high-status groups. This seems to suggest that the texture of the consumed foods was similar at diverse levels of society. By contrast, differences in frequency of dental lesions between these groups could indicate that their dietary compositions varied. While the lower-status individuals would have consumed heavily cariogenic foods such as cereals, the higher-status individuals had access to a more versatile diet and thus were able to maintain better dental health (Kirkpatrick Smith 1998: 107–9).

In LH III Pylos, Messenia, individuals buried in chamber tombs, tholoi, and the Pylian 'Grave Circle'[42] show clear status differences. The tholoi and the Grave Circle have been generally understood as high-status burials (Schepartz *et al.* 2009: 2011). Individuals buried in the high-status burials showed low levels of oral pathologies, including enamel hypoplasia, caries, and antemortem tooth loss (Schepartz *et al.* 2011: 7). Females buried in chamber tombs had higher levels of dental pathologies than males buried in chamber tombs and females buried in elite tombs. The results indicate that high-status individuals had a better dental health and suggest that their diet was more versatile. Of all individuals, lower-status females suffered the most from dental health problems (Schepartz *et al.* 2009, 2011).

The results of tooth wear in the LH III B-C East Lokris, Central Greece, indicate dietary differences related to site location: the diet of the coastal site of Mitrou included more soft foods than the diet of Agia Triada, which was located in the mountainous inland. Such differences could have been caused by variability in diet, resulting from different subsistence strategies (de Gregory 2012: 73).

In sum, the comparative material from MH-LH sites in the Greek mainland exhibits similar oral pathologies to those of the Argive Plain. Caries is found in individuals through time, suggesting that the consumption of cariogenic foods, such as grain, remained common. Antemortem tooth loss, also present in all of the samples, was likely related to caries. Calculus is not examined for every assemblage, and the few results

[42] The Grave Circle of Pylos is most likely a disturbed tholos tomb and cannot be compared with the two Grave Circles at Mycenae. Nevertheless, it is considered to have been used for elite burials (Schepartz *et al.* 2017).

available are non-conclusive. Status differences are present in multiple cases and seem mostly related to the level of caries, tooth wear, or antemortem tooth loss. It seems that especially in the LH III period, lower-status individuals had a diet which included plenty of grain or other cariogenic foods, while high-status individuals had better access to a diversity of foodstuffs, and likely more often to animal protein. These results compliment the results of the skeletal analyses (p. 123).

Isotope signatures

Stable isotope measurements of human (or animal) bone material can be used to examine various socio-economic activities and changes, such as the arrival of new edible plants to a certain area, or the shift from hunting and gathering to agriculture (Papathanasiou 2015: 25). The method can be also used to detect differences in diet (Triantaphyllou *et al.* 2008: 3031; Voutsaki *et al.* 2013: 136). Most commonly, the stable isotopes of carbon (δ13C) and nitrogen ($\delta^{1}5N$) are measured, although oxygen (δ18O), strontium (87Sr/86Sr) and sulphur (δ34S) are also increasingly being used (Eriksson 2013: 126). The method measures the transfer of natural elements from the environment into the human bone material through food consumption.

There are two photosynthetic routes, C3 and C4, by which plants absorb carbon from the atmosphere. The identification of these routes facilitates the identification of the plant type consumed (Eriksson 2013: 128-29). Carbon (and nitrogen) isotope levels can also be used to identify marine resource consumption, as their enriched values usually indicate regular consumption of fish and other saltwater resources (Triantaphyllou *et al.* 2006: 630). The enriched values may be easier to detect in contexts where C4 plants with δ13C-values between terrestrial and marine resources were not consumed regularly (Eriksson 2013: 130; Larsen 2015: 303-4). The main plant protein in human diet, thus, derives either from C3 or C4 plants. C3 plants include temperate grasses (found in the middle geographical zones, vs. tropic and polar zones), trees, shrubs, fruits, and nuts (Iezzi 2015: 92; Triantaphyllou *et al.* 2006: 630). In a Bronze Age Greek context, a 'C3 terrestrial diet' would mainly consist of cereals such as wheat and barley, and legumes. The meat and milk of domesticated (terrestrial) animals would provide an addition to the protein intake (Schepartz *et al.* 2011: 8; Triantaphyllou *et al.* 2006: 630). C4 plants include tropical grasses, such as maize, rice, and millet (Triantaphyllou *et al.* 2006: 630). Of these, only millet was available in Greece during the Late Bronze Age (Valamoti 2016; 52). In the LBA Argive Plain context, any potential presence of C4 plants in the human skeletal material could, thus, indicate the use and consumption of the 'new' food plant, millet.

Nitrogen isotope levels vary according to the position of the consumer in the food chain, also known as their trophic level. Carnivores have higher nitrogen ratios than omni- or herbivores and therefore their nitrogen isotopes can be used to determine the protein component of the diet (Eriksson 2013: 127).

In humans, stable isotope values are measured from bone collagen. Carbon and oxygen isotope values are also measured from a bone mineral called bioapatite. Especially tooth enamel is used due to its good abilities to preserve for extended periods of time (Richards 2015: 15–16). However, isotope values also vary regionally because photosynthesis varies according to climate. Therefore, reconstructions of the local environment and food chains, as well as the past food consumption habits are necessary before any assumptions based on the isotope variation can be made (Larsen 2015: 321). Human stable isotope values are usually compared to the values of animals which represent particular positions in the food chain, for example sheep as full herbivores, and wild predators as full carnivores. Because of the aforementioned tendency for regional variation, these reference data must derive from individuals which are chronologically and geographically as close as possible to the investigated humans (Eriksson 2013: 127). Despite these issues, stable isotope method is considered a reliable method to examine human and animal diets (Papathanasiou 2015: 30).

In the Argive plain area, stable isotope measurements from bone material have been taken from the LBA burials in Mycenae (Nafplioti 2009; Richards and Hedges 2008) and the MBA burials in Lerna (Triantaphyllou *et al.* 2008; Voutsaki *et al.* 2013), Asine (Ingvarsson-Sundström *et al.* 2009) and Aspis of Argos (Triantaphyllou *et al.* 2006). Other isotope studies in southern Greece (Figure 5.12) include LBA sites in Achaia and Boeotia (Petroutsa and Manolis 2010; Richards and Vika 2008; Vika 2011; 2015), Sykia, Laconia (Richards and Vika 2008) and Pylos, Messenia (Papathanasiou *et al.* 2012). This chapter section will present the results of these studies, and discuss the compared data in the context of a potential LBA diet in the Argive Plain, as well as more widely in the Greek mainland.

The Argive Plain

The Argive Plain isotope data derives mostly from MH contexts. As with other bioarchaeological evidence, this chronologically earlier material should not be considered as representative of the LH period. It can be, however, examined to find other types of dietary patterns; for example, whether marine resources were regularly used at coastal sites, or if the elite had a different diet from the rest. The number of examined individuals, as well as the share of adults versus children and infants per site is presented in Appendix 9.

Each three assemblages, Asine, Aspis, and Lerna, largely consist of adults of various ages. Four out of the seven investigated adults yielded results in the MH Aspis (Argos) study. The mean δ13C value was -19.4 ± 0.4‰, and the mean δ15N 9.2 ± 0.7‰. These values are typical for C3 terrestrial diets. At MH Lerna, 48 individuals were sampled for carbon and nitrogen isotopes. 39 of these, 15 male and seven female adults, three juveniles (12-18 years old), five children (6-12 years), eight infants (1-6 years), and one neonate (0-1 years) yielded sufficient results (Triantaphyllou *et al.* 2006: 634, Table 2). The mean δ13C among the Lerna individuals was -19.5 ± 0.3‰ and the mean δ15N 8.4 ± 0.7‰. There was little variation in consumption patterns among adults and subadults, or sexes. Three adult males and one juvenile showed indications to higher plant-based consumption with low nitrogen isotope values, and three adult males showed higher nitrogen values referring to increased animal protein consumption (Triantaphyllou *et al.* 2008: 3031-3032, Table 2). In Asine, 38 individuals from the Barbouna settlement, and the East Cemetery related to the acropolis hill were sampled. Of these, 19 samples (6 from Barbouna and 13 from the East Cemetery) yielded sufficient results. Of the Barbouna individuals, one was a young or prime adult male (18-40 years), and the rest neonates. Of the East cemetery group, two were children (6-12 years), two juveniles (12-18 years), and the rest adult males (4) and females (3) with a variety of age groups presented. The mean ranges of carbon and nitrogen values are not given, but the individual values seem to resemble those in the Aspis and Lerna studies (Ingvarsson-Sundström 2009: 5, Table 1). Although the small number of samples (3) cannot be held very conclusive, the Asine females seem to show higher nitrogen values than most males. This could point to higher consumption of animal protein by females. In addition, one male and one unsexed individual show elevated nitrogen levels comparable to those at Mycenae (Ingvarsson-Sundström 2009: 7-8).

Overall, the MH-LH I people of Aspis, Asine and Lerna suggest similar dietary patterns. At all three sites people mainly consumed C_3 plants and terrestrial animal protein (Ingvarsson-Sundström *et al.* 2009; Triantaphyllou *et al.* 2006: 634-36, 2008: 3032-33). The plant protein would have derived from cereals and legumes, and the animal protein from farm animals. Although the isotope analyses cannot separate between meat or dairy, textual and zooarchaeological evidence suggest that besides milk, cheese was consumed, and that meat was produced for example by fattening pigs (see p.105 and pp.111-114). The elevated nitrogen isotope levels suggest that the Aspis group seem to have had a slightly higher animal protein intake than people buried at Lerna or in Grave Circle B at Mycenae, but the sample size is small (Triantaphyllou *et al.* 2008: 3033). To contrast this, however, recent studies (e.g. Bogaard *et al.* 2013: 12589) have suggested that manuring of cereal crops could result in elevated nitrogen isotope levels in humans who consume them. Manuring a variety of cereal and pulse crops has been included in the Bronze Age farming practices in Greece (pp.71-72 and 101-102). Thus, the few individuals with higher nitrogen levels in Lerna, and in particular the three females of Asine could have consumed higher levels of manured crops instead of animal products. Despite the proximity of the sea, the isotope values do not indicate the regular consumption of marine resources at any of the sites (Ingvarsson-Sundström *et al.* 2009; Triantaphyllou *et al.* 2008: 3032-33).

Mycenae forms an exception to the homologous dietary pattern. The isotope values at Mycenae derive from two burial contexts, the MH III/LH I Grave Circles A and B, and the LHI-III chamber tombs (Richards and Hedges 2008: 225–26, Table 1). 29 individuals were sampled, and of these eight were sexed as males and four as females. The rest, including all individuals from the chamber tomb contexts, remained unidentified (Richards and Hedges 2008: 225–26, Table 1). Age distribution of the individuals is not presented; however, the Grave Circle material mostly consists of adults (see p.122). Mean values for the carbon and nitrogen results are not given but observations on the individual values show an elevated range of nitrogen (several values above 10‰), especially among the Grave Circle individuals. Carbon isotope values, on the other hand, seem to resemble the ranges seen in other Argive Plain contexts (Richards and Hedges 2008: 225-26).

Both groups exhibit values related to C3 based terrestrial diet, but the Grave Circle individuals likely consumed more animal protein than the chamber tomb group. The consumption of animal protein is assumed because the individuals consist mostly of males, who have traditionally had better access to meat, and because the individuals are described as tall and robust which is often considered as a sign of sufficient diet. However, the possibility of manured crops instead of meat consumption causing elevated nitrogen levels in the Grave Circle individuals should be considered. Elite individuals could have had better access to crops that were tended in more intensive methods to ensure sufficient harvest (see Chapter 6 pp.139-150 for discussion about crop growing methods). Additionally, a sizeable number of individuals from both Grave Circles had a significant amount of their protein intake deriving from marine foods. The proportion of marine food consumption is estimated at 20-25 percent (Richards and Hedges 2008: 227). While chamber tombs cannot be directly connected to a specific social class, both Grave Circles are known to be elite graves. Therefore, it appears that that marine foods were consumed especially by the Mycenaean elite (Richards and Hedges 2008: 229). This statement is supported by the fact that the consumption of marine resources seems to have been practically non-existent in the MH and the LH diets all over mainland Greece (pp.127-129), with only one other exception deriving from a palatial context at Knossos, Crete (Nafplioti 2016). Nevertheless, there is also a possibility that the data from Mycenae could reflect a general change in dietary habits over time (Richards and Hedges 2008). In addition, a study of the strontium isotope 87Sr/86Sr values at Grave Circle A indicate that several individuals were non-locals (Nafplioti 2009). These results raise new questions about the origin of the Mycenaean elite and their dietary habits.

In relation to the absence of marine resources consumption in non-elites, there are, however, some indications that fish consumption may not always be visible in the human isotope values. Milner and co-authors (2004: 16) suggest that in certain environments, such as river estuaries, carbonates from terrestrial sources can enter the marine food chain and 'camouflage' the otherwise clear values of seafood consumption. Hypothetically, such enrichment could have been possible in the shallow coast of the Argos Bay, where two perennial rivers carried thick layers of soils from the upper areas of the plain. Another explanation is related to the variation of carbon isotope values in the protein sources; there are some indications that the domination of plant ingredients, as would be expected in the case of cereal-based agriculture, can hide the proportion of marine components in the diet (Milner *et al.* 2004: 18). This could explain why the coastal agriculturalists of Lerna and Asine do not exhibit isotope values indicating marine food consumption. Hedges (2004: 35) further notes that since bone collagen, from which the isotope signatures are measured, regenerates throughout adulthood, marine diet absorbed only in some periods in life may not be visible. Similarly, seasonal, or very low use, for example as fish sauce or another type of condiment of marine resources may be obscured (Heinrich *et al.* 2021: 8). Finally, some (Salazar-Garcia *et al.* 2016) have pointed out that freshwater fish consumption can result in different values than marine resource consumption and is therefore not necessarily visible in the isotope composition. In the LBA Argive Plain, seasonal consumption of marine resources, and possibly cultural factors such as dietary preference to agricultural products might have played a role in the formation of the regional isotope values. As discussed earlier (pp.114-115), there is compelling material and zooarchaeological evidence of fish and marine resource consumption in Bronze Age contexts across Greece.

Comparative results in mainland Greece and Crete

The isotope signatures of the selected MH - LH sites in mainland Greece and Crete (Figure 5.12) align with the general C3 terrestrial diet of Lerna, Argos, Asine and Mycenae. Some individuals exhibit exceptional consumption patterns. In some cases, dietary patterns seem to be connected to site location. For example, in East Lokris (the material derived from the same locations as in the skeletal studies; Tragana, Atalanti, Kolaka and Modi in Figure 5.12), inhabitants of coastal sites were clearly consuming more animal protein than their neighbours in the inland mountains (Iezzi 2015: 100). The coastal site of Almyri in the Peloponnese also showed higher animal protein intake than two inland sites, one in the Peloponnese and one in Central Greece (Petroutsa and Manolis 2010: 618). The animal protein consumed at this site would have most likely derived from secondary products, such as milk and cheese, instead of heavy meat consumption (Iezzi 2015: 100). Greater focus on mixed agriculture in the geographically more accessible coastal areas would suggest a more versatile diet.

The use of marine resources is not visible in any of the mainland communities outside Mycenae. However, recent isotope results from Knossos, Crete, suggest a consumption of marine foods similar to the Grave Circles A and B of Mycenae. The sample consists of individuals from two Middle Minoan II-Late Minoan I cemeteries located in the close vicinity of the palatial complex. Both cemeteries have been considered as elite burial places (Mee and Cavanagh 1990; Nafplioti 2016: 42-44). Several individuals of both cemetery groups yielded isotopic signatures suggesting notable consumption of marine resources. The remaining individuals in both cemeteries had a 'normal' C3 terrestrial diet (Nafplioti 2016: 46–48).

In a few cases, the amount of animal protein varies significantly between sexes. In late MH-LH IIIC Pylos, Messenia, females showed generally lower values of animal protein intake than males, and lower-class females showed lower values than elite females. Dietary differences could not be detected between higher- and lower-status males, or between elite males and elite females (Schepartz *et al.* 2011). More delicate, but similar, differences in animal protein consumption between sexes were detected in Late Minoan Armenoi (Richards and Hedges 2008: 227), and Late Helladic East Lokris (Iezzi 2015: 99). The greater intake of animal protein by males has been explained by a more regular access to feasts, where meat was served in substantial amounts (Schepartz *et al.* 2011).

Most isotope values in the southern mainland of Greece and Crete do not indicate regular consumption of C4 plants. C4 plant use seems to become more common in central and northern Greece (Triantaphyllou 2015: 64-65). In East Lokris, they were consumed regularly at two inland sites, Kolaka and Modi, but no traces were visible in the samples of several other coastal sites in the same region (Iezzi 2015: 102; Petroutsa and Manolis 2010: 618). In the northern Peloponnese, however, C4 plant use has been detected at two sites, Almyri and Agia Triada. Additionally, seeds of millet have been recovered in lesser amounts at LH III Tiryns (Kroll 1982). Petroutsa and Manolis (2010: 616-18) argue that millet was used commonly all over mainland Greece in the Late Bronze Age. Besides humans, LBA cattle used as a reference material to the human isotope values in Agia Triada in the Peloponnese exhibited at least partial C4 plant use (Petroutsa and Manolis (2010: 616-18). This suggests that millet or another C4 plant might have been used for both human and animal feed. Other animal species (cats, dogs, sheep and turtles) used as reference material in the same study showed a C3 dietary pattern, however. These isotope values are the only ones in the southern mainland confirming the consumption of C4 plants. The Argive Plain isotopic evidence derives from chronologically earlier contexts and does not therefore preclude the possible introduction of millet in the LH III. As a comparison, the results in LH III Pylos, Messenia, have not revealed any signs of C4 plant use.

The comparative isotope material from MH-LH sites in the southern mainland and Crete correlates in most parts with the results from the Argive Plain. Although, chronologically, the comparisons between MH/LH I and LH III sites are complicated, it seems that a C3 terrestrial diet remains the general pattern from the MH to the Mycenaean period. C4 plant use, almost certainly referring to millet, seems to be introduced to the diet slowly during the LH III. In the southern mainland its consumption appears irregular. The consumption of marine resources is rare all around the MH and LH southern mainland. Based on the two cases of Mycenae and Knossos, fish seems to have been only consumed by the elites, although not all the individuals buried in the elite tombs consumed the same products. Dietary differences related to social hierarchy seem to be more site-specific than general. Indications to the overall greater consumption of animal protein by males can be detected at Pylos, East Lokris, and Armenoi, Crete.

Summary: Diet and health of the Argive Plain population

Bioarchaeological evidence suggests that from the Middle Helladic to the beginning of the Late Helladic period the diet and health of the Argive Plain population resembled those of the LH III populations of mainland Greece and Crete. However, it has to be taken into account that the socio-political and economic situation may have differed between these periods and influenced dietary patterns or health of specific individuals or groups such as emerging elites.

In general, the health of the Bronze Age population in Greece appears to have been stable. Signs of trauma (injuries, violence, etc.) are present at some sites (e.g. Middle Helladic Asine, Geometric Argos and Late Helladic Athens), but they do not correlate with each other chronologically, and cannot be directly used as evidence of fighting. Lesions related to heavy mechanical activities, possibly agricultural or construction work, hunting, or fighting, are generally present across sex and status boundaries. No clear indications of a diachronic change in physical activities or in the level of illness are visible between the Middle Helladic, Late Helladic or Geometric groups. However, some change can be potentially seen in the average age at death of the adult individuals from the Middle Helladic to the Late Helladic period. Although the sections above present only selected studies of both chronological groups, there are more individuals over 50 or even 60 years old in the Late Helladic assemblages. A more systematic approach, as well as a much larger sample size would be required to examine whether people lived longer in the Late Helladic. Similarly, changes in stature (height) between the Middle Helladic and Late Helladic individuals in the Argive Plain and other areas seem to be small. While Angel (1982) reported the average height for Middle Helladic individuals as 153.5cm (females) and 166.1cm (males), Iezzi (2005: 212) has collected height data from LH III contexts with a mean for males at 167.39cm and for females at 155.04cm. However, caution is required when statures are compared between different social and cultural groups. Height and robustness have been traditionally seen as indicators of wealth and versatile diet. However, various case studies have shown that environmental conditions, genetics, and even urbanization levels have major influence in the physiological characteristics of humans (Heinrich and Erdkamp 2018: 1017).

Porous lesions commonly related to anemia appears to be the one among the most common stress indicators from the Middle Bronze Age to the Geometric period. Of the various types of anemia, iron deficiency anemia, which could be caused by an insufficient diet, has been suggested as the cause of these lesions. There are indications that a diet rich in cereals could restrict iron absorption due to phytate ('anti-nutrient' that has the tendency to reduce the absorption of other nutrients) that is present in grain. Tannins, present in wine, can have similar effects (Iezzi 2009: 184; Kirkpatrick Smith 1998: 141; Larsen 2015: 31). Hookworm or other type of parasitic infection causing internal bleeding is often mentioned, and could be related to unsanitary living arrangements and other issues in past living conditions. Furthermore, since in most of the studies used here porous lesions are believed to affect adult populations, hookworm instead of dietary insufficiency-related anemias appears more attractive. Thalassemia, an inherited blood disease that has been connected with the occurrence of malaria, is commonly mentioned in older studies of the human skeletal material in the Argolid and elsewhere in the Mediterranean. However, the presence of this condition has not been convincingly demonstrated among ancient populations. The lack of vitamin B12 as a result of lactating mothers with low B12 preserves (Walker *et al.* 2009) has not been discussed in relation to the Argive Plain health data. Skeletal material of infants in the assemblages is partially fragmentary and thus inconclusive. However, the MH children at Asine and Kouphovouno were suffering from insufficient nutrition, likely due to infrequent, or completely absent weaning. More studies are needed to examine whether similar problems continue in the LH III period, although the signs of enamel hypoplasia in the MH-LH I adults at Lerna and Mycenae, as well as in LH III females at Pylos, also suggest childhood malnutrition. Infant malnutrition debate is related more widely to the argument of porous lesions developing only on children. In this case adults showing signs of these stress markers in fact representing individuals successful in adaptation, overcoming and tolerating severe health issues through their lives. In this sense, the individuals or Lerna, Asine, and Aspis could represent higher resilience than the individuals of Mycenae, or the LH III individuals of Athens (Kirkpatrick-Smith 1998: 158), with their generally low level of stress markers. Nevertheless, the old age and 'robustness' of several individuals amongst the Mycenae assemblage can also been seen to counter such interpretation.

Dietary reconstructions based on carbon and nitrogen isotope signatures clearly indicate that most of the MH and LH communities in southern Greece and Crete enjoyed a C3 terrestrial diet. Meat and milk from domestic animals, such as sheep, goats, cattle and pigs, would have given a much-needed supplement to the energy and protein needs. Access to these was often selective, with females consuming less animal protein than males, although it is possible that in some cases the elevated nitrogen isotope levels (indicative of animal resources) are, in fact, resulting from manuring practices. The isotopic data seems to indicate that fish and seafood were not part of the everyday diet but could have been included in the diet of the elite. Currently this seems to be true only for the elite of Mycenae and Knossos, since Pylos data has not yielded similar results (Schepartz *et al.* 2011, 2017).

Comparisons of the dietary patterns of MH and LH individuals suggest that food resources and their consumption did not change dramatically over time. Therefore, we can relatively securely establish the basic LH diet of the Argive Plain society. The predominant consumption of cereals and legumes was complemented by animal protein (mainly milk and meat), but not by considerable amounts of marine resources, or by millet, which was mainly popular in northern Greece. However, the stable isotope signatures cannot yet be used to determine the exact composition of the different protein sources in the diet, nor can they define the exact plant or animal species consumed. Therefore, the current level of information remains generic: for example, in East Lokris, all of the studied communities regularly consumed 'a small to moderate amount of animal protein' (Iezzi 2015: 99). In EH - MH Thebes 'animal protein was consumed regularly'. In order to produce more detailed results, the values of the 'end members', or, in other words, the values of individuals with a diet consisting only of terrestrial plants, or only of marine resources, are required (Vika 2015: 80). In some cases, the isotope values of herbivorous animals, such as sheep or cattle, have been used as benchmarks for the human terrestrial plant diet (Richards and Hedges 2008: 223). The only more tangible estimation of the amount of a protein source in the diet concerns the marine resource consumption of the individuals of the Grave Circles A and B at Mycenae. It is estimated that fish and seafood formed up to 20-25 percent of their protein intake. However, the Mycenae results lack benchmarks of animal stable isotope values from the same site, hampering their interpretation (Richards and Hedges 2008: 227). Nevertheless, the difference with other LH mainland human isotope values is notable.

Zooarchaeological data related to fishing and the use of marine resources recovered at the BA Argive Plain sites indicates the use of marine resources during the Bronze Age. In this study it is assumed that marine foods were consumed in the Argive Plain in modest amounts, for example seasonally. Freshwater fish from the still partially open Lake Lerna (see p. 63) could have offered a small protein source as well.

The representativeness of the osteoarchaeological data in this section warrants consideration. While the osteological paradox has been previously discussed, it remains important to ask what kind of insights can the deceased individuals of the Argive Plain provide regarding the living population. For instance, can the increased number of infants and children in the Late Helladic assemblages serve as an indicator of population growth or, conversely, of poorer living conditions in specific communities?

Site contexts introduce another layer of bias to interpretations regarding demographic or dietary patterns. The Argive Plain assemblages primarily originate from elite contexts (such as Mycenae) and settlements that were prosperous and central, if not high-status, during the Middle and early Late Helladic periods (pp.25-31). Despite the apparent similarities in food plant and animal consumption among these sites, their data may not provide sufficient parallels into the diet, age, and sex of smaller rural communities residing in more remote and inland locations. This is evident in the case of LH III Lokris, where inland communities exhibited a higher reliance on hunting and pastoralism, leading to poorer health outcomes for females (Iezzi 2009). There is a need for more comparative studies of osteoarchaeological assemblages from both elite and non-elite contexts to discern differences in dietary patterns related to social status in the Argolid. Additionally, it would be beneficial to compare osteoarchaeological and isotopic data with zooarchaeological data derived from the same chronological and geographical contexts, as this could offer fresh insights into animal protein intake and its availability within communities.

Building upon the available data presented in this section, the following chapter will undertake a reconstruction of farming practices in the Late Bronze Age Argive Plain. The first part of the chapter combines geographical, climatic, technological, botanical, faunal, and osteoarchaeological studies with ethnographic studies in the Argolid region and the broader Eastern Mediterranean to study land use, cultivation, animal husbandry practices, diet, and the annual cycle of activities among the people of the Mycenaean Argive Plain. While anticipating more detailed isotopic investigations into the proportions of different foodstuffs in the Bronze Age diet, this study draws on dietary composition estimates from Classical and recent historical periods. These figures and ranges are then translated into food production needs, forming the basis for reconstructing land use patterns in the Argive Plain (pp.150-166). Ultimately, the reconstructed farming practices and diet will pave the way for the analysis of local agricultural potential (pp.166-178).

Chapter 6

Farming strategies and the agricultural potential of the LH III Argive Plain

Chapter 5 presented archaeological data related to the LBA subsistence strategies collected from various sources in the Argive Plain and elsewhere in mainland Greece. The following chapter combines these data to create a reconstruction of the LH III Argive Plain agricultural system, and to calculate its agricultural potential. Previous models of the agricultural system of this area are limited (see pp.41-46). As such, this chapter provides a new reconstruction of the activities of the rural Mycenaean population.

In this study, the reconstruction of agricultural systems is based on a combination of archaeological evidence and ethnographic analogies, while the calculations of the agricultural potential must rely on historical and ethnographic parallels of land use, crop yields and diet, and modern data on nutrition (pp.51-60). The variables for calculating the LH III agricultural potential are formed by numerical data of 1) the available land area, 2) the food input/output (i.e. what was eaten and what was grown) 3) agricultural strategies including cultivation methods and risk management, and 4) environmental conditions, such as availability of water. Each of these variables can be influenced by people's choices, however.

The following section (pp.132-150) presents a reconstruction of the LH III Argive Plain agricultural strategies as they emerge from archaeological data and ethnographic and historical parallels. What follows (pp.150-166) are models for the LH III diet. These models are used as the basis for the analysis of the production potential of the Argive Plain area (pp.166-174). The chapter is concluded by a summary of the results (pp.174-178), while the reconstruction and the agricultural potential are examined in light of the wider LBA Aegean societal context in the following Chapter 7.

Model of the agricultural practices in the LH III Argive Plain

How people practise agriculture can be defined through a variety of environmental and cultural aspects. The latter are, for example, related to the ways societies organize the governing of land, how it is managed by individuals or groups, who gets to enjoy the profit, or what kind of products are valued or most needed, hence, what should be produced. Although agricultural production and the way it is organized is critically important to local economies, it is often absent in early written sources such as Linear B. To create a more exhaustive image of farming in the LBA Greece, the use of data from other sources such as ethnographic and historical archives, and archaeological assemblages is necessary. Hence, this section examines Mycenaean agriculture and land management through Linear B texts and the data collected from the LH III Argive Plain environment.

Settlement system, political geography and landscape potential

Linear B texts found in Pylos and Knossos (Chapter 2) give suggestions on how the local Mycenaean political systems impacted land use and agricultural production. Similar data of the LH III Argive Plain social and political organization could help to better understand the local system in which food was produced. Unfortunately, the Linear B texts recovered in the Argive Plain offer little information on these topics. A few fragmentary lines in the Argive Plain tablets hint at similarities to those recovered in Pylos, regarding the ownership and use of land in the LH III period. These texts give some grounds to reconstruct similarities in economic and land use organization. Combined with data introduced in Chapters 2, 3 and 5, these fragments can be used to examine the local political geography and its influence on the land use in the Argive Plain.

As discussed in detail on pp.31-36, the Argive Plain in the LH III period was characterized by a settlement pattern different from the other Mycenaean core areas in Pylos or Thebes. The main difference consisted of the presence of several large settlements within the limited space offered by the flat plain. Analysis of the political geography of the Argive Plain and connections between the regional centres and foreign powers suggest that Mycenae, Midea and Tiryns had independent economic systems - at least in subsistence economic sense. Galaty and Pullen (Galaty *et al.* 2014: 452; Pullen 2022) have concluded that there may have been three distinct "states" in the Argive Plain, each with their own subsistence territories. A similar view is held in this study. The plain also contained other settlements with considerable sizes and populations. The extent of the sites and the imports found in Nafplion and Asine (p. 28 and p. 29) seems to suggest that these settlements also enjoyed at least some level of economic and political independence. Notwithstanding this, Mycenae grew as the wealthiest and most powerful site of the Argive Plain during the LH III period (Maran 2015; Voutsaki 1995, 2010; Wright 2004). However, even if the number of imports was most prominent at Mycenae, it is unlikely that it controlled the other Argive Plain sites in their subsistence economic efforts.

In this study, it is assumed that the Argive Plain settlements were able to produce their own subsistence. Due to the scarcity of suitable cultivation land in its close surroundings, Mycenae was the only palatial site that likely had the need to expand its subsistence territory into the adjacent valleys such as Berbati, Nemea and Kleonai (Wells 1998; Wright 2004). The presence of ceramic vessels of Mycenaean origin in Tsoungiza and in the Korinthian territory, and the roads leading from Mycenae through these areas towards the north give credence to this view. It has been suggested that the relationship was likely related to food production (Schallin 1996: 124; Wright *et al.* 1990: 644) but there is no certainty whether this production was substantial enough to provide the palace with stock beyond immediate subsistence needs. The other palatial sites, Midea and Tiryns, as well as Argos, Lerna, Nafplion and Asine, had sufficient access to arable land in their immediate surroundings, at least for subsistence purposes.

People living in these large settlements took care of their own subsistence needs by growing food in the surroundings, and likely by exchanging products (e.g. Sjöberg 2004). Thus, the land surrounding the palatial settlements could have been cultivated by farmers (landowners and leasers) who lived within the wider settlement area and commuted to their fields on a daily basis, as suggested by Bintliff (2019). This commute was likely only for short distances, however, since long distance transportation of harvested crops and workforce requires rather extensive use of animal power, as shown by more recent examples (see pp.138-139 below). Although such a system seems to point to a more independent style of farming with individual plots and storage places, communal work could have taken place at the palatial production sites, olive and fig orchards and wheat fields. The elite and dependent workers of the palatial settlements might have been sustained by food production, on land which was dedicated to direct palatial production or by shares of foodstuffs given to the palaces by local farming communities in exchange for services such as loaning oxen for heavy work (p. 16).

Since at least the three Argive Plain sites, Mycenae, Midea and Tiryns, kept administrative records, perhaps it could be suggested that each of them also taxed their subordinate communities, similar to the Pylian state (pp.15-16). However, no direct evidence of such a system exists. There is no evidence of territorial division related to taxation of the Argive Plain either. Only one text fragment in the Tiryns Linear B tablets (that of an oxherd and 6 GRA of land discussed on pp.10-13) seems to indicate that landholdings were recorded in a comparable way in the Argive Plain as in Pylos. However, since this is only one text, it would be unwise to base conclusions about the economic activities exerted by the palaces of the Argive Plain on it.

As discussed in Chapter 2, taxable products did not include food items such as cereal or legumes, but more specialized products. The subsistence maintenance of the palatial workers and the administrative elite would more likely have come from direct palatial production of bulk products (Halstead 1999c: 36; Shelmerdine 1999b: 21). Evidence of such production is, however, scarce in the LH III Argive Plain material and textual evidence. At least at Mycenae, palatial workers were paid with food rations similar to Pylos. In Pylos, these rations were produced on palatial lands (pp.10-13). Halstead (1992: 60-61) suggests that this agricultural production was located on lands close to the central authority, or near the important sub-centres. Direct production would have been easier to control by the administration when it was closer to these settlements. In this scenario, some of the fertile land in the close surroundings of Mycenae, Midea and Tiryns might have been reserved for the palatial production of staple goods such as wheat, figs, and olives. However, since the palace supported only a limited number of workers with rations (and the rest with land allocations), the production land did not have to be extensive. It is likely that families living within the palatial centres produced their own food independently on lands that were either owned or leased by them. Near Mycenae, the LH terraces found in the vicinity of the walled settlement could have been part of a field system of the palace. But the palatial centres had better access to large animals which would have made travelling to more distant fields easier. The well-established road network of the Argive Plain would have further enabled the easy transportation of goods from further away, for example from the valleys of Berbati, Nemea and Kleonai.

Beyond the large, urbanized settlements, the Argive Plain landscape could have been inhabited by subsistence farmers living in small hamlets and villages, some likely also in single farmsteads, although the evidence of these only comes from locations outside the immediate plain (pp.23-25). Communities inhabiting small groups of houses, perhaps similar to the excavated settlement of Chania in the central northern plain (p. 30), would have lived sustainably. Their dwellings were located close to crop fields, making transportation and heavy agricultural duties manageable even if pack and draft animals were not available. Burial sites, consisting of one or multiple chamber tombs, often seem to be located close to these settlements. Whether these small communities formed the *damoi* of the LH III Argive Plain, as has been suggested in relation to Chania (Palaiologou 2015), cannot be answered conclusively without further evidence.

However, since a Linear B fragment recovered from Tiryns (discussed in detail on p.14) mentions the communally owned *ke-ke-me-na* land, it seems the main owners of this land, the *damoi*, could have been present in the LH III Argive Plain like they were in Pylos. Some of the available land would have been leased out by the *damoi* to various individuals, groups and religious communities (described in detail on pp.8-10). The *damoi* would have likely had agreements with the local palaces about exchanging services. Such agreements could have included the provision of workforce to palatial construction projects. In exchange, the palaces could have leased out draft animals such as oxen, which also appear in the Tiryns Linear B fragments (Brysbaert 2013: 61). Some of the land was saved for private use by the *damoi*. As assumed for the *damo*i land at Pylos, this private land would have been used for personal sustenance. On it, the local communities would have kept their cereal and legume fields, gardens and areas for pasture. It seems logical that many tasks included in crop cultivation and animal husbandry would have been conducted together in these hamlet or village communities. These aspects are the focus of the reconstruction of the agricultural practices presented further on in this study (pp.139-150).

The limited evidence of Mycenaean landownership system leaves many questions about the identity and status of the landowners and leasers unanswered (pp.8-10). In the LH III Argive Plain context, for example, it is not known whether landowners lived in or outside the palatial settlements, and if they held similar power as the landowners at Pylos. After all, the population and size of the three palatial settlements, Mycenae, Midea and Tiryns, grew in the LH III, which means more land was needed to support their workers and inhabitants. Even though agricultural hamlets were still present in the landscape, it is clear that the kinship-based reciprocal economic system of the Middle Helladic had been superseded by a new more urbanized and hierarchical organization (pp.15-18 of this work; Voutsaki 2001, 2010). Perhaps the local farming communities were struggling to define their position in this new order which slowly occupied more of the land that had been the basis of their wealth.

In summary, the agriculture in the LH III Argive Plain may have taken at least three overlapping forms; the traditional, system of hamlet communities using more intensive farming methods, the new system of 'urbanized' households with longer commutes to fields outside nucleated settlements, and the profit-oriented system of palatial production of bulk goods that exploited extensive farming strategies and possibly hired labour. The following section focuses on the agricultural practices of the LH III hamlets and, to some extent, individual households. The palatial production in Mycenaean societies has been comprehensively studied before by Paul Halstead (Halstead 1989, 1992, 1995b, 1999c).

The LH III Argive Plain cultivation space

The geography of the Argive Plain was favourable for extensive cultivation and animal husbandry in the LH III period. The plain provided plenty of flat and gently sloping surfaces that could be turned into fields for cereal, legumes, and tree crops. The agricultural landscape had stabilized over centuries since the Early and Middle Helladic periods, when the notable settlements of the plain, Argos, Lerna, Mycenae, Midea and Tiryns, were first founded (pp.25-31 and 63-65).

The majority of the soils on the plain consisted of Pleistocene and Early Bronze Age alluvial fans, and to a lesser extent of Late Bronze Age alluvial deposits (see details on pp.65-69). These deposits offered a fertile basis for cultivation. The coastline, which was located a kilometre closer to Tiryns than currently, and the surroundings of Lake Lerna were marshy, and the lake was still partially open in the LH IIII. These areas, totalling *c*. 1000ha, could not be used for crop cultivation. Archaeobotanical records (pp.91-92) indicate the presence of various weeds and grasses in the surroundings of Tiryns. These grasslands could have provided pasture for animals, including the oxen supervised by the palatial administration of Tiryns (pp.10-13 and p. 107).

Problems for agriculture might have been caused by longer periods of drought, which would have diminished water retained in soils during the winter rains. Periods of drought might also have influenced the water levels in reservoirs such as springs, rivers and aquifers (see pp.63-64). Another environmental aspect influencing agriculture was the limited space of the plain for cultivation. Bordered by high altitudes and the sea, the plain had restricted potential to provide food production areas to the populations of the LH III palatial settlements. Access to fertile areas in the north, west and east was difficult, since it would have required crossing challenging landscapes and high altitudes. The valleys nearby, accessed through narrow passes, may have offered essential subsistence aid (pp.62-65 and below).Agricultural production is usually focused on flat surfaces and gentle slopes,

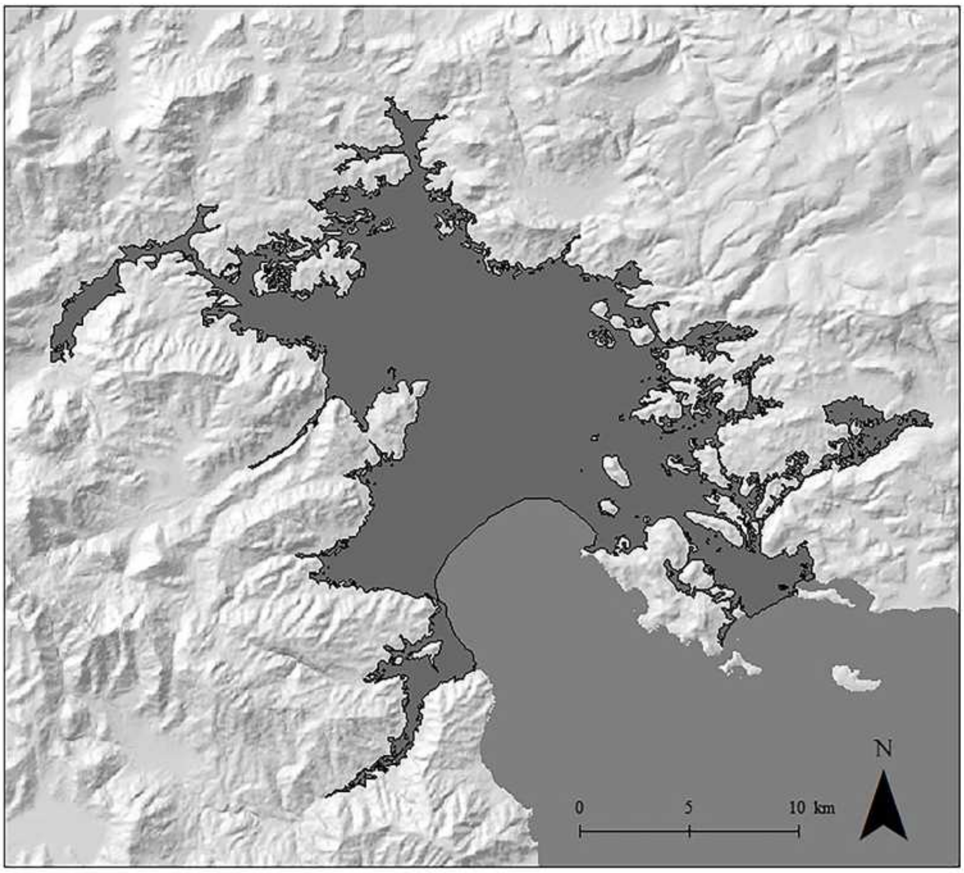

Figure 6.1. The land area (dark grey) that could be used for agriculture on a slope under 6°.

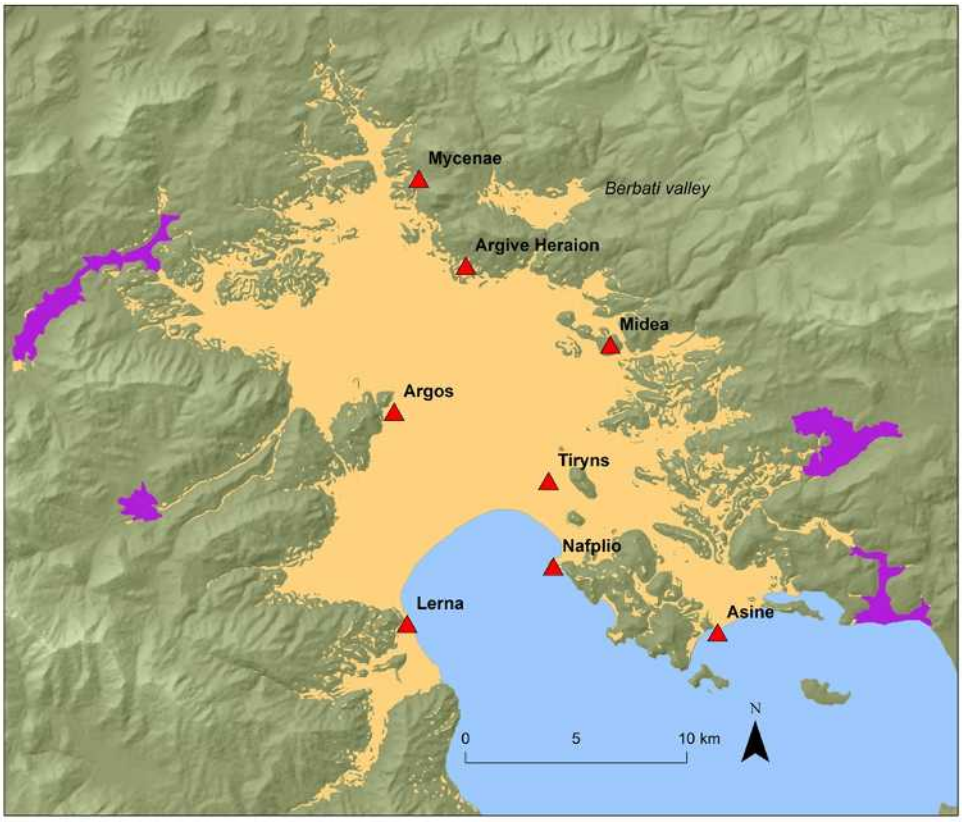

Figure 6.2. Areas (purple) excluded from the agricultural space because of difficult access.

but can be increased by creating terraced platforms. Following Fallu's analysis (2017: 117-118, Figure 42; pp.69-74 of this book) of the lowest threshold of terraced fields around Mycenae, a threshold of 6° was defined for land that needed modification before it could be cultivated. Figure 6.1 presents the area below 6° that was suitable for cultivation on the plain and in its immediate surroundings. The potentially cultivable land area presented in Figure 6.1 totals 30,000ha,[1] but it is unlikely that the entire area was cultivated in the LH III period. In Figure 6.2, some of the small side valleys (3000ha in total) have been excluded. These areas were far away or with a challenging accessibility to be commuted to from Argive Plain settlements a daily basis. The remaining Argive Plain area totals 27,000ha of potentially cultivable land.

Figure 6.1 also demonstrates that Asine and the Berbati Valley are naturally connected to the plain area. Excluding these areas from the plain seems arbitrary but considering their possible political independence in the LH III (see pp.20-23 and pp.25-31), they should be examined separately from the plain (Figure 6.3). Two other valleys, Nemea and Kleonai, were likely connected to the political area of Mycenae. When these areas are excluded from the plain, the remaining area totals 25,000ha. Excluding the coastline from this, the total amount of flat agricultural land of the plain was, therefore, *c.* 24,000ha, as illustrated in Figure 6.4 (see pp.166-167 for a summary and the use of these figures in the calculations of the agricultural potential). These calculations are based on topography only, and do not consider alternative land losses.

By using the parameters collected from studies of modern and Bronze Age terrace systems in the Aegean (pp.69-74), the space added to the cultivation space of the LH III Argive Plain by terraces was modelled (pp.72-

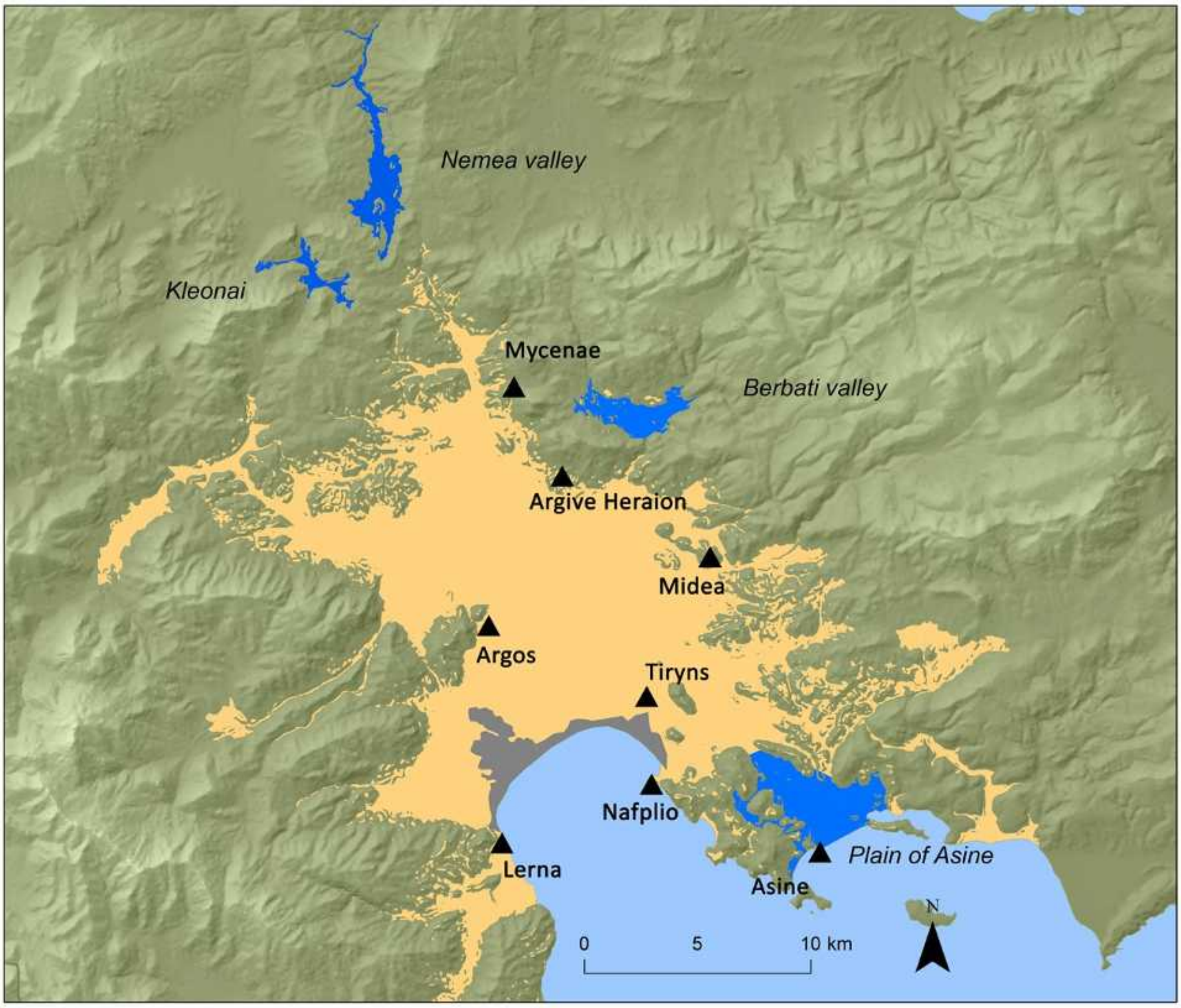

Figure 6.3. The 'production areas' outside the Argive Plain, the valleys of Nemea, Kleonai and Berbati, as well as the plain of Asine, all marked in blue.

[1] 30,124ha according to ArcMap metadata.

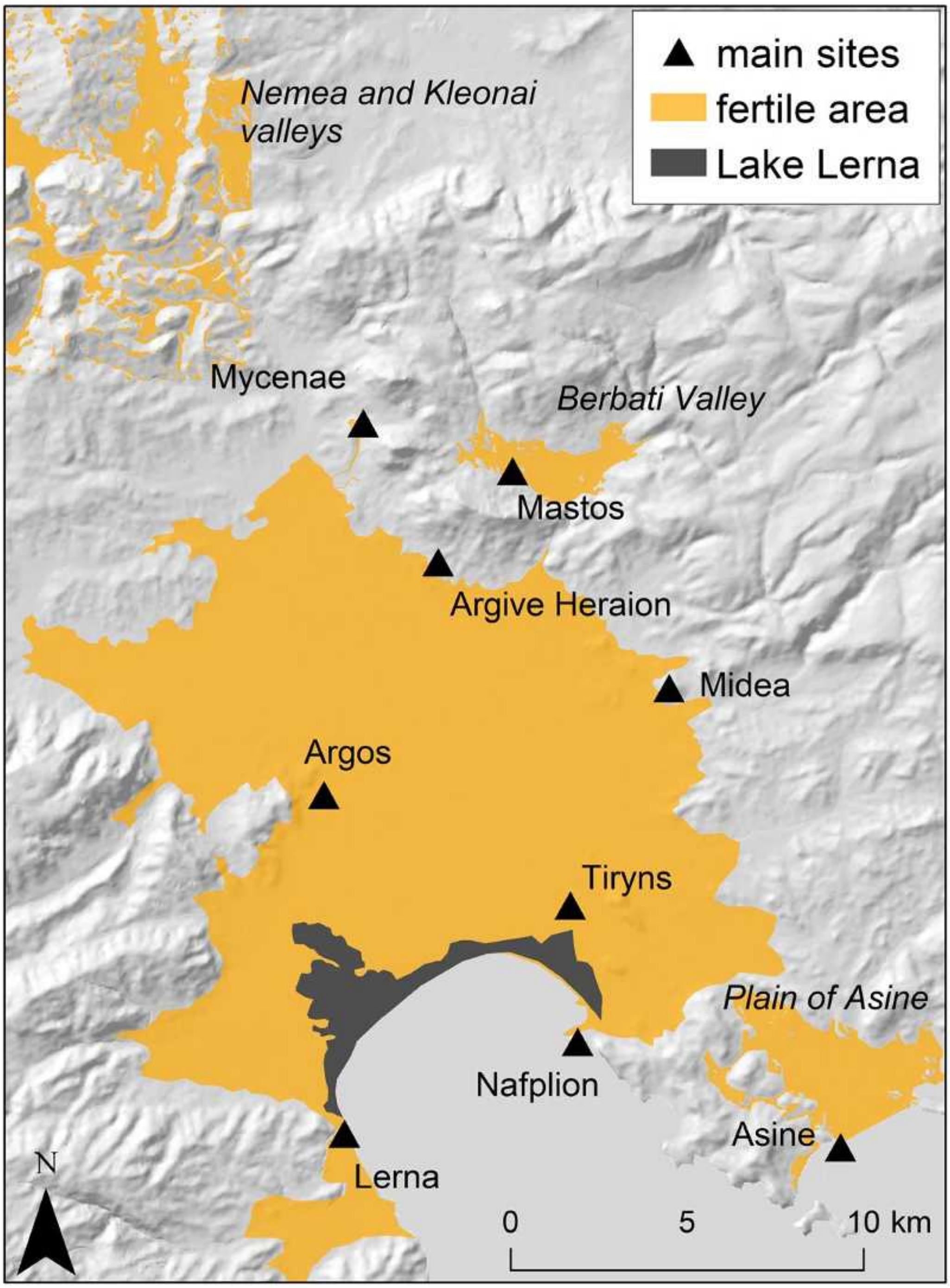

Figure 6.4. Final agricultural area of the Argive Plain based on topographic and soil variables.

74). The model limited the terraced area to 2.5km from the edges of the flat (under 6°) surface. It is assumed that terrace building was most prevalent around locations with the largest populations. Therefore, terraced areas were further limited only to the vicinity of the major LH III settlements of the plain. Terrace building conducted by small communities and single households would have remained at a small scale and, as such, added little to the overall cultivation space. The total slope area that could be terraced in the surrounding areas of the notable Argive Plain settlements was estimated at *c.* 3300ha. It is likely that a considerably smaller share of this area was used simultaneously, however. These figures are discussed in Chapter 6, which presents the agricultural potential of the area in the LH III period.

Land use distribution

In recent historical times, land use in Greece has been characterized by land fragmentation occurring due to generations of land inheritance. In remote areas such as the mountainous Methana peninsula (see pp.54-56 for ethnographic studies), this resulted in farmers owning small pieces of land kilometres apart. Settlements tended to be located between two extremes, upland terraced fields and lowland flat plateaus. The fields were often as far as 45 minutes from the settlement on foot (Forbes 1976a: 238). On the island of Karpathos, the villagers of Olimbos kept their legume and vegetable gardens close to their village, but the cereal fields were divided into a large number of small units, most of them located one hour's walk away in a fertile valley (Halstead and Jones 1997: 271).

Commuting to far-away fields was challenging and time-consuming before the appearance of modern road networks. Pack animals and dirt roads and pathways were used to travel hours between dwellings and fields, which meant that during seasons of heavy labour the costs of traveling exceeded the benefits of the harvest and people found ways to remain at the field sites. Often, the solution was to build temporary field houses and sheds close to the fields. In Karpofora, Messenia, families moved to the field houses for the duration of the harvest period. There, field houses also included vegetable gardens (Aschenbrenner 1972: 160, 1976: 60-62). Threshing floors could be built in the vicinity of the temporary field houses (Halstead and Jones 1997: 274). Sometimes fractionation could be beneficial, for example when different crops could be sown in different environments according to their specific growing needs. When not all crops were placed in one location, at least some of them may have survived through environmental hazards such as droughts or frost (Forbes 1976a: 242).

Traces of potential LH III field houses or temporary storages have not survived (pp.81-82). Large animals that could have been used for heavy agricultural duties, including the transportation of harvested products, were likely not available to most common farmers in the LH III, although sharing them between several households might have been as common as it was in recent history (pp.117-118). Linear B evidence of LH III landowners (pp.10-13) has shown that one individual could hold rights to several plots which might have been spread over various locations. However, this was not a result of land division but of leasing from multiple landowners. Thus, there is no evidence suggesting land fragmentation that resulted in long travel distances between the hamlet or farmstead and the fields in the LH III. On the contrary, the Argive Plain farming communities likely owned modestly sized plots of land located nearby their dwellings.

An early 20th century subsistence farmer in Greece usually owned a piece of land of small to moderate size (a few hectares) which was used for habitation, cultivation, gardening, and animal husbandry. The latter might have included areas for grazing, as well as structures such as pens and enclosures for the animals. Most of the pastureland was shared with other inhabitants of the village and located away from cultivated fields. Examples from Karpofora in Messenia and Fourni in the Southern Argolid show that sheep and goat pastures often included slopes of low maquis vegetation and "wastelands" along river courses and roadsides. The forested slopes were also commonly used to collect firewood (Aschenbrenner 1972: 48; Gavrielides 1976b: 267). According to pollen evidence, slopes surrounding the Argive Plain grew similar maquis types of plants in the LBA (pp.86-90). Wastelands along riverbeds, lakesides and ravines were available for herds of ovicaprids. Herding animals in these locations would have not taken space from cereal cultivation or gardening.

In modern farms, the share of land dedicated to crops varies according to climate variability, characteristics such as slope and soils, and the farm's possible specialization on crops or animal husbandry (variable approaches in Forbes 1982b; Gavrielides 1976b; Koster 1977). In Didyma, in the Southern Argolid, the average land holding for a farmer specialized in sheep herding was 7ha. Of this, nearly half (44 percent) was kept fallow and the rest was farmed with cereals, legumes grown as fodder, and vegetable gardens. In winter, the fallow land functioned as a sheep pasture, although village communal land was also used for this purpose (Koster 1977: 248). In the nearby plain of Troezen, the mean land holding was much smaller, *c.* 2.9ha. Here, the farmers focused on crop cultivation instead of animal husbandry. Land fragmentation was exceedingly high, resulting in the scattering of these 2.9 hectares into plots of only 0.1-2 ha. The amount of arable land in the total landholding was *c.* 36 percent (Table 6.1). Small number of grapevines were grown on the remaining land, but most of it was kept either fallow (*c.* 25 percent), or fallow with trees (*c.* 59 percent) (Forbes 1982: 84, Figure 9). Finally, in early 1960s Messenia, the average size of landholding was 3.4ha (combined results of four villages). Of the cultivated land, 27.1 percent was cultivated with cereals, but half of it was usually kept fallow (van Wersch 1972: 177-178).

The distribution of crop species in the land use pattern of the LH III subsistence farms can be compared to the distribution in modern rural farms with certain reservations. Dry or rainfed farming was the widespread practice of agriculture in the Aegean in the LH III period, like it was in the early 20th century. Irrigation, except for light hand irrigation of water-needing plants such as vegetables, was likely not required. Before the development of industrial fertilizers, the fertility of land in consecutive years had to be ensured by manuring or by rotating fallow and cultivation, or legumes and cereals (pp.93-95). Each of these practices could have been used in the LH III. The share of land kept fallow in the LH III would have likely followed the logic of recent subsistence farms, amounting to about half of the arable land. Halstead (1995a: 16) has argued that a plot size of *c.* 2-3 ha was sufficient to provide subsistence for an average LBA household. Linear B evidence mentions several plot sizes, for example GRA 2 or 3, or large landholdings of GRA 94. Converting these into modern sizes or volumes has been a challenge only few have undertaken (pp.10-13), but no secure data is available.

Agricultural practices in the LH III Argive Plain.

In order to successfully practise agriculture, the ancient farmer had to possess knowledge of the growth requirements of different species, and the needs of domestic animals. Furthermore, the farmer had to be prepared for periods of poor harvest or even for a total failure of crops (Gallant 1991). Ethnographic studies in rural Greek communities have demonstrated the importance of climate, in particular the winter rains, in the cycle of agricultural activities. If local climatic conditions were not profoundly different from today, the LH III Argive Plain farming practices probably followed a somewhat similar cycle. However, similarities in the scheduling of farming activities in the past and more recent times does not directly indicate that these activities were conducted in a similar way (for example by similarly sized labour forces), or that agricultural productivity remained the same. Nevertheless, the following section presents a reconstruction of the LH III agricultural activities as they were conducted according to the Mediterranean agricultural calendar.[2] Archaeological data are combined with ethnographic parallels to formulate a reconstruction of what may have been the most important activities related to agriculture in the LH III period. The metadata of the ethnographic studies used in this chapter are presented compiled in Appendix 2.

Preparation for the agricultural year

In the Argolid, winter rains usually began in the late fall, around November, and lasted until April (pp.76-78). Traditionally, the preparation of land for the rainy season included fertilization and tillage of fields. These practices created ideal circumstances for the germination of seeds which were sown a few weeks later. If manure was not scarce, fertilisation could take place twice in the course of the fall (Bevan *et al.* 2013: 261; Halstead and Jones 1997: 273).

Tillage was done by hand, or by using large animals such as cattle to pull a plough which opened the soil to water (Halstead 1995a: 11). In the LH III Argive Plain, oxen were possibly loaned out by the palace to the local farming communities for tillage and other heavy duties providing an opportunity to enforce dependency relationships (Brysbaert 2013: 64-69; Halstead 1995a: 18). Traditional agriculture in Greece has been dependent on animal power for traction and transportation, especially because of long distances between settlements and fields caused by land fragmentation (Halstead 1987b: 84). In the LH III, both intensive and extensive methods may have been used, depending on the location and size of the settlement. It is possible that in the fringes of the Argive Plain and in its neighbouring valleys, small rural settlements, such as those farmsteads recorded in the Berbati-Limnes survey (see 3.1) were located closer to cultivation areas. For them, the need for large animals may have been less essential and either manual labour alone, or sharing them between multiple households might have been sufficient for completing heavy agricultural tasks. Furthermore, since oxen (and other large domestic animals) cannot be used in reaping, harvesting was carried out through manual labour in any case (Halstead 1995a: 13-14).

Manuring was a known agricultural method in the LH III period, even if it has been more often connected to the intensive farming methods of the Neolithic period (see 4.1.3.3). Manure of sheep, goats, cattle and pigs could have been used to fertilize soils (pp.115-119). In the LH III period, the wool-producing flocks of Mycenae and possibly Tiryns likely grazed in the upland areas surrounding the Argive Plain. Long distances from the plain would have decreased the availability of sheep manure, which is why fields cultivated by the inhabitants of these large settlements were likely mostly unmanured and left for fallow instead. Conversely, small farming households had the opportunity to collect manure from the few animals they kept for sustenance, and use this selectively for example for tree crops and vegetable gardens. Their animals could have also been left to graze on stubble after harvest, or kept roaming semi-freely in the surroundings of the settlement. Evidence of cattle, pig, and sheep diets at Mycenae indicates that not all animals of the larger centres were taken elsewhere to pasture either, but rather managed on fallow fields and stubble (p. 110). Household waste could have been collected for fertilization too, but only if it was not used to feed pigs, which were commonly kept in the LH IIII Argive Plain.

[2] Brysbaert (2020: 65, Table 2) has recently presented a similar overview of agricultural activities, which can also be observed in a table form.

In the previous chapter (pp.116-117), some examples of manure production per flock of common household animals were given. If the LH III manure production resembled recent examples, a modest flock of 10-15 sheep or goats could have produced manure for a small plot, perhaps less than 1.5 ha. If Halstead's (1995) suggestion of average plot sizes of 2-3 hectares per a LH III household is used, about half of the subsistence land could have fertilized. The collection and spreading of manure could have been done by the joint workforce of multiple households. Ethnographic examples show that traditionally manuring was applied to poorest soils (Halstead and Jones 1997: 273) or plants that had the highest cash potential, such as wheat grain and tree crops (Forbes 1982a: 236). Although the methods have been considered to belong in contrasting farming regimes, bare fallowing and fertilization have been used in recent historical farms simultaneously.

Archaeological evidence suggests that at least some terraces were also manured in the LH III (p. 71; Bull *et al.* 1999; Kvapil 2012). Crops cultivated on them must have included species which needed additional fertilization, although isotope evidence of manuring suggests legumes were often fertilized in the Bronze Age (see pp.95-97). Tree crops such as olive, vine and figs, have historically been favoured on terraces, and these have also been often fertilized in more recent history. Their fruits would have been desired by the Mycenaean palatial centres. As assumed in this study, barley was the main food crop for the rural population and wheat was favoured by the elite. The production of cereal crops could have mainly taken place on flat lands. Barley does not need fertilization (although there is Bronze Age evidence of it growing in fertilized conditions, see pp.94-95), and wheat (at least emmer and bread wheat) requires particularly good soil and moisture conditions to grow. These may not have been consistently available on terraces. Terraces could also have been cultivated with intercropping cereals and tree crops, which would have been fertilized together. However, since there is no conclusive evidence of intercropping in the Late Bronze Age, even though some mixed grain and legume finds from LBA storages could suggest this (pp.92-97 of this book; Jones *et al.* 1986; Sarpaki 1987: 219), in this study terraced and unterraced fields are modelled after monocropping.

In recent agricultural communities, early fall, before the beginning of winter rains, was also a period for general maintenance tasks such as repairing terraces, collecting firewood and insulating house roofs (Bevan *et al.* 2013: 261; Brysbaert 2020: 65, Table 2). In the LH III Argive Plain, firewood was likely collected from the maquis vegetation on the hillslopes surrounding the plain (pp.88-89; Bevan *et al.* 2013: 261). Forested areas on the higher altitudes surrounding the plain held forests of pine and mixed oak and leafy trees, which could have provided material for maintaining and building houses and shelters, maybe even boats, ships and harbour facilities (see Boswinkel 2021 for timber use in Mycenaean monumental construction). The equally abundant grass vegetation (pp.88-89 and pp.99-100) provided materials for basketry, mats and furniture, needed in households and storages.

The early fall was also used for weaving and spinning the sheep wool collected in early summer (see also Brysbaert 2020: 65, Table 2). In the LH III Mycenae, this could have involved dozens of females and their children in textile workshops (pp.8-10). Men used this period for fishing and hunting (Forbes 1976b). Fishing was probably done in the shallow coastal area, and the autumn could have presented a seasonal increase of marine resource consumption, although not to such an extent that it left a mark in their isotope records (pp.126-129).

When labour force was not needed in household and agricultural tasks, it could be directed to large scale construction projects, such as the building of the walls at Tiryns, Mycenae and Midea, and the highways crossing the Argive Plain (Timonen and Brysbaert 2021). Brysbaert (2020: 65, Table 2) has placed such periods of construction more specifically in May and the fall months from August to November. After harvesting and crop-processing of the previous summer was finished, food storages were full and workers could have been reimbursed with food rations by the palace.

Sowing seeds, harvesting olives

Cereal and legume crops were sown in late fall and early winter. Sowing would not start before the winter rains had properly arrived, as even moderate changes in rainfall could cause severe crop failures or prevent plants from maturing (Forbes 1976b; Halstead 1995a; Halstead and Jones 1997). If rain volume remained low, the LH III farmer could have chosen to sow more drought tolerant crops such as barley. Although wheat is abundant in the LH III textual evidence, this study is more inclined to agree with van Wersch's (1972) suggestion of 70-30 percent division for barley and wheat consumption amongst the non-elite society due to barley's tolerance towards varying environmental conditions.

Traditionally, a seed ratio of 1:10 has been used in studies of ancient cropping strategies (Osborne 1987: 45). This means that for each unit of sown cereal seeds, the expected yield would be ten times larger. However, ethnographic accounts and cropping experiments indicate that seed ratio can vary considerably per year (Forbes 1982a: 357-64; Gallant 1991: 48, Table 3.1.). It can also vary according to the type of crop cultivated (Gallant 1991, 48), and according to the type (intensive or extensive) cultivation methods used (Halstead 1987b: 85). Forbes (1982a: 359) compared the assumed 1:10 seed ratio to the grain production in the Southern Argolid and noticed a variation of high and low ratios every second year. While in the odd years the ratio was 1:11, in even numbered years it was only 1:6. The average was about 1:8.5. Although the average in this case was lower, the 1:10 ratio can be considered reasonable for modelling crop yields in this study.

In more recent agriculture, legumes and sometimes barley were sown well before wheats, because an earlier harvest could be used to feed lactating ovicaprids (Forbes 1982: 243-46; 1976c: 131; Halstead and Jones 1997: 271-73; Hansen and Allen 2011: 882). In Amorgos, supplementary fodder such as common vetch and grass pea was used for a few months, especially during the ploughing season. This reduced the size of the grazing area but increased labour costs (Halstead and Jones 1997: 280). It was common to let animals roam free on the legume fields in the springtime and only collect a share of the ripe pulses for domestic use. According to Forbes (1982: 248), fodder cultivation is a fairly recent introduction, at least in the Methana peninsula, and until the 1970s grazing was the main way to feed animals even though it meant that they suffered from mild malnutrition. The abundance, and advanced state of processing and storing of legumes in the LH III Argive Plain storage contexts suggests that most of the legume harvest was used for the sustenance of people, not animals. However, legumes and cereals were fed to some pigs, sheep and cattle, as indicated by the isotope evidence of animal diets in the LH IIIB Mycenae (p. 110).

While the sowing of cereal and legume crops took place in the early winter, olives were ready to be harvested. Olives meant be eaten fresh are traditionally harvested in late fall, and the fruit for oil extraction one to two months later (Aschenbrenner 1972: 53; Osborne 1987: 45). Linear B evidence points to regular olive oil use in the Mycenaean societies (Melena Jiménez 1983 and pp.8-13 of this book). Thus, olive cropping must have been regular in a variety of environments (designated spaces and wastelands) in the Argive Plain as well (pp.97-99, and Foxhall 2007). Nevertheless, the demands of the local elites, but also the existing infrastructure of the local palatial economies would have resulted in a large-scale need of olives (see Livarda *et al.* 2021 for evidence of the intensification of olive cultivation in the Minoan Palaikastro, Crete). Here 'cropland' is used to refer to the areas of wide-ranging tree cropping located in the LH III Argive Plain to separate them from the more organized, irrigated modern-day orchards.

The LH III farmers had many ways to obtain olive oil. Olive picking is arduous - one tree takes several hours' work for about four adults (Aschenbrenner 1972: 54). Therefore, it could have been performed as a collective effort by several households of a village. Since the Argive Plain palatial centres likely controlled a large share of the production of olives and olive oil, harvesting these trees would have required the employment of an additional workforce. If farmers were employed to work in the palatial croplands, oil or a share of the harvest might have been their reimbursement. Until recent history, oil (or wine) presses were shared amongst the community instead of being owned by single households (Aschenbrenner 1972: 55). Controlling the use of presses for olive oil or wine making, as well as the mills for flour making, would have been another way for the Mycenaean palaces to establish dependency relationships. It is possible that the Argive Plain sites filled some of their oil needs by importing it from outside areas such as southern and western Crete (pp.82-86).

Keeping busy with sheep

The end of the modern calendar year might have been another period with a less labour-intensive schedule for the LH III Argive Plain farmers. According to recent ethnographic notes, sometimes lambing would already begin in the early weeks of the year, however, lasting until late spring (Koster 1977: 48). During the milking season, ewes were milked at least twice a day, and sustained by early spring fodder of barley or pulses (Halstead 1995a: 12; Koster 1977: 227). Much of this milk was used to make cheese, which was sold at the local markets (Blitzer 1990: 38-39; Koster 1977: 230-34). Sufficient milk production was ensured by culling male lambs soon after birth (Tzevelekidi *et al.* 2014: 429).

Small, rural LH III households would have likely kept only a few animals, mainly sheep or goats whose maintenance costs are relatively low. Depending on the size and location of the settlement, its inhabitants could have gathered their sheep or goats into larger flocks to be herded and milked together away from cultivation areas (e.g. Koster 1977: 230-34). Herding has traditionally been a task for children, in particular young boys (Baudy 1995: 191), or women (Forbes 1982). Isotope evidence of the diets of LH III sheep, pigs and cattle at Mycenae suggests that intensive animal husbandry methods were present also in large central settlements, even if herding of large flocks took place in remote locations simultaneously. Diets suggesting the consumption of cereals and standing water suggest either a flow of goods from smaller settlements towards the central place for specific purposes such as sacrifice, or that even in palatial settlements, regular households managed with mixed subsistence farming.

The Argive Plain zooarchaeological assemblages are inconclusive about the main exploitation strategy of sheep and goats on household levels, but it seems that both wool (and fiber) and dairy were preferred (pp.106-109). Thus, milking, lambing and culling could have taken place as communal efforts. The sheep and goat herders of mid-20th century Southern Argolid would make cheese together, pooling the milk of their own animals and sharing the cheese produced from this mixed milk. This freed the workforce to other tasks such as harvesting and crop-processing (Koster 1977: 230-31).

Plucking of the wool of sheep and goats[3] probably required the palatial administration to hire additional workforce. Wool cutting could be done with knives (Andersson Strand 2014: 44). The process was usually completed before the hottest summer months (Koster 1977: 230-34). Collected wool had to be transported to the palatial settlements where it was given to textile workers for weaving, or handed out as a reimbursement for labour services (Nosch & Andersson Strand 2003: 199-200;). Unfortunately, there is not enough evidence of Late Bronze Age wool processing methods to analyse its labour costs. Wool could have been pre-processed by the herders and other workforce before it reached the palatial centres. Ethnographic data implies that after plucking, wool fibres were likely sorted based on colour, strength, length or other criteria, washed (especially if dyeing was applied), and combed or whipped to arrange the fibres evenly (Andersson Strand 2014: 44-46). Dyeing, spinning, fulling, and weaving took place in the palatial workshops, or in locations outside the palatial settlements to which the central administration sent specific quantities of wool to be turned into textiles (pp.15-18 and pp.103-106). These textiles were returned to the palace as finished clothes which were used by the elite. Although there are no records of wider wool or textile trade across the Mediterranean, it seems possible that such exchange took place. There are no records on how the non-elite manufactured their textiles either, but one could speculate households took care of their own needs. Perhaps raw materials and textiles were exchanged between individuals and households, as rather large quantities of processed wool were needed to produce one piece of clothing.

Calving takes place in late spring and includes similar arrangements with milking and culling as sheep and goat management (Dahl and Hjort 1976: 41). The cattle lactation period lasts up to nine months and is highly intensive for the first three to four (Dahl and Hjort 1976: 143). During the late spring and early summer months, lactating cows need access to particularly rich pasture land, or to additional. The surroundings of Lake Lerna might have offered a sufficient pasture, including the 'coastal grasses', which, according to the isotope data of animal diets, were consumed by the LH III cattle at Mycenae (Price *et al.* 2017).

Spring months have traditionally kept farmers busy with manuring, ploughing and weeding (Aschenbrenner 1976: 163; Forbes 1982a: 253). Weeds have often been collected for animal fodder (Forbes 1982: 258-62). Summer vegetables are planted in gardens in the late spring, and human-induced germination of fig trees takes place to ensure higher production rates (pp.97-98).

Season of heavy labour

Cereals and legumes were harvested in late spring and summer. Legumes for human use are usually harvested and processed before midsummer. Some legumes might be left in place to be consumed by animals who simultaneously fertilize the field (Halstead and Jones 1997: 271; Koster 1977: 227). Wheat and barley are usually harvested closer to midsummer (Forbes 1982: 268; Halstead and Jones 1997: 271).

In the LH III, crops were cut with stone and bronze (and perhaps wooden) sickles. The number of bronze sickles increased towards the LH III period in mainland Greece (Blackwell 2011: 75-79; Newhard 2003: 77-106; Sarpaki 1987: 130; pp.80-81). Blackwell (2011: 75-76) has suggested that the Bronze Age centres of the Eastern Mediterranean controlled the making and use of these items. Recent Greek farmers usually either cut cereals low, taking much of the straw with them and storing it for further use, or cut them at mid-height, leaving most of the straw in the fields to be fed on by animals. The stored straw could be used as animal fodder, or for other purposes such as furniture making or basketry (Halstead and Jones 1997: 274). Harvesting is laborious and requires the effort of the entire household. While reaping and cutting must be conducted manually, leasing pack animals for transportation from wealthier landowners has been a common practice in the traditional Greek farming communities (Forbes 1982: 268-69). The LH III Argive Plain farming communities could have completed harvesting and processing together, sharing pack animals or leasing them from the palatial administration.

Harvesting in the early summer was followed by crop-processing, which included multiple phases such as threshing, winnowing, and sieving (see also Brysbaert 2020: 65, Table 2 for scheduling). Crop-processing has traditionally been communal work, even though cleaned crops have been stored separately by each household

[3] Here plucking or cutting of wool is preferred instead of shearing which refers to the shear, the scissor-like cutting tool used in later periods to perform wool cutting. This tool was not available in the Late Bronze Age.

(Whittaker 2000: 63-64). Most of the processing has taken place outside settlements, on and in the vicinity of threshing floors. Threshing floors or other crop-processing materials such as threshing sledges are absent in the LH III Aegean (with one potential exception at Kalamianos, see pp.81-82) but the techniques were known elsewhere in the Eastern Mediterranean. The cleanness of the crop at LH III Midea, Tiryns and Lerna (pp.91-92), seems to suggest that at least some of the processing, took place adjacent to cultivation areas, and that crops arrived in these settlements relatively clean. A number of threshing floors must have been located on the gently rolling foothills of the eastern Argive Plain for local use, perhaps in connection with terrace systems as in the Mycenaean Kalamianos (pp.81-82). Some of the late processing probably took place in the settlements, before storage or even before cooking. The by-products of these activities might have been collected for later use as fodder or fuel, as has been customary in traditional communities.

After crop-processing, the cleaned products (and possibly by-products) were stored for future use. Based on the scarce evidence of storage spaces in LH III settlements in the Argive Plain and elsewhere in mainland Greece (pp.82-85), it seems that various types of storage strategies were in use. Households might have had private storages for subsistence needs, but also space in larger storages, perhaps for special products such as olive oil. Other larger storage spaces could support *c.* 15-20 people for a year, the inhabitants of a hamlet type of settlement. The palatial centres of the Argive Plain do not appear to have had large storage spaces for the use of the entire settlement populations, although some centralization of storage can be detected in the archaeological evidence. These storage spaces, such as the 'Granary' of Mycenae could have held products for the elite and administrative use. Individual households of these central places would likely manage their own storage and food facilities (pp. 82-85 and 91-92).

Recent subsistence farms in Greece usually have at least a one-year supply of basic foodstuffs (Forbes 2017: 18; Halstead and Jones 1997: 288). In the Methana peninsula, an average household storage contained two years' worth of wheat, and four years' worth of olive oil. However, keeping the same products stored for the full two years significantly increases the risk of loss for certain foodstuffs. Therefore, if new surplus was available, stored goods were regularly circulated (Forbes 2017: 18). Ideally, the aim was to produce enough goods for storage to last over poorer agricultural years. This stock could be 50-100 percent over the minimum requirement for 'survival' (Forbes 1982: 356-375, 2017: 9; Halstead 1989; Winterhalder *et al.* 2015). In rural communities, the storing of foodstuffs did not only concern food for human consumption, but also fodder. For example, on Amorgos, both food fodder and seed grain were stored in the household (Halstead and Jones 1997: 285). However, as discussed earlier, the LH III finds indicate the use of most of the stored items in human cuisine. Therefore, here storage is only considered in relation to human dietary products and how much of them need to be produced to fill it for a year (pp.82-85).

In the warm summer months that followed harvest and crop processing, only vegetable gardens needed special attention mainly in the form of weeding and watering (Brysbaert 2020: 65, Table 2; Forbes 1982: 274). In pre-industrial societies, larger herds of sheep and goats often follow a winter-summer grazing pattern in which flocks stayed in high-altitude pastures until late fall (Koster 1977: 227-28). As suggested previously in this study, the Limnes highlands east of the Berbati Valley functioned as pastures for the sheep of Mycenae and Tiryns. This area has traditionally been inhabited by shepherd communities, and in the LH III, it would also have provided the colder summer temperatures needed to sustain grass vegetation. In addition, the coastline towards Nafplion was still commonly grazed by ovicaprids in the late 1980s and 1990s (Shay *et al.* 1998: 318). In modern-day Amorgos, however, fallow fields provided natural grazing for sheep from January-February until late spring, and the stubble left from harvesting from June until October (Halstead and Jones 1997: 280).

At the end of the summer, figs and grapevine yields would ripen (Aschenbrenner 1972: 56; Hansen and Allen 2011: 816). Forbes (1982: 274-277) reports that in the Methana peninsula, figs had to be picked every second day during the harvest season. In the LH III Argive Plain, fig collection would have been a concerted task, possibly supervised by the "fig-overseers" employed by Mycenae and other centres (p. 10). It is probable that most of the fig harvest was dried. This could suggest that the fig rations mentioned in Linear B texts concern dried fruit. Traditionally, figs were dried out in the sun by placing them on the ground on top of straw mats, or on cane frames (*kalamota*) (Kappas *et al.* 2019). The abundance of fig seeds among the archaeobotanical assemblages (pp.97-98), seems to suggest that the fruit was widely available, not just for the use of the palatial elite and dependent workers, but for all levels of the society. Some of the fruit of lesser quality could have been fed to animals, as has been customary in modern times (Kappas *et al.* 2019). Fig leaves and other leaves used as fodder have usually been collected at the end of the season (Aschenbrenner 1972: 57).

Grapevine harvest and winemaking took also place in the fall. While winemaking can be conducted efficiently by few individuals, the harvest and transportation of the grapes is laborious (Aschenbrenner 1972: 55, Table 4-3; Forbes 1982: 240). In the LH III rural communities, grape picking would have been done collectively, and the number of grapevine plants was likely limited. Nevertheless, the palatial orchards would have required a considerable number of labourers during the harvest season. As with the olive oil, the local farmers extracted to work on the palatial land could have been reimbursed with a portion of the harvest, or the finished product.

The agricultural year ended with the culling of older animals and the unwanted offspring (e.g. male lambs). Traditionally, culling has taken place only after it was known how many young calves and lambs survived their first months (Koster 1977: 230-234) but if the LH III societies were focused on wool or dairy production, unwanted male lambs and calves were likely already killed weeks after birth in the spring. Lambs and calves representing both age groups are present in the Argive Plain assemblages (pp.106-109)

As has been the custom in historical and recent farming societies, the season likely ended in a feast in which the Mycenaean palaces provided a meal of sacrificed animals. Halstead and Isaakidou (2004) have studied the burned animal bones recovered in the LH III context (*c.* 1200 BCE) at the palace of Pylos. Although the timing of this festivity remains unknown, the amount of meat received from the sacrificed cattle and deer could have fed hundreds, if not thousands of attendants (Halstead and Isaakidou 2004: 148-149). Similar evidence of possible animal sacrifice for feasting was also recovered in the LH III Tsoungiza (Dabney *et al.* 2004). Feasting would have provided the Argive Plain inhabitants a sense of unity and strengthened the relationships between the palaces and farming communities.

Crop yields

A variety of environmental and technological aspects, many of which are described in the previous sections, influenced crop productivity in the LH III period. Historically, crop productivity in the Mediterranean is characterized by significant fluctuation from poor to very rich years. These aspects need to be considered in order to create any credible estimations on what could have been Late Bronze Age crop yields in the Argive Plain.

It seems that no dramatic differences between past and current soil and climatic conditions can be observed under the current light of information. Therefore, climate's influence on Late Bronze Age crop yields was perhaps not critically different than for the yields gained by pre-industrial rural communities of southern mainland Greece. Because the variety of crops and other plants in the LH III Argive Plain contexts is large, it must be assumed the local climatic conditions were sufficient to maintain mixed plant husbandry and to produce a sufficient harvest, even if this richness of resources would have been used as a protective measure against bad years. The LH III crop yields can, therefore, be modelled based on modern rainfall and temperature.

Experimental studies on modern crops have concluded that applying manuring to cereals can significantly increase yields compared to crops which are left unmanured (Olesen *et al.* 2009). Both methods were used selectively in the Late Bronze Age to enhance crop productivity. However, yields were unlikely to reach volumes comparable to modern day cereals and pulses, boosted by industrial fertilizers. Therefore, any comparisons to the agricultural production of recent historical subsistence farms can only be made by excluding those using notable amounts chemical fertilizers, and even then, by carefully considering the prevailing political and economic conditions (e.g. cash cropping) that may influence in farming practices (pp.47-50).

Late Bronze Age yield estimates of cereal and legume yields are scarce. Therefore, parallels drawn from Classical and recent contexts offer a practical method to formulate estimates of crop yields of the ancient past. However, this cannot be done without carefully considering the influence of technological availability, or political and economic strategies of each time period on farming methods, settlement locations, and consequently on yields (pp.47-50). The remaining part of this section will give range estimates for the main crops cultivated in the LH III Argive Plain by looking at available parallels and considering these data against the socio-political, economic, and environmental situation they were recorded in.

Estimations of Bronze Age and historical cereal yields usually concern only two grain types, wheat and barley. 'Wheat' could refer to bread wheat (*Triticum aestivum*) even though other wheat species, such as emmer, are more abundant in the Bronze Age archaeological samples (pp.91-92). Yield estimations of einkorn and emmer (410-692kg/ha) are presented only by Hansen and Allen (2011: 884, Table 14.11)for Early Bronze Age Tsoungiza. Their figures are based on experimental studies in France and England[4] with the notion that due to climatic differences between these and the Aegean, Early Bronze Age yields most likely resembled the lower ends of the resulting yield ranges. In this study,

[4] 692-1571kg/ha for einkorn and 1730-2480kg/ha for emmer, respectively.

Table 6.1. Average yields of wheat and barley in various sources. The section above represents yields based on ethnographic fieldwork, and the section below yield estimates for historic and prehistoric time periods.

Historical Mediterranean yields	**Wheat kg/ha**	**Barley kg/ha**	**Source**
Asvan, central Turkey 1940	630	410	Hillman 1973
Village 2A/06, Aleppo, Syria 1977-78	651	824	Gibbon 1981
Village 4/04, Aleppo, Syria 1977-78	235	307	Gibbon 1981
Greece before 1925	975	1216-1534	Jardé 1925
Attica before 1925	353	580	Jardé 1925
Argolid and Corinth 1921	735	610	Jardé 1925
Messenia 1921	738	699	Jardé 1925
Crete	858	804	Allbauch 1953[5]
Greece	898	944	Allbauch 1953
Crete 1947	778	853	Allbauch 1953
Kosona, Methana, Greece 1962-73	619-1138		Forbes 1982[6]
Estimations for ancient Greece	**Wheat kg/ha**	**Barley kg/ha**	**Source**
Greece, 'Ancient'	624-936	1024-1280	Jardé 1925
Messenia, Classical and Hellenistic	772	1157	Roebuck 1945
Messenia, Late Helladic	900	750	van Wersch 1972
Tsoungiza (Nemea), Early Helladic	410	410	Hansen and Allen 2011
Attica, Classical	436	742	Garnsey 1988, 1998
Boeotia, Classical	486-804	486-804	Bintliff 1985[7]

an average yield range for "wheat" is compiled from yield estimates for different wheat species. This is done because the archaeobotanical assemblages collected from the Argive Plain sites reveal no dominance of one wheat species over others, and because due to annual variability, it cannot be stated with certainty, that one wheat species produced higher yields on average than others. In addition, the nutritional values of emmer, einkorn and bread wheat are quite similar, which means that merging them into one 'wheat' does not notably influence the dietary composition models which form the basis for the agricultural potential (p. 157).

'Barley' is considered in this study as the common type of barley (*Hordeum vulgare*), although different barley species (e.g. *hexastichum*) were included in the LH III species assemblages.

Table 6.1 presents ancient and recent historical yield estimates for wheat and barley in the Mediterranean and West Asia. There seems to be no consensus whether wheat or barley produced higher yields. Osborne (1987: 45) notes that barley produces higher yields than wheat but has a lower calorific content and thus the two cereals can support the same amount of people per hectare. Van Wersch (1972: 185) suggests that, based on modern observations, barley produces higher yields than wheat only when both are sown in poor soils or otherwise unsuitable environments. Varying methods for recording crop yields combined with the use of different volumetric systems by different researchers and areas make it challenging to compare yield estimates. For example, the weight of grain varies notably according to how much processing (e.g. dehusking) it undergoes before it is weighed (Hansen and Allen 2011: 885). Such details are usually not discussed in publications, although they could make a significant difference to the study of past yield estimates.

Of the estimations for ancient Greece, van Wersch (1972) has based his figures on ethnographic observations he made during an archaeological survey in Messenia. Garnsey (1988) has converted his figures from the descriptions offered by Classical authors. The rest are combinations of these types of data and data from recent food surveys and statistics offered for example by the United Nations, European Commission, and the U.S. Department of Agriculture. Yields drawn from historical textual evidence can be biased for a variety of reasons (see pp.54-58).

Differences in the local environmental conditions, such as rainfall, have been seen as the main cause for the

[5] The original source uses bushel as the volumetric indicator for cereal. I have translated these estimations by using the conversion rate of the U.S. Grain Council (available at https://grains.org/markets-tools-data/tools/converting-grain-units/), according to which 1 bushel of wheat or soybeans equals to 27.216kg and one bushel of barley equals to 21.772kg.

[6] Figures for Kosona are calculated averages of even (619kg) and odd (113 kg) years yield. The mean for the entire 11-year period is 855kg/ha. Forbes uses stremma as the spatial unit, which here has been changed into hectares with the principle 1 stremma=0.1h[a.]

[7] Bintliff uses bushel per acre as his volumetric unit. I have translated this into kilograms per hectare according to modern conversion rates by the U.S. Grains Council. Available at https://grains.org/markets-tools-data/tools/converting-grain-units/.

notable variation amongst crop yields in ethnographic records (e.g. Allbaugh 1953; Forbes 1982). However, the use of chemical fertilizers combined with different cultivation strategies is most probable reason why there is such high variation between estimates from different chronological and geographical contexts. Of the ethnographic studies used in this study, industrial fertilizers were not used in the Village of Asvan in central Turkey. Manure was, however, applied in some cultivation areas close to the village. Usually these fields were also irrigated (Hillman 1973b: 220). According to Hillman (1973a: 236), any cultivation areas further than two kilometres away from the village were left dry and unmanured, as these methods proved uneconomical to the local farmers. The rainfall and main subsistence strategies of the area resemble that of the LH III Argive Plain (Appendix 2). In the other case study areas, low quantities of fertilizers were used to cultivate cereal and cash crop fields. Even though fertilization was modest, it can still be assumed that these yields compare less well with the LH III yields than those of Asvan. Hansen and Allen (2011) have come to similar conclusions in relation to the Early Helladic Tsoungiza in the Nemea valley.

In this context, one must discern the differences and similarities between the assumed LH III cereal cultivation in the Argive Plain and the crop growing practices in Asvan and other Greek sites where ethnographic data are available. Additionally, a determination must be made as to whether Classical figures indeed offer better parallels to the Late Bronze Age crop yields. Regarding the disparities between these two data sources, ethnographic records appear to provide more detailed accounts of the conditions under which cereals were grown than ancient historical texts, or studies using these texts to estimate land productivity ranges (pp.54-56).

While it is acknowledged that ethnographers may introduce biases into their recordings, the information from these studies is often more straightforward to compare to the prevailing economic constraints. Thus, it is easier to examine the methods, farming strategies, and market approaches that contributed to the recorded range of yields. Ancient Classical sources, on the other hand, offer limited information in this regard, as they are written by authors whose works may have been influenced by their status, and who might have not had practical experience in farming. Moreover, Classical farming practices likely differed from those of the Late Bronze Age, though the extent of this difference remains a subject of debate. Studies based on ancient texts provide interpretations of crop husbandries, that often derived from recent historical examples. Ethnographic data, though tied to a specific moment in time, is somewhat less interpretative.

As discussed on pp.139-150, it appears likely that Mycenaean farmers employed both intensive and extensive crop cultivation and animal husbandry methods. The settlement pattern in the Argive Plain suggests the presence of several potentially palatial elites, each with their own crop production targets. Although defining where this wheat was grown is currently impossible due to the lack of evidence of land division between palatial sites on the Argive Plain, it could have been produced through less laborious methods further away from the settlements. This approach would have kept yields modest, but the cultivation of larger areas would have ensured a sufficient harvest to meet the various needs of the palace. Similarly, wheat and barley grown by the non-elite inhabitants residing in these palatial settlements was likely located on fields further away on the plain and its fringes. This implies that these cereals probably cultivated using extensive methods, resulting in lower yields.

In contrast, smaller communities like villages and hamlets on the borders of the plain (although evidence of these is scarce on the plain itself, as discussed in pp.20-25) and in neighbouring valleys may have had the opportunity to practice more intensive agriculture, with cultivation areas and pastures located closer to their residences. Consequently, cereal yields would have been higher due to manuring and occasional irrigation. Even within these larger and smaller communities, labour-intensive, and less labour-demanding activities could have taken place simultaneously, depending on factors such as land fragmentation, demands for surplus production due to taxation, or climatic and environmental changes which pushed farmers to use more protective farming methods.

Consequently, it would not be beneficial to categorize the LH III Argive Plain as an agricultural area managed entirely either by extensive or intensive methods. Land productivity should be viewed as a fluid and fluctuating aspect of local farming. For this reason, cereal (and other crop) yields are observed as ranges with a considerable variation between the lowest and highest values. These ranges can incorporate yields produced by a variety of extensive and intensive farming methods without the need to arbitrarily divide the Argive Plain into districts of different types of farming.

In this study, the figure of 400-600kg/ha is used for both wheat and barley. These estimates compare well with the reports of Hillman (1973a and b) and reflect the decline in yield sizes observed when moving further away from the village of Asvan. Wheat could have produced more than 600kg/ha if it was manured regularly but likely gave more unpredictable in yields than barley. Barley could have produced 400-600kg

Table 6.2. Yields of species of legumes in the Eastern Mediterranean. All numbers are kilograms per hectare.

Region		Pulses	Lentil	Bitter vetch	Vetch	Grass pea	Fava bean	Chickpea	Reference
Aleppo/Syria 1977-78		-	838	-	379	-	-	-	Gibbon 1981
Asvan, Turkey 1940		-	400	700	-	900	-	250	Hillman 1973
Crete 1947		965	-	-	-	-	-	-	Allbaugh 1953
Dhidyma, Southern Argolid 1960s		-	-	-	-	-	5700[8]	-	Koster 1977

without manuring or irrigation due to its better tolerance of poorer environmental conditions. This study will also assess the agricultural potential with a higher figure, 800kg/ha, to see if such productivity would enable higher agricultural potential which would be better comparable to previous LH III Argive Plain population numbers. In addition, since isotope evidence gives some grounds to think barley was occasionally manured and irrigated by Late Bronze Age farmers, such high yields for barley might not be completely ungrounded. Wilkinson *et al.* (1994: 497) have suggested similar figures for barley production in the Early Bronze Age Mesopotamia. Wilkinson *et al* (ibid.) also argued that crop yields decrease when the distance to fields from the settlement grows due to the increased labour requirements which result in the use of less labour-intensive farming strategies. Thus, nearby fields of the Argive Plain communities could produce yields of 600-800kg per hectare, while the yields in fields located further from the settlement (3km<) stay at 400 or 300kg per hectare.

Yield estimates of pulses have received much less attention in archaeological or ethnographic studies than those of cereals. Table 6.2 presents legume yields recorded in ethnographic studies from Eastern Mediterranean contexts (see appx. 2). The yields of different legume species show notable variation. Since synthetic fertilizers were not used in Asvan, the yields recorded here appear better comparable to past legume yields (Hillman 1973a and b). Toxic pulses such as bitter vetch and grass pea produce notably higher yields than the more common food legumes, lentil and chickpea. This could explain the ubiquity of bitter vetch in the Bronze Age archaeobotanical assemblages (pp.95-97).

[8] Koster (1977, 354) reports that a plot of 0.5 stremmata produced 285 kg of Ficia faba. If this is transformed into kg / ha, a high number of 5,700 kg / ha is yielded. The field where they were planted was irrigated, which might explain the difference in yield size compared to the other *pulses.*

In the Late Bronze Age, beans, peas, and other leguminous species were likely grown in garden-like conditions, as indicated by archaeobotanical (and isotopic) evidence, and by the absence of legumes in the Mycenaean texts (pp.95-97). These were staple foods, perhaps produced in the backyards of every other household. It is also possible, that some legumes, for example vetches, were rotated with cereals. Such fields would have been more intensively managed than cereal fields following fallow rotation regime. Manuring and hand irrigation of gardens and intensively managed fields increased legume yields. In this study, a range of 300-700kg/ha is used as the legume yields for the LH III. Textual references from Bronze Age Mesopotamia and Syria suggest somewhat similar ranges (425 to 681 l/ha) (Widell *et al.* 2013: 90).

Estimates of Bronze Age olive yields, as well as ethnographic records of olive yields in modern rural communities in which olive is not cultivated as a cash crop, are rare. Table 6.3 presents the few examples collected for this study. Since olive is bimodal, producing a high yield only every second year (Aschenbrenner 1972: 54; Osborne 1987: 45), two estimates of olive and olive oil yields are often given. Of these, Aschenbrenner's observations of traditional tree cropping in Messenia are used in the calculations of the agricultural potential in this study. This is due to the better environmental resemblance of Messenia (compared to Cyprus) to the Argive Plain.

While using these figures, one has to be aware that olive 'cultivation' in the Late Bronze Age might have has a much less systematic nature compared to the 1940s and 50s Messenia. Olive has traditionally, and historically been harvested from trees that grow on wastelands. Orchards abundant to the Greek landscape today are managed with mechanized irrigation systems, fertilizers and bulldozers, and thus a fairly recent phenomenon. The existence of orchards in the LH III Argive Plain, or elsewhere in the Mycenaean territories, can be debated. The example figures used here derive from relatively pre-mechanized context where trees spread outside designated cultivation areas are also reported (Aschenbrenner 1972: 53). Nevertheless, bulk of the yield comes from systematically planted trees, and therefore does not offer the best possible parallel to the likely less systematic Late Bronze Age tree cropping. As discussed in previous sections (p.97-99 and 139-150), there are some references in the Linear B texts towards careful monitoring and managing of tree crops. This could indicate at least a type of orchards being in use also in the LH III Argolid, especially since demands for olive oil were notable by all sectors of the society. The yield range of recent historical Messenia serves, therefore, as a reasonable parallel to Mycenaean olive harvests.

Table 6.3. Estimations for the yields of olives and olive oil with references. Olive yield is bimodal. The lower figure indicates the yield in the 'off' year for olives, and the higher number the main year of production.

Region	Olive kg/ha	Olive oil kg/ha	Reference
Karpofora, Messenia 1968-69	548/1150	192-288[9]	Aschenbrenner 1972
Classical Greece	-	150/400	Osborne 1987
LBA Cyprus	180-398[10]	-	Padgham 2014

Table 6.4 presents some estimates of fig and grape yields in recent and LBA contexts in the Eastern Mediterranean. Of these, the study of Aschenbrenner (1972) is based on observations in a recent subsistence agricultural environment in Greece and will be used for the calculations in this study. It records a fig tree density of 100-120 trees per hectare, and a production rate of *c.* 25kg of fruit per tree, thus some 2500 kg/ha. The season for fresh fruit is short, only about four weeks in August-September (Aschenbrenner 1972: 56, Table 4-4). Therefore, when considering the role of figs in the LH III diet, the nutritional values of dried fruit should also be considered. Based on modern values in the USDA database,[11] fresh figs are *c.* 2.6 times heavier in weight than dried figs because they contain water that evaporates when the fruit is dried. Thus, 2500kg harvest of fresh figs would translate into *c.* 960kg of dried figs. Fresh and dried figs have different calorific and nutritional values, as more dried figs fit into one volumetric or weight unit than fresh figs. These differences will be included in the diet estimations (pp.150-167).

Table 6.4. Estimations of the average yields of figs and grapes in the Eastern Mediterranean.

Region	Fig kg/ha	Vine kg/ha	Source
Karpofora, Messenia 1968-69	2500	14-17,000	Aschenbrenner 1972
LBA Cyprus	-	1753-4382	Padgham 2014
Fars Province, Iran 1994-2007[12]	517	-	Bagheri and Sephaskhah 2014

The debate surrounding the cultivation of olive trees in orchard conditions also extends to figs. Aschenbrenner's study (1972: 56) outlines how local farmers have experimented with planting fig trees extensively in various environmental conditions, recognizing their fruits as excellent cash crops. Notably, successful production predates the use of chemical fertilizers and relies solely on manure. While the Messenian yield might be slightly higher than ideal for a Mycenaean parallel, it is essential to consider the significant demands of the palaces on the plain for figs, which constituted half of the rations for palatial workers.

In his study, Aschenbrenner (1972: 55) recorded the yields of grapes and currants together, as villagers of Karpofora used the fruits mixed to make wine. Currant is not native to the Mediterranean, however, and could therefore distort the estimate for grapevine. Therefore, the estimation by Padgham (2014) is the best available comparable to the potential grapevine production rate in the LH III Argive Plain.

Bare fallow was likely the favoured practice for cereal cultivation in the LH III Argive Plain. Moisture can effectively enable or limit plant growth in dry and semi-dry areas (Wallace *et al.* 2015: 2). In the LH III Argive Plain, intensive watering would have been challenging for the inhabitants of the large settlements, because many of them needed to commute longer distances to their fields. Watering of kitchen gardens growing pulses and vegetables would have been possible for most, however. As discussed earlier, ethnographic accounts suggest that, generally, half of the cultivated land was kept fallow (Forbes 1982; Gibbon 1981; Koster 1977).

[9] Aschenbrenner (1972: 163) estimates that 4-6kg of fruit produces c. 1kg olive oil, and in the calculations the average of 5kg of fruit for 1kg of oil is used. Here only the 'good year' harvest is considered.

[10] Padgham (2014: 30, Table 2.25) divides the agricultural land into marginal (i.e. 180kg/ha), average (272kg/ha) and best (398kg/ha) land. The complimentary figures for grapes are 1753kg/ha (marginal), 2921kg/ ha (average), and 4382kg/ha (best).

[11] Based on the USDA database where fresh figs contain *c.* 79% of water, and dried, uncooked figs *c.* 30%.

[12] Figs were grown in rainfed conditions, with an average annual rainfall of 407mm in 1994-2007.

Thus, only half of the cultivated land can be considered to have produced cereal harvest.

Besides fallow, crop losses must be included in the estimations of the LH III Argive Plain crop yields. Crop losses can take place in all phases of the processing. Losses can also be caused by birds and rodents eating seeds while still in the field, or by dramatic weather changes such as frost or heavy rains. Crops are further lost in storage to insects, rodents and mould (Forbes 2017: 12). In this study, a total loss of 15 percent is used to estimate all the losses taking place in the separate phases of the crop production chain and storage. The number is used also by Padgham (2014: 30), who uses it to measure losses in the LBA Cypriot agriculture. As a comparison, FAO statistical data of losses taking place in traditional straw and mudbrick storages in modern Senegal (although the stored foods are millet, sorghum, and pulses) show a loss between 1.4 and 19.9 percent. Total post-harvest losses for peas and soybeans in modern Brazil amount to *c.* 10-15 percent (Grolleaud 2002). Besides the 15 percent crop loss, the total volume of harvest is further reduced by the *c.* 10 percent of grain seed which had to be stored for the sowing of new harvest the following year (see pp.140-141 above).

Summary: agricultural cycle in the LH III Argive Plain landscape

In the LH III period, the Argive Plain was going through many changes in its social and political structures. These changes were reflected in the local agricultural system, which likely took multiple forms. In the MH period, local society consisted of small kinship-based communities practicing subsistence agriculture. By the LH period, the accumulation of wealth and power by a new elite resulted in new types of needs for agriculture. These needs culminated in the LH IIII period, when the newly established polities of the plain focused on wheat and fig production, and wool textile and olive oil manufacturing. Other products, those with added value, could have been produced for trade too. This might have affected the local resource availability. An increase in population raised the demand for additional cultivation space and more reliable harvests. Previously, terraces might have been built on a small scale by farmers. The increased need for the palatial centres to produce cereal and tree crops for their own needs might have necessitated the need to cultivate more marginal lands, such as slopes. Terracing could have been needed for tree crops whose production was directed to palatial use especially around Mycenae where suitable land for cultivation was scarce.

The productivity of crop cultivation likely increased in the LH III because could have been enhanced with methods such as manuring was used to improve soil fertility. Due to the growing use of animal power, which made the transportation of products from areas further away was easier. Animal power was not necessarily available for the smaller farming communities and households, which is why it seems likely that intensive methods such as manuring remained as part of the regular Mycenaean agriculture to some extent. The For the palatial inhabitants, the newly built highway system from the Argive Plain towards the Berbati Valley, Corinth, and Epidavros might have helped to increase the exchange of products, including products without luxury status. The strategy of the palatial centres to maintain large animals such as oxen for traction benefitted the smaller farming communities as well, although their use came at a price; to provide labour services to the palace in return. Thus, the traditional small agricultural communities of the Argive Plain faced a situation in which more and more power over production shifted towards the elites. While subsistence production still took place independently and unrecorded, these communities to some extent became dependent on the new central administrations and began to provide them seasonal labour and possibly products in a form of taxation. Some people might have transferred their residency to the central settlements, where they earned their living by combining tasks in the palatial workshops, administration, and farming. The increasing sizes of Mycenae, Tiryns, Midea, and perhaps Argos and Nafplion suggest that such a lifestyle was attractive. Such a change in habitation may also have been necessitated by a need for protection.

Changes in the agricultural system during the LH period and the increasing sizes of the largest Argive Plain settlements provide reasons to question whether the capacity of the area was sufficient to support its inhabitants. Based on the information presented above, the following sections evaluate this question by, firstly, estimating the best composition for the local diet, and secondly, by calculating the agricultural potential of the area in the LH III based on this diet model.

The LH III Argive Plain diet

In archaeology, indications of past food sources can be found in various types of evidence, such as plant and faunal remains, isotope evidence from bone material, and remains of foods in containers. Reconstructing the human diet is often more challenging. Detailed understanding of the past cultivation and animal husbandry practices, as reconstructed in the previous section, is essential for the reconstruction of the LH III diet, which is a major aspect of the analysis of the agricultural potential. This reconstruction, presented in the following section, will firstly consider the isotope and skeletal analysis conducted for the MH-LH individuals in the Argive Plain and elsewhere in mainland Greece (pp.119-129). Since isotope studies cannot separate different plant species included in the consumed C3 plants, nor give estimations of relative amounts of plant and animal foods in a person's diet, these elements must be augmented through other means. Ethnographic studies offer a way to explore the diet of rural populations. What must be considered in such comparative analysis are the cultural and societal changes which might have changed food composition over time. For example, most of the traditional Greek diets used as examples in this study include crops such as potato and tomato, which were introduced in Europe late. The consumption of these products in modern diets may reduce the consumption of other foodstuffs such as legumes, which are indigenous to the Eastern Mediterranean. If not acknowledged, this could distort the composition of foodstuffs in the model diet.

Despite these biases, the dietary practices of recent rural communities in Greece and the Eastern Mediterranean can help to shed light on the average consumption of cereals, legumes, meat and milk which likely formed the basic components of the LH III diet. These estimations can be compared to the Linear B texts which have provided some data on the food rations given to some of the palatial workers (Gregersen 1997; Palmer 1992; see also pp.8-15 of this publication). Written records of diets in the Classical period can provide other comparative information.

After a list of the main foodstuffs included in the LBA diet is established, these foods can be further examined for their content of energy, protein, fats, carbohydrates and other essential nutrients. Nutritional analysis will help to estimate whether the proposed combination of foodstuffs (i.e. the diet model) was sufficient to maintain a relatively healthy lifestyle for the LH III Argive Plain inhabitant. For this analysis, the modern guidelines of the FAO, WHO and UN provide valuable tools (pp.58-60).

The LH III average food composition

Chapter 5 provided several types of data which can be used to map the main components in the average LH III Argive Plain diet. Comparison with studies elsewhere in mainland Greece and Crete confirmed that rather similar lifeways were maintained around the Aegean. These data indicate quite unanimously that C_3 plants formed the main component of the local diets. Animal protein was a small but important part of the diet, while fish and seafood were probably not consumed in significant amounts. The consumed meat came from cattle, sheep, goats, and pigs, and dairy was also provided by ovicaprids (pp.106-115). Local elites likely had a more versatile diet, but the present study is mainly interested in the simpler diets of farming communities. Skeletal analysis showed that anaemia was common amongst the MH and LH I populations. However, it is not known whether it was related to dietary deficiencies or caused by other conditions such as parasitic infections or genetic disorders.

As discussed in the beginning of this publication (pp.13-18), food rations recorded in the Linear B tablets of Pylos, Mycenae and Knossos were likely paid in monthly quantities, and these included *c.* 20 litres of figs and 20 litres of grain (Nosch 2003: 15; Palaima 2008: 386). In (wheat) grain this would be *c.* 15.2kg/month or 0.57kg/day, in dried figs *c.* 12.4kg a month, or 0.42kg/day.[13] Thus, in a year, the workers would have received *c.* 148.8kg of figs and 182.4kg of grain. Although these volumes are referred to as food rations, it remains unclear whether they were meant for personal or for household use. Nevertheless, the figures above can be compared to the LBA diet composition and its nutritional content in the following sections.

The evidence of cereal and legume flour, and the boiling and grinding of these crops suggests that cereals and legumes were most likely eaten in porridge and bulgur forms, mixed with a liquid which could have been water or milk. They might also have been made into flat breads (pp.93-94). Residue analyses from LBA cooking pots in mainland Greece and Crete suggest that meat was sometimes added to these dishes, and olive oil was extensively used in cooking (e.g. Evans and Garner 2008). Cooking in water or other liquids such as milk might change the energy and nutrition content of the food, and therefore has to be considered in the analysis of the LH III diet composition (see pp.154-159).

These data provide essential information on the food sources and ingredients of a daily diet in the LH III period. However, much remains unknown. For the calculations of the agricultural potential, it is important to establish exact volumes of each main component of an everyday "food plate". Since archaeological evidence can provide only general data on the LBA diet composition, comparative data can be sought in Classical and traditional dietary records.

Comparative data from Classical sources

Table 6.5 presents a compilation of the consumption estimates for the LBA and Classical Greece. The estimations are based on the assumed energy requirement of an adult person. This means that the percentage equals the calorific intake (kcal) that presumably derived from cereals. These energy requirements vary according to the individual's

[13] Aqua-calc.com conversion tool website used USDA nutrient data to convert food mass etc. According to this tool, 1 litre of dried figs equals to *c.* 0.63kg, and 1 litre 'ancient wheat' *c.* 0.76kg.

age, sex, and workload. Workers such as miners or agriculturalists conducting physically heavy labour needed more calories than people who are engaged in less physical activities (Foxhall and Forbes 1982).

What is apparent is that these estimates are interlinked. Two studies, one by Jardè (1925) and the other by Foxhall and Forbes (1982) form the basis for most of the other analyses. Another remark must be made about the chronology of these estimates. Most of these studies concern the "ancient" world. This means that they are based on Classical texts which, for example, deal with rations handed out to military personnel. The only estimate of grain consumption in the LH III period (van Wersch 1972) uses similar Classical sources. Therefore, although the use of the term 'ancient' in these works is seemingly applicable to a wider chronological context, in reality the figures are firmly connected to the Classical and later periods in Greece (in some cases also in Rome). At the same time, each of these studies use ethnographic or recent historical statistical data to back up their interpretations on Classical farming strategies. As discussed earlier (pp.56-58), it is important to be aware of the biases created by the use of these types of data in interpreting prehistorical decision-making.

Foxhall and Forbes (1982) have calculated the 'ancient Greek' consumption by comparing the 1973 FAO nutritional recommendations with ethnographic data, and with grain consumption figures from Classical sources. The latter mainly concern Greek and Roman handouts to military personnel. In order to determine a person's daily energy needs (the minimum needed intake of calories), Foxhall and Forbes use a similar method to the present study, in which they adjust the FAO energy recommendations by age, sex, weight and various activity levels (see pp.154-159). Consequently, the average calorific need for a highly active adult male is set at 3337 calories per day. Foxhall and Forbes (1982: 56) then compare these figures to Classical textual sources, in which the basic ration of (wheat) grain is one *choenix*. Since this unit measures *c.* 0.839kg and contains *c.* 2803kcal, it could have provided *c.* 84 percent of the daily energy requirement of a highly active ancient male. Having such a high share of the daily diet based on cereals sounds somewhat incredible to the authors. Thus, they suggest that *choenix* was the maximum need for grain which also included some buffer stock against shortages. More realistically, cereals likely provided 70-75 percent of the daily energy intake (Foxhall and Forbes 1982: 71-72). This range compares well with the maximum grain consumption in modern developing countries. Based on these data, Foxhall and Forbes (1982: 71-72) reconstruct a consumption rate of 0.58kg per day and 212kg per year for a highly active 'ancient' person. They (1982: 69-70) further suggest that one of the most significant changes between ancient and modern times has occurred in olive oil consumption. While ancient consumption figures are not known, a few ration figures from Classical works indicate significantly lower rates of use of oil by an average Classical citizen than by a traditional farmer. In such a case, the additional calories needed for daily subsistence were likely obtained from grain, which was more abundant.

Amemiya (2007: 75) adjusts the FAO recommendations of daily calorific intake by the consumption figures produced by Allbaugh (1948), who reported significantly lower calorific intake for the local population in his ethnographic-economic study of post-World War II Crete compared to modern FAO recommendations. Amemiya, thus, suggests that the FAO recommendations can be reduced by 15 percent to arrive at the ancient consumption figures. According to him, the total calorific need amounted to 2331kcal per person per day and of this, 70 percent was obtained from grain. Amemiya further suggests that poor citizens ate barley while the rich consumed wheat (2005: 114, Appx 6.2). According to him, the biological need of grain per person was *c.* 178kg (4.46 *medimnoi*) of wheat or *c.* 274kg (8.29 *medimnoi*) of barley per year.[14] Of his estimates in Table 6.5, the biological need for wheat and barley and the values for rich citizens and mine slaves are presented. The rest of the values he presents fall between these figures and do not provide additional information.

Jardé's thorough discussion of the ancient Greek agricultural economy has often been used as the basis for studies dealing with grain yield and consumption rates. Jardé formulated his figures by adjusting the production and consumption estimations given by German economic historian K. Julius Beloch, who published his first study of the ancient Greek demography, *Die bevölkerung der griegisch-römischen Welt*, in 1886.[15] By criticizing Beloch's (1886: 33) suggestions of the *c.* 264kg (8-medimnoi) annual consumption of barley by an adult male (based on Classical textual references), and especially of the consumption figures for females and children,[16] Jardè (1925: 135-43) reconstructs an average grain consumption rate of *c.* 3hl or 230kg[17] a year.

[14] 1 medimnos is *c.* 51.8 litres of grain, or, due to the different weights of the two species, *c.* 33kg of barley or 40kg of wheat (Amemiya 2005: 1; van Wersch 1972: 185).

[15] Some years later, Beloch continued studying the ancient Greek and Roman societies and their economies in his series *Griechische Geschichte* (I-IV, 1912-1927).

[16] Beloch suggests both consumed 5 medimnoi without giving further explanation while Jardè suggests a ¾ consumption for females and 1/2 for children, also without relying on data but rather on his own intuition.

[17] The author of this book has converted the volumetric units to kilograms as follows: 1 hl equals 100 litres of wheat. One litre weighs *c.* 0.772kg. Thus, 3hl is *c.* 230kg.

Table 6.5. The share (in percent) of different foodstuffs in prehistoric and early historic diet in Greece.

Area and period	Foodstuff	Consumer	% of diet	kg/yr	Reference
Ancient Greece	cereals	person	70-75	237	Foxhall and Forbes 1982
4th cent. B.C Athens	wheat	person (biological need)	70	178	Amemiya 2005
	barley	person (biological need)	70	274	
	wheat	rich citizen	60	153	
	barley	mine slave	90	428	
Classical Greece	cereals	person	75	150-230	Garnsey 1988
Ancient Greece	cereals	person	75	230	Jardé 1925
LBA Messenia	cereals	person	-	235	van Wersch 1972[18]
Classical Greece	cereals	person	65-70	-	Gallant 1991
	fruits, pulses, vegetables	person	20-25	-	
	oil, meat, wine	person	5-15	-	

Garnsey (1988: 89) adopts the maximum consumption of grain (230kg/year) from Jardé, but also suggests a minimum requirement of 150kg per person per year.[19] The most likely consumption rate of grain lies in between these two figures, at *c.* 175kg/year (Garnsey 1988: 102, Table 7). Garnsey emphasizes the importance of barley in the Classical Athenian society due to the minimal risk and high profit related to its production. Nevertheless, his consumption rates refer to grain in general, possibly to a mix of both wheat and barley, since both were consumed by the Athenians.

Gallant (1991: 68) lowers the suggestion of Foxhall and Forbes (1982) on the share of grain in the diet composition to 65-70 percent. He (1991: 66) seems to prefer a lower range because ethnographic comparisons from rural areas in Greece and the Eastern Mediterranean show considerably lower rates of cereal consumption.[20] Gallant (1991: 68) also wants to emphasize the role of vegetables, fruit and legumes in the ancient diet following the notions of a few ancient authors such as Galen and Athanasios. Gallant does not explain in detail how he formulates his consumption rates but suggests (similar to Foxhall and Forbes) that archaeological and textual evidence indicate much lower olive oil and meat consumption in comparison to modern times. Gallant does not present his own estimations of grain or other foodstuffs consumption in weight or volume.

Finally, van Wersch studied the LBA food production and consumption of the population as a part of the MME survey in Messenia, western Peloponnese. Thus, his study is one of the few focusing on the Bronze Age instead of "ancient Greece". Van Wersch (1972: 185-86) formulates his cereal production figures by comparing the recent wheat economy in Messenia, studied by Aschenbrenner (1972), to earlier estimates for the ancient world, given for example by Jardè (1925), Roebuck (1945) and Ventris and Chadwick (1956). Van Werch (and Roebuck and Jardè) suggest a daily consumption of 1 litre of grain flour per adult male. This number derives from the Classical Attic volume *choenix*, mentioned in Classical literature as the daily ration given to military personnel (see Foxhall and Forbes 1982 above). Translated to kilograms of mixed cereals, this would have amounted to *c.* 239kg per annum.[21] Van Wersch then compared these figures to the traditional grain consumption in Messenia, which at the time of the survey was *c.* 200kg of processed grain meal per annum. He further adjusted this figure by 0.85 to include the losses to grain seed during milling, arriving at an average LBA grain consumption of 235kg/year.

All the estimates above and in Table 6.5 are expressed in kilograms, although, as pointed out by Foxhall and Forbes (1982: 42), this is rarely the case when ancient grain figures are analysed. The original sources are usually expressed as units of volume. Translating volume into weight can be complicated, because the nature of the measured foodstuffs (e.g. hulled versus

[18] Van Wersch estimates that cereals formed the 'mainstay' of the LBA diet, and of the total consumption of 1 litre per day, 70 percent was barley, and 30 percent wheat.

[19] The source of the latter figure is not presented but it possibly presents an adjustment to the ancient consumption based on ethnographic data, which shows lower consumption rates in rural communities.

[20] For example, cereal consumption was some 50 percent of the diet in Messenia according to Aschenbrenner 1972, and 35-45 percent in the Methana peninsula according to Foxhall and Forbes 1982.

[21] Van Wersch proposes that 1 litre of barley translates to *c.* 0.618kg and 1 litre of wheat to *c.* 0.772kg, and that the average consumption of these main cereals was 70 to 30 percent in favour of barley. Thus, the mean consumption grain per day would be 0.654kg and 239kg per annum. Van Wersch also applied a conversion rate of 0.67 to adjust the figure to the needs of females, elderly individuals and children, arriving at an annual 160kg per capita consumption.

Table 6.6. Amounts of different foodstuffs (kg/yr) in ethnographic studies of rural communities in the Mediterranean.

Area and period	Food	% of diet	kg/yr	Reference
Crete 1947-8	cereals	28	128	Allbaugh 1953
	meat, fish, eggs	6	28	
	milk and cheese	8	35	
	oils and fats	7	31	
	pulses and nuts	5	23	
	vegetables, fruits, olives	29	132	
	wine, beer, spirits	8	39	
	sugar, honey	1	5	
Messenia 1969-70	bread	-	110	Aschenbrenner 1972
	cheese	-	30-37	
	olive oil	-	30-125	
Kosona, Methana, 1970s	wheat	-	160/200	Forbes 1982[22]
Aleppo, Syria 1977-8	cereals	-	223-281	Gibbon 1981
Asvan, Turkey, 1940s	wheat	78.5	320	Hillman 1973
	meat and milk	16	-	
	grain legumes	3.5	20	

free threshing cereals) and level of processing alters their weight. Foxhall and Forbes (1982: 68-9) further point out how ancient ration figures of grain are hardly comparable to modern cereal consumption rates, the latter representing considerably lower rates. They suggest that rations were always given in higher amounts than what the actual consumption was, so that part of the share could be saved or exchanged to other products.

Rural diet in ethnographic studies

As seen in the previous section, Classical sources are not particularly informative of the consumption of foodstuffs other than cereals. Therefore, ethnographic sources can be used to examine the possible consumption of meat, dairy, olives, figs, and wine, which were an integral part of the LBA diet. The estimates of Classical consumption of cereals and other foodstuffs in Table 6.5 can be compared to the ethnographic consumption data compiled in Table 6.6. The amounts of foodstuffs are presented in kg per year, and, when applicable, in percentage of the diet.

These figures show interesting variations. While Allbaugh's study is the most comprehensive, as expected it includes many food items used in the post-World War diet, which were unfamiliar to LBA farmers. These items include eggs, sugar, potato and tomato, of which the latter two form a major share of the vegetable-consumption in rural households. Gallant (1991: 62–64) points out how at the time of Allbaugh's study, Crete was still recovering from the war which drove the island into an economically difficult period, resulting in some level of malnutrition in many places. Allbaugh's work has often been used in studies reconstructing ancient diets, including the present study (see previous section). Being aware of the biases related to his work, Allbaugh's figures can be compared with other ethnographic data as well as the reconstructed figures for the ancient world. The most notable difference is the share of cereals, 28 percent, which is exceptionally low compared to estimations for the LBA and Classical diets. It is low even though the majority of the Cretan population consisted of small farming communities growing grain in the 1950s (Allbaugh 1953, and Appendix 2 of this book).

In Asvan, Turkey, cereals constituted almost 80 percent of the consumed calories, similar to the postulated LBA and Classical diet estimates. However, measured

[22] 160kg for an adult female, 200kg for an adult male.

in weight, the consumption of wheat was considerably higher (320kg) than what has been estimated for ancient Greece. In Asvan, legumes were consumed in exceptionally low amounts (3.5 percent), and remaining calorific intake was mainly received from animal products. The share of legumes is also low in the dietary composition for Crete (5 percent). Nevertheless, in both locations, legumes were cultivated purposefully. The low consumption figures thus likely indicate the cultivation of legumes as fodder. Considering the abundance of legume species in the LH III archaeobotanical samples (Appendix 4), their consumption was presumably higher in the LH III period, especially since vegetables such as tomato and potato were not available. Legumes have been found in processed forms and in storage contexts, which seems to refer to their use as food.

Finally, as suggested by Gallant in relation to ancient rural diets, the consumption of dairy appears equally low in modern rural contexts, with only *c.* 16 percent in Asvan, and 14 percent in Crete. Meat consumption is also low in traditional farming communities (e.g. Koster 1977: 354-358).

Summary: Diet models based on a comparison of data

The estimations for the LBA and Classical diets suggest that the quantity of cereals consumed by an average adult was about 200-230kg annually. This is more than the rations of grain given to the Mycenaean palatial workers (*c.* 182kg/year if converted with USDA data). This amount would probably have formed at least 65-75 percent of the total diet. However, there is only one ethnographic study in which cereal consumption was at such a high percentage (79 percent) (Hillman 1973). In this study, however, *c.* 100kg more cereals were consumed than in the ancient estimates. The estimates of the different data sets do not seem to compare very well. Therefore, the following section asks whether it is possible to make a diet reconstruction with a combination of the ancient and ethnographic estimates.

This study will approach the issue by establishing two models for the LBA Argive Plain diet. The first model will follow the previously presented estimations and assumes that 75 percent of dietary energy was received from cereals. The composition of other foodstuffs in the diet loosely follows the model of Gallant (1991), who suggests a 20-25 percent share for fruits and pulses, and 5-15 percent for oil, meat and wine. The second model decreases the share of cereals to 40 percent. By doing so, the model approaches the abovementioned ethnographic parallels, but replaces potato, tomato and other 'new' vegetables with higher consumption of legumes, olive oil and animal products. The two diet models are introduced in more detail. The following section first analyses the nutritional content of the food items included in the LH III diet.

The nutritional composition of the Late Bronze Age diet

The following section introduces models for the potential LH III diet composition, and then compares the nutritional and energy content of the foodstuffs included in them with the average nutrient and energy requirements of a person with a certain energy expenditure. These estimations are based on the basic methods of nutritional ecology (see pp.58-60 for further introduction to the methodological background). The results evaluate the sustainability of each diet model. If sufficient for human subsistence, the diet models can be used to calculate how many people had their basic dietary needs met by the food production that took place in the LH III Argive Plain.

Similar to Foxhall and Forbes (1982 and onwards), the present study uses the guidelines for energy and nutrient requirements provided by FAO to examine past diets. These requirements have been updated according to the most recent (2004) FAO guidelines. In addition to the intake of calories (i.e. energy), the intake of fats, protein and carbohydrates are examined. Together, these components can give a sufficient indication of the sustainability of the presented diet model.

Energy requirements

As discussed in Chapter 4, basic human subsistence depends on the balanced relationship between energy intake and its expenditure through basal metabolism and various levels of bodily functions and physical activity. One way to present this relationship is to estimate the minimum energy needs of an average individual in kilocalories (kcal) and compare this to the calorific content of the person's diet.

The current recommendation for calorific intake by the FAO/WHO (2004) is presented in Table 6.7 It consists of two main aspects, the Basic Metabolic Rate (BMR), and the Physical Activity Level (PAL). The BMR measures how much energy is required to maintain essential bodily functions. Here the FAO/WHO (2004: 37, Table 5.2) average for 18-30-year-old adults have been used. The equations are based on age, body weight and body composition (FAO/WHO 2004: 35). The BMR is multiplied with the PAL, measuring the average level of physical exercise a person experiences on a daily basis. According to the FAO standards (FAO 2004; Snodgrass and Leonard 2009: 225), the higher end of the 'vigorously active' lifestyle includes more than six hours of agricultural or other physically challenging work per day (see also p. 59). This seems comparable with the lifestyle of the LH III farmers. The result is the Total Energy Expenditure (TEE), which reflects the minimum number of calories required to maintain the lifestyle of a given person.

These simple calculations can cautiously be applied to the LH III individuals (Table 6.7). This first requires the determination of the average weight of an LH III adult, which can be reconstructed from the known heights of Bronze Age individuals. The individuals buried in the Grave Circle B at Mycenae and in MH Asine were tall, males 160-180cm, and females (only in Asine) 158.8cm on average (Angel 1973, 1982; pp.121-122 of this book). However, comparative data (pp.123-124) from other LH contexts point to ranges of male heights between 164 and 170cm and female heights between 149 and 160cm. Based on these, an average height of 167cm for a LH male and 154.5cm for a LH female can be suggested.

The Body Mass Index (BMI) measures the relationship of a person's weight and height. Adult BMI ranges from 18.5 to 24.9 (kg/m^2). When studying the recommended energy intake on a population level, the FAO/WHO (2004: 40) recommends using a median BMI of 21.0. Thus, the average weight of a 167cm tall LH III male is 59kg, and a 155cm tall female 51kg (both BMIs are 21.2). As a comparison, Foxhall and Forbes (1982) use an estimated body weight of 62kg for an ancient Greek male based on the FAO 1973 mean. They estimate this based on the average heights of males (162.2cm) in Classical Attica (Angel 1945) and 1948 Crete (163.5 cm) (Allbaugh 1953). Their weight-height relationship results in a BMI over 23, which settles towards the higher end of the normal weight range. A higher BMI can perhaps better reflect the mean in the Classical period. However, in this study a lower BMI is assumed to better reflect the active lifestyle of the LH III farmers.

In the calculations below, a vigorously active lifestyle with a PAL indicator of 2.0 is used. FAO/WHO (2004: 38, Table 5.3) points out that the highest end of the range, 2.4, would be difficult to maintain over extended periods of time. At the same time, the low end of the vigorous lifestyle may better reflect the low seasons of agricultural work, as well as the lifestyle of individuals with different professions and ages.

Calculating with the FAO/WHO recommendations, the required daily need of energy is *c.* 3161kcal for the LH III males and 2485kcal for the LH III females. However, average energy requirements are often expressed as the mean of all members of a family or a household. The number of people included in an average LBA household is discussed elsewhere (see pp.36-38). Here (Table 6.8), a household of 6 with two adults, one older female, and three children of different ages can be assumed, following Foxhall and Forbes (1982: 72). Children are assumed to have had a vigorously active lifestyle. Even though the youngest children were not involved with the heaviest of agricultural tasks, they were likely assisting from early on with household tasks and animal husbandry. Here it is assumed that an older female such as a grandmother or a more distant relative would have been taken in as part of the household in case of a premature death of her male partner. This female is assumed to have had a lower workload. Calculated from these figures, the household total would be 14,202kcal per day, and the average intake need of a household member 2367kcal/day.

The figures presented above are rather close to those used by Foxhall and Forbes (1982: 71-72; p. 151.), who suggest the average calorific requirement of an 'ancient' person was 2583kcal/day. Their figure is based on a household average slightly higher than used in this study (15,495 kcal). Their higher household average is a result of the assumed much higher energy requirements of children and adolescents, which the authors themselves criticize. By calculating the calorific requirements for children separately, this study can thus present lower but presumably more realistic average figures. In the examples above, children require *c.* 55-65 percent of an adult male's calorific needs, while Foxhall and Forbes (1982: 72) estimate this requirement as 66-70 percent.

In the end, a 2400kcal per day average requirement for energy (rounded from the household average of 2367kcal) is used in this study to calculate the dietary needs of the LH III Argive Plain population. The adult average would be *c.* 2800kcal/day but the lower figure is more appropriate when including a variety of ages and societal classes. As a comparison, Kowarik *et al.* (2012) have suggested that due to the extremely prominent level of physical labour, the energy need for an average male working in the Bronze Age salt mines of Hallstatt was 3696-3852kcal per day. On the contrary, the previously mentioned study by Allbaugh (1953) in 1948s Crete showed that the local farmers could survive with a notably lower calorific intake, on average 2547kcal/day. Thus, a wide variation exists between the energy requirements of different populations in different times.

Protein, fat, and carbohydrate requirements

Although a large number of vitamins and other nutrients are needed to maintain long-term human subsistence, the examination of the calorific (energy) content, as well as the intake of protein, fats, and carbohydrates can already give reasonable indications to whether a diet is sufficient to keep a person alive. Table 6.9 introduces the estimated minimum protein, fat, and carbohydrate requirements for the LH III

Table 6.7. Basic energy requirements per sex and activity levels as given by the FAO/WHO and adjusted to the LBA individuals according to their reconstructed weights (marked in bold).

FAO/WHO 2004	**Basic Metabolic Rate (BMR)**		**Physical Activity Level (PAL)**	**Total Energy Expenditure (TEE)**
Method	Male	Female	Depending on lifestyle	BMR x PAL
	15.057 x kg + 692.2kcal	14.818 x kg + 486.6kcal		
Vigorously active male 70kg/kcal	1746.19		2.00-2.40	3492-4191
Vigorously active female 55kg/kcal	1301.59		2.00-2.40	2603-3124
Active or moderately active male 70kg/kcal	1746.19		1.70-1.99	2969-3475
Active or moderately active female 55kg/kcal	1301.59		1.70-1.99	2213-2590
Vigorously active LBA male 59kg/kcal	1580.563		2.00	**3161**
Vigorously active LBA female 51kg/kcal	1242.318		2.00	**2485**

Table 6.8. Calculated daily energy needs of children and elderly in a LBA household. The formula for calculating the BMR of children was calculated by the author, while the BMR of the older female is provided by the FAO/WHO. The weights of the children are taken from the mean weights for 3-0, and 11-18-year-olds provided by FAO (1991).

Individual	**Formula**	**Basic Metabolic Rate (BMR)/kcal**	**Physical Activity Level (PAL)**	**Total Energy Expenditure (TEE)**
Male child 3-10 yrs, 15kg	22.706 x kg + 504.3kcal	845	2.00	1690
Female child 3-10 yrs, 15kg	20.315 x kg + 485.9kcal	791	2.00	1581
Male adolescent 10-18 yrs, 50kg	17.686 x kg + 658.2kcal	1543	2.00	3085
Female 30-59.9 yrs	1301.59		1.75	2200

individuals based on the energy intake indicated in the previous section.

According to the FAO (2013: 27, Table 3), the basic protein requirement of an adult person is 0.66g/per day. Here the average weights of the estimated LH III adults (pp.p. 155) are used. Recommendations for daily fat intake vary according to the intake of other nutrients, above all the carbohydrates. The ideal average of fats is *c.* 20-30 percent of the energy intake (kcal) but can vary between 15 and 35 percent (Elmadfa and Kornsteiner 2009: 59). Fats acquired from different foods contain a multitude of lipids, fatty acids and other combinations, some of them more beneficial than others. To keep it simple, this study will only observe the total fat content of different foodstuffs.

According to the FAO (1998), an adult person should receive a minimum of 50 grams of carbohydrates per day. The recommended amount of carbohydrates is *c.* 55 percent of the total energy intake (kcal). This amount should derive from a variety of food sources, of which cereals, fruit, pulses, vegetables are the most important. Intake of 75 percent or above is considered to have adverse effects on the nutritional balance since excess intake will reduce the absorption of healthy fats, protein, and other essential nutrients. In a sustainable diet, it is preferable that more energy is obtained from carbohydrates than from fats (FAO 1998).

The nutrient content of foods

Table 6.10 below presents the average nutritional content of various foodstuffs included in the LBA diet reconstruction. This table is based on the nutritional information of food provided by the United States Department of Agriculture (USDA) database of Food and Nutrition which is available online (USDA 2019). Although there may have been differences between modern and LBA food items, for example in the genetic, physical, and nutritional characteristics (see pp.58-

Table 6.9. Recommendations for the daily protein, fats, and carbohydrates intake for an average LBA individual with a daily energy intake of 2400kcal.

Nutrient recommendations	Protein/day	Fats/day	Carbohydrates/day
Method	0.66g x kg[23]	15-35% of kcal[24]	55-75% of kcal (min. 50g)[25]
LH III individual 51-59kg	34-39g	360-840kcal	1320-1800kcal

60), these modern data represent the most sufficient available data for the purposes of this book.

A few remarks on the items included in Table 6.10 must be presented: firstly, the table presents the values of energy, protein, fats and carbohydrates of uncooked foodstuffs with the exception of meat, which presents the values of cooked, braised or boiled meat with salt. Secondly, distinct species of cereals from the wheat family (emmer, einkorn, and bread wheat) have been grouped together under one title, 'wheat'. As seen in Appendix 10, which lists the nutritional values for each food item in more detail, the values of these species are close to each other. For example, organic einkorn has 333, durum wheat 339, and whole-grain wheat flour 340 kilocalories per 100 grams.[26] These values vary slightly depending on the brand of the product listed on the USDA database.[27] Due to this rather small range, using the individual values of different wheat species in the dietary calculations would not improve the reliability of the dietary analysis used here. Therefore, all three species, emmer, einkorn, and bread wheat can be grouped together, and the averages of their calorific, protein, carbohydrate, and fat values can be used in the dietary reconstructions in this study.

Similar to cereals, different legume species have been grouped together as one generic item. The calorific contents of fava beans, lentils and peas settle on an equally small range to cereals (Appendix 10). Since archaeobotanical data do not enable reconstructions of the dominance of any of these species in the local food economy, and because the USDA database does not contain data on archaeobotanical finds of legumes such as vetchling, bitter vetch or grass pea, most commonly recovered in the Bronze Age Greek contexts, examining various legume species separately would not add value to the LH III dietary analysis.

Appendix 10 further shows how the calorific content of food items can vary notably when they are processed, cooked, or dried, as opposed to their raw or fresh forms. For example, raw lentils contain 352kcal per 100 grams, while cooked lentils only contain 116kcal per 100 grams. These differences are likely caused by loss of water. According to Urbano and co-authors (2007: 48), lentils, fava beans, peas and beans share somewhat similar calorific content compared to cereals. Thus, the entry of raw legumes with higher calorific content most likely represents their split (dried) form. When dried, water has been diluted from the bean and therefore more beans, and thus more calories, can fit into a weight or volumetric unit. About 70 percent of fresh or water-cooked legumes is water and therefore they contain less calories (see USDA 2019 for water content and other nutritional data per species). In this study, the values of processed and dried legumes have been used. In such form, legumes can be better compared to cereals, which are also examined in their 'raw', unprocessed forms. Both set of values can be considered to represent the items as they would have been stored.

Appendix 10 also presents the nutritional values of some cooked food items as examples of the variation in values. Using the USDA values for cooked foods would be problematic, however, since modern cooking often includes the use of salt and other ingredients which were not available in the LH III. Furthermore, in the database, cooking methods are often poorly explained. Analyses and experiments on Late Minoan cooking pots have revealed that the preparation of one meal could have taken several phases from frying to boiling. At the same time, cooked food was necessarily consumed every day, but calorific needs could have been filled for example with dried, fermented or pickled foods (Morrison *et al.* 2015). Thus, values resembling the storage forms of these products seem to provide the safest option for diet reconstructions.

Vegetables are excluded from this Table (6.10) because there is not enough archaeological evidence to support the selection of specific vegetable species for the dietary reconstruction. Melon, and various greens and roots could have been consumed as indicated by the scarce macrobotanical finds in Tiryns (pp.99-100). Greens are rich in vitamins and minerals but have low values of the four main components examined here.

[23] Based on FAO (2013: 27, table 3) and WHO (WHO/FAO/UNU 2007: 88, table 4) data.
[24] Based on Elmadfa and Kornsteiner (2009).
[25] Based on FAO/WHO (1998).
[26] Comparing these to some calorific values given to cereals in ancient studies, Hansen and Allen (2011: 879, Table 14.10) in the EH Tsoungiza context suggest that barley contains 318kcal per 100 grams, and Foxhall and Forbes (1982: 51-58) give processed cereals calorific values of *c.* 332-334 per 100 grams in their study about ancient grain consumption.
[27] The USDA database mostly includes modern day branded products instead of generic food items.

Thus, they would not drastically change the intake of energy, protein, fats, or carbohydrates.

Of fruits, only figs, grapes and olives are included, as these are each clearly attested as LBA food plants by archaeobotanical evidence. Of these, figs were likely consumed fresh and dried, while grapes and olives were consumed fresh unless processed into oil and wine. As with legumes, the calorific content of figs is related to the dilution of water and therefore varies according to the form of serving. In this study, based on their water content in the USDA database, fresh figs are considered 2.6 times heavier than dried figs. Fresh and dried figs also have different nutritional contents, as in their condensed form dried figs contain higher amounts of calories and other nutrients (see p. 148 for yields).

In antiquity, wine was prepared by mixing it with water and possibly by adding various sweeteners, herbs or spices during consumption (e.g. Morris 2008). This was likely true for the wine served in the Bronze Age too. Therefore, the modern nutritional values of wine vary too much to make sufficient comparisons with the LBA wine, and the drink is not included in the final calculations. Overall, it is assumed that, of these three fruits, figs were consumed the most, while grapevine and olive cultivation mostly focused on wine and oil production.

Zooarchaeological evidence gives only very general indications to how animals may have been exploited in the LH III Argive Plain. Milk of all ovicaprids, cattle, sheep and goats, could have been consumed fresh or in fermented forms. Cheese was likely consumed in the LH III, but currently it cannot be established in what kind of volumes, or whether it was available to everyone in the LBA society (p. 104). Considering the benefits of the longer storage life of cheese compared to fresh milk, it has been included in the models here as a common staple. The nutritional content of milk and cheese vary significantly from each other. In this study, dairy consumption is divided evenly between cheese and milk. Such division results in the lower consumption of cheese in weight since it contains more calories than milk. It is assumed that, although mechanical and chemical processes take place in modern milk and cheese preparation, the essential nutritional composition of whole milk or cheese bears comparison to the LBA values. The use of modern values in studies of ancient dairy consumption is common (e.g. McClure *et al.* 2018). Three traditional cheese types from the USDA database were chosen; white cheddar type made solely of cow milk, Feta cheese of goat milk, and traditional Greek light-yellow cheese, 'kefalotyri', made of sheep milk. Each cheese is made of only one type of milk, which helps to examine the role of each milk-producing animal in the LBA food economy.

Pigs would have been the only domestic animals solely raised to produce meat and fat. For an average LBA household, it would have likely been too expensive to keep a large number of pigs only for meat production. Thus, the meat of sheep and goats might have been consumed more. Meat, nevertheless, formed a minor part of the LBA diet composition (pp.150-154). Ideally, the values used in this study would derive from boiled meat, following the trace analysis results of BA cooking pots (p. 150), which suggest meat was prepared by boiling and possibly served together with boiled cereals and/or legumes. Meat could have also been cooked on open fires, or it could have been consumed dried. Modern values of cooked meat usually refer to the fried, grilled, or oven-cooked dishes and therefore do not necessarily reflect the ancient values in the best way. In addition to cooking/related biases, goat meat has naturally much lower calorific and fat content than mutton, pork or cattle meat. Lamb meat is higher in fat than the meat of adult ovicaprids. However, today's meat producers tend to trim fat and sell meat as 'low-fat' (often visible in the USDA database). The sample meats used here have been chosen because they can contain both lean meat and fat. Finally, besides lean meat, other parts of the carcass such as intestines, hoofs, or bone marrow were likely consumed in the LBA, and these usually have different nutritional values. This analysis only includes lean meat (and fat).

These food items and their nutritional values are used to calculate the average intake of a LBA adult in two main diet reconstructions, one rich with cereals (diet model 1), and the other with an increased volume of pulses (diet model 2). These diet models are presented below. Besides these two main models, two sub-models, a and b, have been created to better examine the impact of the consumption of animal products and barley-based cereal consumption versus wheat-based cereal consumption on the sustainability of these diets.

The LH III diet analysis

The following section presents two main diet models, 1 and 2, for the LH III adult population of the Argive Plain. The foodstuffs included in these models derive from the archaeobotanical samples gathered in the Bronze Age Argive Plain settlements, and, to a lesser extent, from the LH III textual references to food items. These data are combined with ethnographic data of crop-processing and preparation for consumption. The relative shares of different foodstuffs in the diet models are based on historical and ethnographic comparative data of diets in rural contexts, and foodstuffs available in the Classical and LBA Greek societies. Diet 1 represents the traditional model of the LBA and ancient Greek diets. In it, cereals form the largest share of the diet composition. In diet 2, the volumes are adjusted

Table 6.10. The average calorific and nutrient content of different foodstuffs in the LBA diet as presented in the USDA database. Further information on the items is compiled in Appendix 10.

Food	Energy kcal/100g	Protein g/100g	Carbohydrates g/100g	Fat g/100g
Barley	354	12.5	73.5	2.3
Wheat	352	13.82	69.81	1.96
Legumes	352	24.6	61.1	2.2
Olive, ripe, Greek	105	0.88	6.06	9.54
Fig, fresh	74	0.75	19.18	0.3
Grapes, fresh	69	0.72	18.1	0.16
Fig, dried	249	3.3	63.87	0.93
Olive oil	884	0	0	100
Sheep's milk	108	5.98	5.36	7
Goat's milk	69	3.56	4.45	4.14
Cow's milk	61	3.15	4.78	3.27
Cow's milk cheese	370	26	6	27
Goat's milk cheese	321	17.9	3.57	25
Sheep's milk cheese	357	25	3.57	28.6
Mutton/ lamb	313	24.96	0	22.89
Goat	142	26.9	0	3
Pork	242	28.2	0	13.5
Beef	235	27.06	0	13.44

in order to examine the impact of pulses and animal products on the LH III diet.

In addition, two sub-models, a and b, are created to examine how a different composition of animal products and barley and wheat emphasis impact the nutritional content of a diet. As explained previously, animal products such as meat may have not been equally available to all levels of the Mycenaean society, as it might have been dependent on the costs of keeping animals. Therefore, in sub-model a, sheep and goats are the main sources for dairy and meat, while cattle and pigs are consumed in low amounts. In sub-model b, the roles of cattle as dairy producers and pigs as meat producers are emphasized. In addition, in model a, barley is considered as the main consumed cereal, while in model b the emphasis is on wheat.

The following section has three main foci; first to establish LBA diet models which can be used as the bases for the calculations of the agricultural potential; second, to examine in more detail the sustainability (i.e. healthiness) of the LBA diet consisting of the given foodstuffs and their composition; and third, to challenge the traditional idea of a cereal-based LBA diet in which legumes do not have a well-defined role. The values concerning the intake of foodstuffs and nutrients of each diet model are compiled in appendices 11a and 11b.

Two diet models

In diet model 1 (Figure 6.5), 75 percent of energy derives from cereals, dried and fresh fruit comprise 10 percent of the diet, legumes and oil 5 percent each, and meat and dairy products 2.5 percent each. Dried fruit comprises only dried figs, as figs were extensively used in the Mycenaean societies, but their season is short, and therefore the fruit was likely consumed mostly dried (pp.97-98). This diet composition resembles that of the Classical world put forward by Gallant (1991), who suggested that 20-25 percent of energy was obtained from fruits and pulses, and 5-15 percent would come from oil, meat and wine. Cereals as the main component of the 'ancient' diet has further been suggested by various scholars (see pp.151-153 and Table 6.5 for references). Fish is excluded from this model, due to the inconclusive results of isotope analyses on fish consumption in the Bronze Age. If marine foods were consumed, it took place seasonally and in insignificant amounts (pp.114-115).

Diet model 1 is further divided into two sub-models, 1a and 1b. In 1a, 70 percent of the total cereal consumption consists of barley and 30 percent of wheat, the latter comprising the average nutritional values of the three most common LBA wheat species: einkorn, emmer, and bread wheat. Legumes consist of the average of the nutritional values of peas, fava beans, and lentils. Of fresh fruits, 60 percent consists of figs, 35 percent of grapes, and 5 percent of olives (so-called table olives). Sheep and goats produce 80 percent, and cattle 20 percent of the total dairy consumed (both cheese and milk). Finally, sheep, goats and pigs produce 90 percent of the total meat consumed, while cattle produce only 10 the remaining percent.

In diet model 1b, the consumption of barley and wheat is reversed. 50 percent of milk and cheese are produced by sheep and goats, while the remaining half derives from cattle. Pigs produce 40 percent of the total meat consumed while sheep, goats and cattle produce 20 percent each. These figures are visualized in figure 6.6 a and b. The sub-models a and b remain the same when they are combined with diet model 2.

In diet model 2, the composition is adjusted to increase the share of pulses in the diet (Figure 6.7). Oil consumption in diet 1 is low compared to the 31kg consumed in 1940s Crete according to Allbaugh's report. Therefore, in model 2, it rose from 5 to 10 percent.

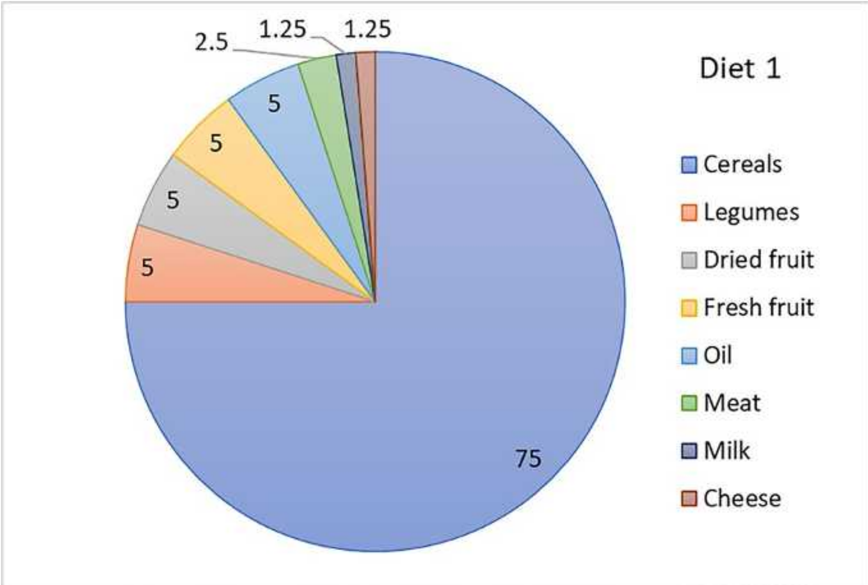

Figure 6.5. The composition of different foodstuffs in diet model 1 as percentages of the total.

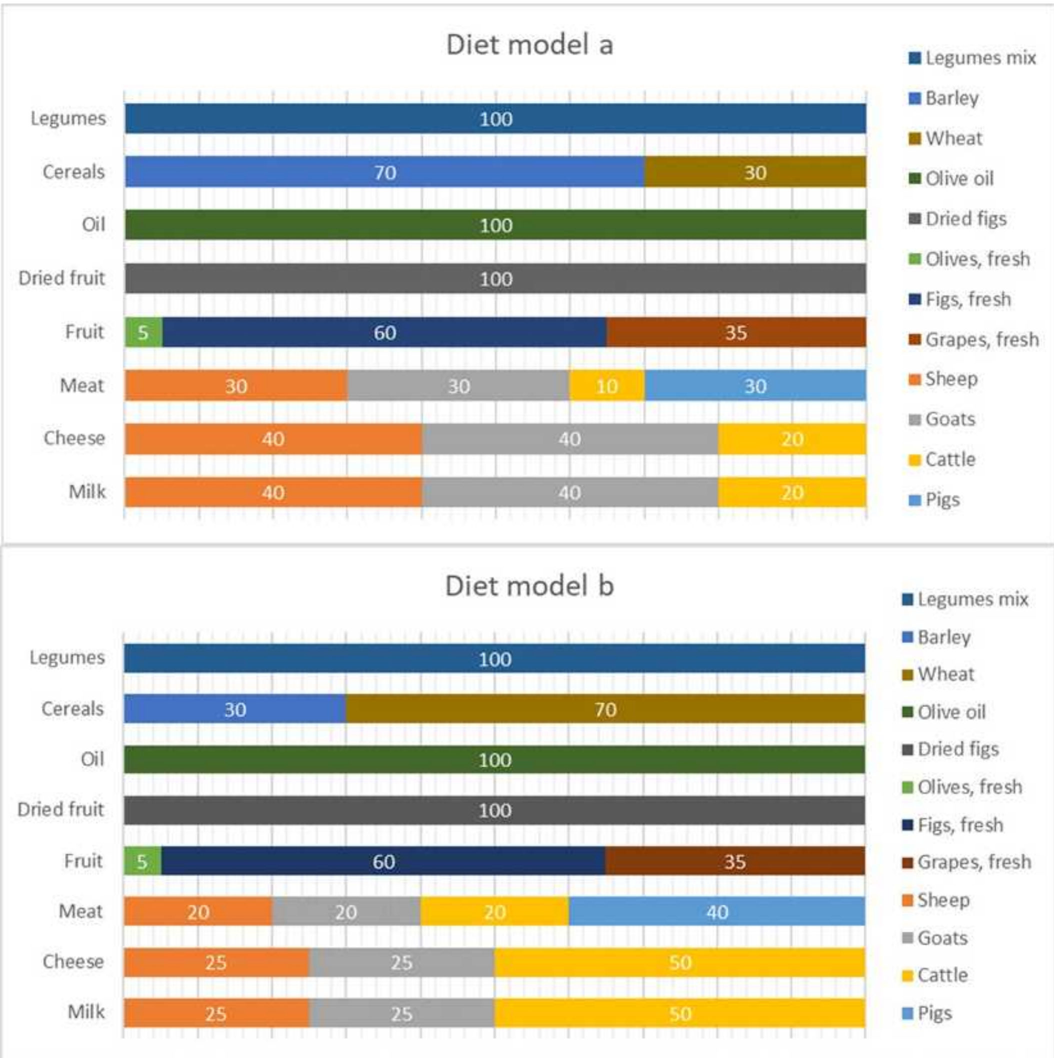

Figure 6.6. Two diet sub-models, a and b, in which specifically the consumption of cereals, meat, and dairy is examined in more detail. The shares of each food item are of the total food resource (cereals, legumes, meat etc.) consumption in diet models 1 and 2.

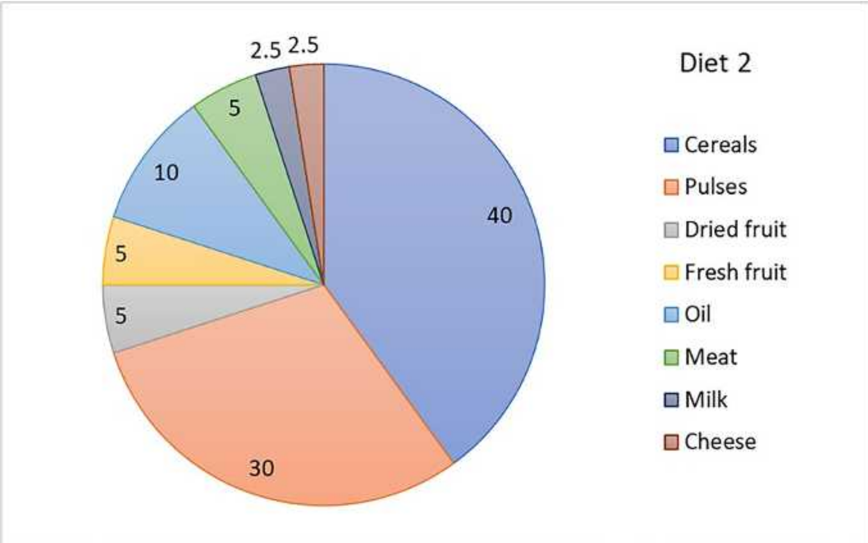

Figure 6.7. The composition of different foodstuffs in diet model 2 as percentages of the total.

Since the lower share of cereals gives more freedom to balance out the composition of other foodstuffs, the share of meat and dairy products are also slightly increased. As with diet model 1, cereal, meat, and dairy consumption in diet model 2 is further divided into two sub-models, 2a and 2b, according to the examples presented in Figure 6.6.

Diet analysis

The nutritional analysis of each diet model was produced in Excel through a set of simple calculations. Firstly, the calorific requirement for an average LH III adult, 2400kcal per day (see p.155), was divided according to the diet compositions in models 1 and 2. The shares of foodstuffs in these models were translated into daily calorific targets. For example, cereals comprise 75 percent of the diet composition in model 1, which equals 1800kcal. This means that a LH III individual should receive 1800kcal per day by eating cereals. In model 1a, 70 percent, *c.* 1260kcal, of this amount is received from barley, while in model 1b it is received from wheat.

By using these target figures, it was calculated how much of each foodstuff is needed per day in weight (grams or kilograms). For example, in diet model 1a, 60kcal is supposed to be received from meat. Of this, sheep contribute 30 percent, goats 30 percent, pigs 30 percent, and cattle 10 percent. Each meat type has slightly different calorific content, which is why each of them should be consumed in slightly different quantities. In some cases, these differences can be more notable: boiled goat meat has the lowest calorific value and *c.* 12.7 grams would have to be consumed per day, while of cooked lamb with a higher calorific content only *c.* 5.8 grams would have to be consumed per day to reach the daily calorific target. The annual consumption of each foodstuff was extrapolated from the daily consumption by multiplying the results by 365 (Figures 6.4-6.8).

In the next phase, the intake of three other nutritional components, proteins, carbohydrates, and fats, was calculated from the daily consumption of each foodstuff. In Table 6.10, the protein, fat and carbohydrate content of foodstuffs is expressed as grams per 100g. For example, barley contains *c.* 12.5 grams of protein per 100 grams (i.e. 12.5 percent). Thus, the daily share of barley in diet model 1a, *c.* 356 grams, would contain *c.* 44.5 grams of protein. While the recommended protein intake per person is given in grams by the FAO, carbohydrates and fats are usually expressed as kilocalories from the total daily energy intake. In order to better compare them with the FAO recommendations, the intake of carbohydrates and fat in each diet model was converted to kilocalories. For the conversion, FAO (2003, Table 3.1) offers conversion rates for fats (1 gram contains *c.* 9kcal) and carbohydrates (1 gram contains *c.* 4kcal).

In the final phase, the results of each diet model were compared to the recommended values of these four nutritional components. The results are presented in Table 6.11.

Annual food consumption

Figures 6.8 and 6.9 show the annual consumption of each food item in diet models 1a and 1b in kilograms. Overall, in both models, cereal consumption reaches *c.* 186kg annually, olive oil amounts to 5kg, and *c.*12 kg of legumes are consumed. Dairy, milk and cheese are consumed slightly more in model 1b, in which the share of cattle milk is increased. According to the USDA data,

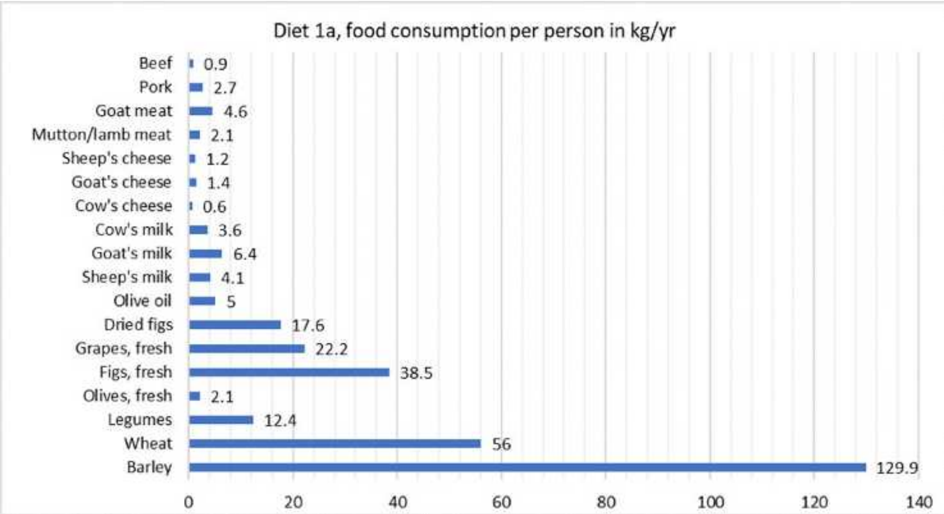

Figure 6.8. The annual consumption of different LBA foodstuffs per person in kilograms in diet model 1a.

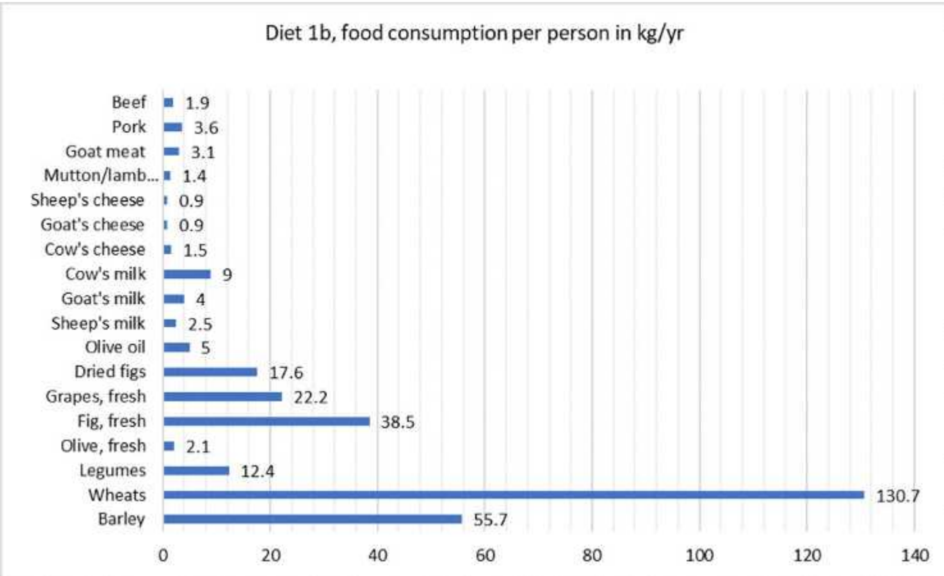

Figure 6.9. The annual consumption of different LBA foodstuffs per person in kilograms in diet model 1b.

cow milk contains less calories than the milk of sheep and goats which is why it should be consumed in higher quantities in order to reach the daily energy target in this model. Finally, in both models, *c.* 110kg of meat is consumed annually.

The share of fruit seems emphasized in diet models 1 a and 1b. This is partially caused by the exclusion of vegetables from the diet composition, and the separation of pulses as their own food item. In Gallant's model (1991), fruits and pulses together form 20-25 percent of the diet, while in Allbaugh's study of 1948 Cretan farmers show that vegetables, fruit and olives together formed *c.* 29 percent (132kg) of the diet composition. Therefore, the share of fruits, 10 percent, may not be completely misleading in a diet rich with cereals. However, the share of dried figs, *c.* 17.6 kg in these models, is much lower compared to the rations received by the Mycenaean palatial workers in Linear B sources (148.8kg figs and 182.4kg grain, as converted in pp.150). 150kg of dried figs would amount to *c.* 4.3 percent[28] of the annual calorific intake alone.

Oil consumption in this model is six times smaller compared to the consumption (*c.* 31kg) in post-WWII Crete (Allbaugh 1948). As Foxhall and Forbes (1982: 69) suggested, oil consumption in ancient Greece could have been notably lower since the energy intake was

[28] Annual calorific intake: 2400kcal x 365 = 876,000kcal; 150kg of figs = 37,350kcal.

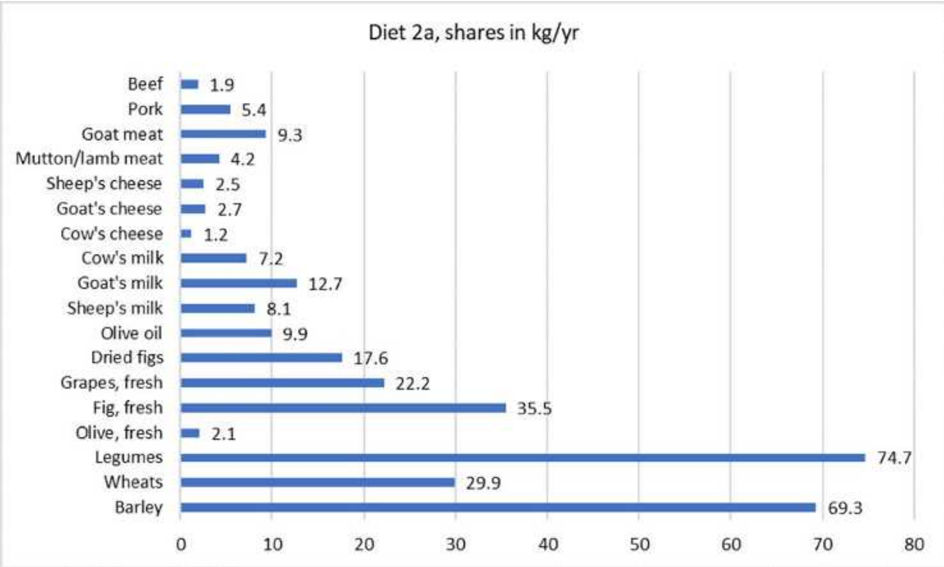

Figure 6.10. The annual consumption of different LBA foodstuffs in kilograms in diet model 2a.

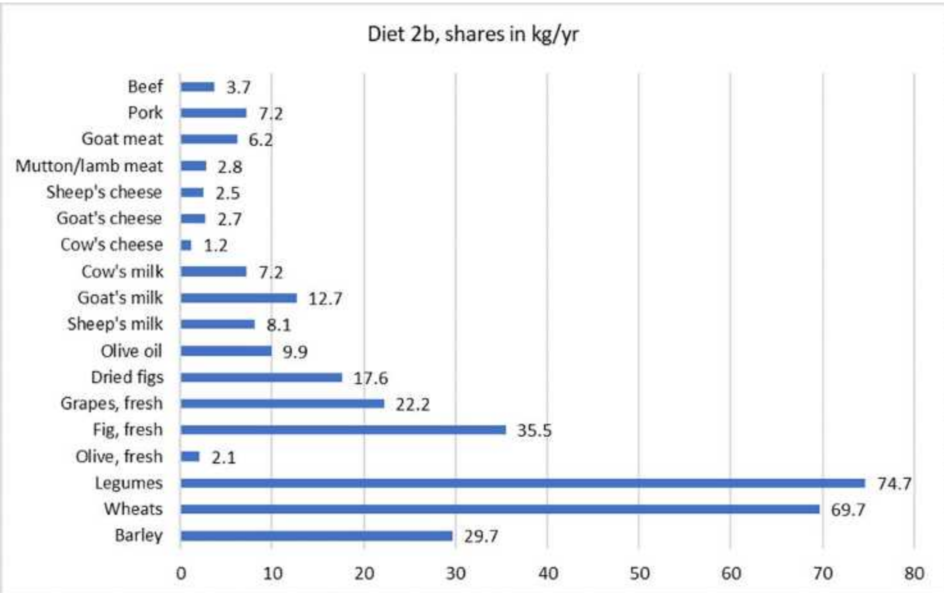

Figure 6.11. The annual consumption of different LBA foodstuffs in kilograms in diet model 2b.

replaced by high quantities of cereals. According to them, ancient Roman farm workers received some 0.539 litres of oil per month, which would amount to *c.* 6.5 litres of oil annually. It seems possible that oil was not consumed in extensive volumes by the LH III farmers either, especially since its availability may have been more restricted due to poor access to presses (see p.99 and p. 141).

Similar to oil, the consumption of dairy and meat are much lower in diet model 1 than in Allbaugh's study. In diet model 1a, milk and cheese together amount to *c.* 16.7kg, and in diet model 1b they amount to18.8kg, versus Crete's 34.5kg. The annual *c.* 10kg meat consumption in diet model 1 a and b is almost three times lower than the consumption in Crete, where *c.* 28kg was eaten in a year. Again, the considerably higher consumption of cereals balances out the calories otherwise received from animal products. Low amounts of dairy and meat may, however, have influenced the intake of other nutrients.

As expected, the shares of different foodstuffs appear more balanced in diet 2 (Figure 6.10 and 6.11). Cereals, which now contribute 40 percent of the total energy intake, amount to *c.* 99kg annually, while the second largest energy provider, legumes, adds up to *c.* 75kg. This may have some significant effects on the intake of protein and other nutrients. Fruit consumption stays the same in both models. However, oil consumption is doubled in diet model 2, now comprising *c.* 10kg annually. This quantity is still low compared to the post-WW Cretan oil use which was three times higher. Similarly, dairy consumption has increased notably, with *c.* 27kg milk being consumed in diet 2a and 28kg in 2b. Cheese is consumed the same amount in both sub-models, with 6.4kg, which is about two times the amount of diet model 1. Overall, the annual dairy consumption in diet model 2, *c.* 33-34kg, resembles that of post-WW Crete where it was *c.* 34.5kg (Allbauch 1953). Finally, meat consumption in diet models 2a (20.8kg) and 2b (19.9kg) also comes closer to the figures reported by Allbauch in Crete (28kg).

Protein, carbohydrates and fats in diet models 1 and 2

The calculated values of protein, carbohydrates, and fats in each diet model is compiled in Table 6.11. These figures are calculated from the nutritional values provided for each food item by the USDA (2019) database. The fat value represents the total amount of fats received from each food composition model, and it does not distinguish between distinct types of fatty acids, some of which can be considered as 'good' and some as 'bad' fats. The intake of each nutritional component is further related to their bioavailability in foodstuffs, and to the digestibility of food (see below for further discussion). Therefore, these nutritional values can only give general indications to the sustainability of the LH III diet. The values are calculated based on the daily consumption of food. The average daily consumption in weight and kilocalories is presented in appendices 11a and 11b.

The daily protein intake recommendation by WHO/FAO (2003: 56, Table 6) is clearly exceeded in diet models 1a and 1b, where 75 percent of the diet consists of cereals. However, variation between the two sub-models a and b is small, meaning that the emphasis on barley or on sheep and goat-based dairy and meat in model a does not significantly impact protein availability in comparison to increased wheat, and cattle and pig-based consumption in model b. The largest protein providers, cereals, simply overshadow the other food sources as protein providers, decreasing the role of other foodstuffs. In diet models 2a and 2b protein availability increases up to three times the recommended numbers. This is caused by the higher protein availability in pulses and their emphasized share in the sub-models.

There are indications that an extremely high protein intake can prevent the absorption of calcium (Hoffman and Falvo 2004: 124), and that receiving more than 50 percent of total dietary calories as protein (25 percent for pregnant females) is detrimental to health (Snodgrass and Leonard 2009: 227). The protein intake in all four diet sub-models remains under these thresholds.[29] Therefore, it is unlikely that excessive protein intake would have caused major health issues to the LH III Argive Plain population. Furthermore, protein is available in a large variety of food sources, but for dietary purposes it can be divided into two major groups, animal-based proteins and plant-based proteins. While animal proteins include all the important amino acids needed for human sustenance (for example for tissue growth), plant proteins usually lack some of these essential amino acids. This means that the bioavailability of amino acids is lower in plant food sources and therefore they are less available for the use of the human body. Since plants provide the main protein source in each diet model, the high levels of protein intake do not necessarily indicate an unhealthy situation. If plant protein arrives from various sources, the combination of proteins with different amino acid compositions can provide a sufficient intake without meat (Hoffman and Falvo 2004: 122).

Table 6.11. Nutrient intake in diet models 1a, 1b, 2a and 2b with WHO/FAO recommendations for intake of protein, carbohydrates and fats for an adult resembling the size and level of activity of a LH III person.

NUTRIENTS	Protein g/d	Carbohydrates kcal/d	Fats kcal/d
Recommendation	**34-39**	**1320-1800**	**360-840**
Diet 1a	88	1,816	307
Diet 1b	91	1,782	301
Diet 2a	110	1,548	476
Diet 2b	115	1,683	477

Fats received from food amount to *c.* 307kcal of the daily total in diet model 1a, and only *c.* 301kcal in diet model 1b. Both figures remain notably under the recommended range of 360-820kcal per day[30] (Table 6.11). Such low intake is mainly caused by the emphasized role of cereals and legumes, which contain low levels of fats. Fat provided by cereals and legumes comprises about 35 percent of the total fat intake in both sub-models. In addition, the consumption of olive oil and animal products is low. Oil, nevertheless, comprises *c.* 40 percent of the total fat intake. FAO (2010: 48-49) has recommended the minimum fat intake as 15 percent of the daily energy requirement. In the diet models 1a and b, only *c.*12.5 -12.7 percent is received. Since the LH III Argive Plain population likely had a highly active lifestyle, regularly receiving such low levels of fat might have had consequences. Receiving a low amount of fat can result in an insufficient intake

[29] FAO (2003) gives a conversion rate of *c.* 3 for protein to kilocalories (kcal). The maximum of 115 grams of protein in diet 2b would have provided *c.* 345kcal which is 14 percent of the daily calorific intake.

[30] The amount of fats is calculated with the FAO (2003) estimation (the so-called Atwater general factor system) that one gram of food of any type contains *c.* 9kcal of fat.

of other micronutrients such as fat-soluble vitamins (FAO 2010: 48-49). However, it is possible that other fat-containing foodstuffs, such as pig fat, were regularly stored and consumed in the LH III Argive Plain, as has been customary to traditional Mediterranean communities (Albarella *et al.* 2007, and pp.109-111 of this publication). In addition, seasonally consumed seafood and fish would have added important healthy fatty acids to the diet.

In diet models 2a and 2b, fat intake settles comfortably on the recommended range, comprising *c.* 476kcal in diet model 2a and 477kcal in diet model 2b. This comprises little less than 20 percent of the total daily energy requirement. Due to the assumed vigorously active lifestyle, the average diet could likely contain even more fat and remain sustainable. The higher intake is mainly caused by the increase of olive oil in the diet composition. In diet model 2, oil comprises *c.* 50 percent of the total. The increased consumption of animal products brings in about 27 percent of all fat intake.

The examples in diet models 1 and 2 indicate that oil would have had a particularly significant role in the LBA diet. If the suggestion of Foxhall and Forbes (1982: 69) about low oil consumption in ancient Greek societies is true, such plant-based and low-fat diets would have likely not been sustainable enough to support the population long-term without health-related issues.

As expected, carbohydrates are the largest energy source in models 1 and 2. In diet 1a and 1b, *c.* 75 percent of the daily energy requirement is received from them (Table 6.11). This amount is close to the upper limits of the sustainable range (WHO/FAO 2003: 56, Table 6). The highest intake of carbohydrates, 1816kcal, in diet 1a is caused by the emphasized role of barley in the diet composition. Barley contains considerably more carbohydrates than wheat, legumes and other foodstuffs in the LH III diet models.

In diet models 2a and 2b, the share of carbohydrates of the total energy is optimal, comprising *c.* 65-70 percent of the energy intake (Figure 6.10). Again, the difference between the two sub-models 2a and 2b seems to be related to the emphasis on barley in model a, and wheat in model b, the latter containing lower quantities of carbohydrates. Dried figs are another important carbohydrate source in each diet model. It is challenging to define their precise role in the LH III diet composition since, as mentioned earlier, the LBA textual references suggest a much higher fig consumption per person, whereas in most ethnographically recorded diet compositions figs are not separated from other fruit and vegetables.

Summary: comparison of the diet models

Comparison of the two models, diet model 1 which is based on the traditional idea of a cereal-rich diet composition with very little meat and dairy, and diet model 2 which is loosely based on Allbaugh's study of the traditional rural diet in Crete, shows that the decrease of cereals and increase of legumes mainly influence protein intake, but that in fat and carbohydrate intake olive oil and animal products play a more prominent role. Both diet models could have been able to maintain life. Since vitamin, mineral and other micronutrient intake is not explored here, it is further uncertain if these two models include aspects which could be harmful to human health. One such aspects could be an insufficient intake of calcium, further hindered by the increased consumption of carbohydrates in diet model 1. The main problem of diet model 1 is, however, the low levels of fat intake. For individuals who conduct heavy physical labour on a regular basis, this could turn out to be a problem in the long term. Nevertheless, since the figure here is not far from the lowest threshold of recommended fats intake, it can be assumed that diet model 1 still offered a relatively sustainable composition of foodstuffs for the average Mycenaean farmer.

In this sense, diet model 2 does not offer many surprises compared to diet model 1. It also remains within the thresholds of a sustainable, healthy diet composition, and in fact it offers a more balanced model in regard to fats and carbohydrates, which better reflects the current FAO and WHO recommendations. Since in this diet model the share of legumes is notably larger than in model 1, either intercropping or cereal-pulse rotation could have been introduced to achieve higher legume harvests. Legumes may have required watering which would have meant additional workload, with added difficulty of tending these crops if fields were located far away from the settlements. However, as suggested by Halstead (1987b: 82-83), watering could have been possible for small communities such as single farmsteads with limited amount of space and an effective labour unit formed by the farming household. In addition to labour costs related to the growing of legumes, their potential toxicity should be considered when Diet model 2 is examined for its nutirional qualities. Neurolathyrism can occur if some 30 percent or more of the diet consist of toxic pulses for a prolonged period of time (Heinrich and Hansen 2018: 126; Lambein *et al.* 2019: 824). In Diet Model 2, the share of all legumes is set high, to 30 percent. The model assumes, however, that not all of the legumes included in this share were naturally toxic species, but a wider variety of different legumes. In addition, processing, cooking and fermenting could have been used to reduce their harmfulness (Lambein *et al.* 2019:

824-825; Valamoti *et al.* 2011). Therefore, it is assumed that the volume of pulses in Diet model 2 did not result in health risks.

For the analysis of the agricultural potential, it is more important to acknowledge that both models could be able to sustain an average adult long-term. The differences between these two diet models may be more prominent in the analysis of the agricultural potential, where the variation in land use and crop yields is compared to the diet models. The results are presented next.

The agricultural potential of the Argive Plain

The following section presents the analysis of the agricultural potential of the LH III Argive Plain. The analysis is based on the variables discussed in detail in the beginning of this chapter. Table 6.12 presents an overview of these variables, and appendices 15 and 16 present the calculations for the agricultural potential in detail. The analysis consists of three main elements, 1) the total amount of land available for agriculture, 2) the land use in a given year, and 3) the amount of land needed to sustain one LH III person. These variables are compared to the personal needs for agricultural (i.e. food) products, which, in turn, are based on the LH III diet models introduced previously. The results are presented as ranges of people who could be sustained by the agricultural production that took place in the LH III Argive Plain region.

Of the variables in Table 6.12, the size of land suitable for agricultural use in the Argive Plain and its surroundings was estimated as *c.* 24-30,000ha (pp.134-138). The size varies according to whether the neighbouring areas, the plain of Asine and the valleys of Berbati, Nemea and Kleonai, as well as terraced slopes are included in the production area.

Land use rate indicates how much of the available land is in (agricultural) use simultaneously. It varies, for example, according to the cultivation techniques in use. In this study, it is assumed that cereals were cultivated in rotation with bare fallow years. This means that each year approximately half of the land preserved for them was left uncultivated. In order to include this fallow land in the model, the land needed to produce these crops for food is multiplied by 50 percent. Other LH III food crops, such as legumes and fruits were grown with intensive methods which did not include fallow years. It is acknowledged that both intensive and extensive methods were likely used simultaneously by Mycenaean communities. Fallowing could have been mainly used by communities residing in larger settlements, and cereal and legume rotation with regular manuring could have been used by rural communities. In the latter case, the 50 percent increase to land use would not be necessary, as all land would be under crop cultivation of some sort. Nevertheless, as the focus of this study is on the Argive Plain, and its LBA settlement pattern refers to dense habitation in several larger centres (pp.20-23 and 25-31), cereal cultivation with fallow years could have been the more general strategy of the local farmers who needed to commute longer distances to their fields.

Table 6.12. Variables used in the analysis of the agricultural potential of the Argive Plain, excluding land use models which are based on the diet models presented in section 6.2.3.

Agricultural land	Size/ha
Minimum land area (only the Argive Plain)	24,000
Adjacent valleys and plains in total	2800[31]
Terracing (maximum area of slopes)	3300[32]
Range of cultivation land	24,000-30,000
Yield	**kg/ha**
Cereals	400/600/800
Pulses	300/700
Olives	550/1110
Figs	2500
Other variables	**Multiplier**
Fallow rotation (only with cereals and legumes)	2
Crop losses (15%)	1.15
Seed ratio (1:10, only with cereals and legumes)	1.1

Besides fallow, the seed spared for reseeding is included in the model as an additional 'expense'. As discussed earlier (pp.140-141), a seed ratio of 1:10 is used in this study. Based on this, the production needs of cereal and legume crops are increased by 10 percent (i.e. with a multiplier of 1.1). Again, since tree crops are managed in a different way (i.e. by pruning), reseeding expenses are not calculated for them. Crop losses taking place during processing and storing of goods are further included in the calculations. A maximum of 15 percent loss is used in this study. This is estimated for all crops by increasing their production need by 15 percent (i.e. by using a multiplier of 1.15).

In the analysis that follows, the suitable land in the Argive Plain and its surroundings is used for agriculture with a 100 percent land use rate. In reality, the LH III land

[31] Adding Berbati Valley 544ha, Plain of Asine 1355ha, and Nemea and Kleonai Valleys 900ha totals 2799ha, which has been rounded to the closest hundred.

[32] Includes only the terraceable area within the 2.5km buffer zone from the largest LBA settlements, 3329ha.

use rate was probably much lower because space was preserved for other activities, and because geographical features such as ravines and rivers could not be used for agriculture. As explained before (pp.138-139), the land use rate in traditional Greek farms has usually been about 50 percent of the available plot. Nevertheless, by using a 100 percent land use rate, the analysis results in a maximum agricultural potential that can be considered as the ultimate limit for resource exploitation before such activities become unsustainable. This maximum range can be then re-examined by comparing it to figures produced by lower land use rates, and this way form a better understanding of the regional resources availability and sustainability.

The essential part of the analysis is the division of the total available land area by the land area that was needed for the food production of one LH III person. This 'personal land need' derives from the food composition models presented above. The average yield of each food item in the composition is divided by the requirement of this foodstuff by one person per year. The result is an area of land that was needed to produce the foodstuff for one person. These land areas are then added together as one 'subsistence plot'. In addition, the space needed for pasture for dairy and meat-producing animals is included in the analysis. Pasture sizes can be estimated from stocking rates which indicate how much space one animal of certain weight and milk production rate needs for its subsistence (pp.106-115 and Appendix 8). The resulting land area can be considered as a 'plot' needed by one LH III Argive Plain inhabitant for their animals.

After establishing the abovementioned variables, the analysis of the agricultural potential then evaluates how many of these personal plots fit into the total available agricultural space. The result is a number of people (i.e. a number of plots of specific size) who could be sustained by this land.

As with diet, the agricultural potential analysis results in two main models, 1 and 2, each with two sub-models, a and b. The variation between these models is based on the variation between the previously presented diet models. Therefore, only a very modest variation can be expected between models 1a and 1b, or 2a and 2b.

Individual production areas

First part of the analysis for the agricultural potential is to estimate how much food needed to be produced for the annual needs of one LH III individual. Following this estimate is the calculation of the size of the land are that was needed to produce each food item in the annual dietary model. In diet models 1a and 1b, 75 percent, or 1800kcal, of daily energy is received from cereals (Appendix 11a, Table 1). In model 1a, this means that one person should consume *c.* 356 grams of barley and 153 grams of wheat, in total *c.* 510 grams of cereals per day (Appendix 11a, Table 2). In model 1b, in which wheat consumption is higher than that of barley, the latter should be consumed *c.* 153 grams, and the first *c.* 358 grams, or combined *c.* 510.5 grams per day (Appendix 11a, Table 3). Differences in cereal consumption between the two submodels, a and b, are rather insignificant because the two cereal types have very similar calorific contents. Extrapolated to annual consumption one LH III Argive Plain inhabitant should have consumed cereals some 186kg per year to reach the 75 percent target of model 1 (including both submodels).

In order to turn this consumption figure into an annual production need and further into land area, one needs to consider crop losses and land use rate. First, the annual consumption of cereals is multiplied by 2 in order to include fallow land which is assumed to include around half of the available cereal cultivation area. Additional 1.1 multiplier is used with cereals to consider crop losses caused by reseeding. Finally, the 1.15 multiplier is used to include food losses in the final production target figure. In total, the annual production need of cereals is, thus, about 235kg per person in both submodels (Appendices 11a and b). Interestingly, this figure resembles the estimate of van Wersch for the LBA Messenia (pp.152-153). The same set of calculations is conducted with each foodstuff included in the LH III diet composition models.

Once the annual production need for each foodstuff is known, the space needed to produce them is calculated. Table 6.13 presents a summary of the results. When yields per hectare are divided by the annual production need of each foodstuff, one arrives at a figure which indicates the amount of land needed for one person's food production. The land areas estimated for each foodstuff are summed together to arrive at the total amount of land needed by one person, a kind of personal subsistence plot. According to model 1, one LH III person would have needed 0.7-1.34ha of land to produce all cereal, legume, and tree crops for their own use.

Additionally, in order to produce milk, cheese and meat for personal use, this person would need pasture space for their domestic animals. Assuming that one LBA cow weighing some 200-300kg produces 1000kg milk per year (pp.111-112 and Appendix 7) and according to model 1a one person needs 4.13kg of that milk per year, that person needs *c.* 0.00413 percent of that milk, and, thus, the cow. According to modern cattle stocking rates (1.6-3.1ha per animal, appx. 8), this 0.0413 percent of a cow needs *c.* 0.00656-0.01271ha (*c.* 65.6-127m^2) of pasture. Approximately ten units of milk are needed to produce one unit of cheese. As an example, the pasture space to produce cheese made of cow milk for one LH III person ranges from 0.01088 to 0.02108ha in submodel 1a.

The LBA sheep are estimated to have produced *c.* 60-100kg of milk annually, while goat milk yields were higher, some 100-300kg (Georgoudis *et al.* 2011). Calculated in a comparable way as with cattle, one LH III Argive Plain inhabitant needed 0.08985-0.22204ha of pasture for their sheep and goats in order to produce dairy for their personal use in sub-model 1a.

The 'cold dressed weight', the weight of a dead animal after the removal of skin, organs and other offal, varies according to how well the animal has been fed before slaughter. For cattle, Dahl and Hjort (1979: 165) give an average of 45-50 percent of the living weight. Here, it is assumed that a LBA cow could provide some 100-200kg of meat. In model 1a, one person's need for cattle meat (i.e. beef) is estimated as 0.93kg per year .[33] This low quantity is justified by the higher use of sheep and goat meat which was more easily accessible to the average farming household. To produce this quantity of meat, 0.00864-0.03317ha of pasture is needed. Thus, in model 1a, one LH III Argive Plain inhabitant would have needed 0.02608-0.06696ha of pasture for their cattle to produce dairy and meat.

The carcass weight of sheep and goats varies more than that of cattle (Dahl and Hjort 1979: 201-203) but on average it often stays between 40 and 50 percent of the animal's live weight. Here, 45 percent has been used and sheep and goats are assumed to produce *c.* 22kg of meat each. Calculated in a comparable way as with cattle, one LH III Argive Plain inhabitant would have needed 0.10554-0.14072ha of pasture for their sheep and goats in order to produce meat for their annual needs.

Finally, the cold dressed weight of pigs is estimated between 40 and 65kg. Unfortunately, there is not enough data to give reasonable estimations on pig pasture. What can be noted, however, is that one pig producing 52.5kg of meat (the mean between the weight range) could feed *c.* 16 people in model 1a and 12 people in 1b, storage losses included.

Using modern stocking rates to estimate the pasture needs of Bronze Age cattle, or any past domestic animals for that matter, is of course problematic (see pp.115-118). As concluded previously, modern stocking rates offer a database best available for estimating pasture space limitations in ancient agriculture. They can give an idea of what kind of land areas may have had to be excluded from the space reserved for cultivation and habitation for animals. There is a good possibility that modern thresholds for animal pastures are much higher than in the ancient past. Such variables will be considered in the final analysis of the agricultural potential, and its implications to the population that could be supported by the Argive Plain.

Table 6.13. 'Personal' plot sizes in sub-models 1a and 1b. The two rightmost columns of the table indicate, how much space (in ha) is required to produce a foodstuff for one person's annual dietary needs. Since most of the foodstuffs in the LBA dietary model yield varying volumes each year, spatial needs of each product are calculated from the minimum and maximum volumes of their respective yield ranges.

	Dietary need kg/yr	**Total production need kg/yr**	**With min. yields ha/pp[1]**	**With max. yields ha/pp**
Diet 1a				
Cereals	186	235	1.18	0.59
Legumes	12	16	0.05	0.02
Fruit crops	60	89	0.06	0.05
Olive oil	5	6	0.05	0.02
Land need, plant crops			**1.34**	**0.68**
Dairy	17	20	0.22	0.11
Meat	10	12	0.17	0.11
Land need, total			**1.77**	**0.87**
Diet 1b				
Cereals	186	236	1.18	0.59
Legumes	12	16	0.05	0.02
Fruit crops	60	89	0.06	0.05
Olive oil	5	6	0.05	0.02
Land need, plant crops			**1.34**	**0.68**
Dairy	19	21	0.22	0.1
Meat	10	11	0.16	0.09
Land need, total			**1.72**	**0.87**

Ultimately, when the pasture space required for dairy and meat-producing animals is added to the space needed for crop production in submodel 1a, a personal subsistence production plot of *c.* 0.87-1.77ha is created. This plot size equals to the space one LH III Argive Plain inhabitant would have needed to produce all the

[33] In the diet models presented in this chapter, human energy requirements that should be filled by meat are estimated from the calorific values of cooked meat, which loses weight when fat and liquids evaporate during the cooking process. Therefore, comparing the cold dressed weight of meat produced by animals with consumption needs based on cooked meat does not give the best comparison, but it is estimated to be sufficient for the purposes of this study.

[34] Pp = per person.

foodstuffs for their annual needs in diet model 1a. In submodel 1b, the maximum of this 'plot' size is slightly lower than in 1a, 0.87-1.72ha, due to an emphasis towards cattle as the dairy and meat provider.

In model 2a, the annual need for cereals by one LH III Argive Plain inhabitant is about 99kg, and when reseeding and losses are added, about 125kg (Table 6.14). Legumes are needed annually some 94kg when losses in cultivation and storage processes are counted for. In submodel 2b, these quantities vary only by a few hundred grams. In model 2a, the production targets of cereal, legume, and tree crops can be achieved on a 0.54-1.1ha of land plot. When animal pasture is added, the spatial needs to produce all items needed for personal sustenance is from 1.00 to 1.99ha in submodel 2a and 0.92-1.87ha in submodel 2b. Thus, although the spatial needs for crop cultivation alone are lower in model 2 than in model 1, emphasized by the much larger portion of legumes in the everyday diet, the increased need for animal products in model 2 results in a larger 'plot size' (Table 6.14).

Table 6.14. 'Personal' plot sizes in sub-models 2a and 2b, calculated in a similar way as in Table 6.13.

	Dietary need kg/yr	Total production need kg/yr	With min. yields ha/pp	With max. yields ha/pp
Diet 2a				
Cereals	99	125	0.63	0.31
Legumes	75	95	0.3	0.13
Fruit crops	77	89	0.06	0.05
Olive oil	10	11	0.1	0.05
Land need, plant crops			**1.1**	**0.54**
Dairy	34	40	0.45	0.23
Meat	21	24	0.35	0.23
Land need, total			**1.99**	**1.00**
Diet 2b				
Cereals	99	126	0.63	0.31
Legumes	75	94	0.1	0.04
Fruit crops	77	89	0.06	0.05
Olive oil	10	11	0.1	0.05
Land need, plant crops			**1.10**	**0.54**
Dairy	37	43	0.45	0.2
Meat	20	23	0.32	0.18
Land need, total			**1.87**	**0.92**

The newly established land areas needed to produce food for one LH III Argive Plain inhabitant can now be compared to the land that was available for agricultural use in the Argive Plain.

The agricultural potential in Model 1 (a and b)

Now that the individual plot sizes, the agricultural space needed to sustain one person in the LH III Argive Plain, have been established, they can be compared to the total agricultural space available in the region. This is done by simply dividing the available space by the individual 'plot' sizes. Table 6.16 (Table 6.15 functioning as the key to yield variation per crop type) presents a summary of the results of the agricultural potential of the Argive Plain in sub-models 1a and 1b, presented in detail in Appendix 15. The results in Table 6.16 are divided into two parts, the first including only the space needed to produce plant crops such as cereals, legumes and tree crops; and the second including the space needed for plant crops and animal pasture. This helps to clarify the effect of dairy and meat production on the regional resource availability.

If 75 percent of food production focuses on cereals but all crop yields are at the lowest end of the yield range, the LH III Argive Plain can sustain *c.* 17,600 people (rounded from submodels 1a and 1b). If cereal produces 600 kg/ha instead, the population size grows rapidly to *c.* 24,700 even if other crop yields remain at their lowest (Table 6.16). As expected, when 75 percent of the regular diet consists of cereals, their production success has a dramatic impact on the local agricultural potential.

When each crop type produces yields from the higher end of the range (i.e. cereals 600kg, legumes 700kg, olives 1100kg per hectare), the flat plain alone can provide sustenance for about 27,000 people. This figure represents the maximum population with 100 percent land use. As mentioned earlier, such land use rate is exaggerated and therefore the number of people inhabiting the LH III Argive Plain could have been significantly lower. If the highest yield for cereals, 800kg, is used the plain capacity reaches 34,700 people. Considering earlier estimates which resulted in a size of some 20,000 inhabitants of the LBA Argive Plain (see pp.36-38), such potential could have provided additional wealth to the local elites in the form of agricultural stock.

Animal pasture is not included in the estimates above. Pasture space preserved from cultivable land changes the agricultural potential of the plain rather notably. By using the lowest crop yields and the lowest milk and meat yields for the animals, one LH III Argive Plain inhabitant would need *c.* 1.77ha for their sustenance in model 1a. Consequently, the Argive Plain could only support *c.* 13,600 people. As a comparison, the total population of the LH III(B/C) Mycenae and Tiryns, has been previously estimated as 11,300 (pp.37-38). Therefore, because the agricultural potential represents the maximum population with a 100 percent land use, according to this model it is unlikely that the Argive Plain could even provide long-term sustenance to the inhabitants of the two largest settlements, let alone to other communities in the region. In fact, only by using the highest yields for plant crops (i.e. 600-800kg/ha for cereals) and animal products, the plain could provide sustenance to a population above 20,000 people (*c.* 21,900-27,900 in model 1a and *c.* 22,500-27,600 in model 1b). However, the potential pasture space on the surrounding slopes, terraced fields or in the neighbouring valleys have not been included in these estimates. The space for animals is directly taken from the space on the flat plain without defining whether it is actual areas reserved inclusively for grazing, or the fringes of settlements and wastelands which were not used for cultivation.

Since cereal cultivation is in this study considered mostly conducted with extensive cultivation methods (i.e. with fallowing), animal husbandry might have followed extensive strategies as well, especially when it was under palatial control. As exhibited earlier (pp.167-169), one LH III Argive Plain inhabitant needed less than one domestic animal to provide for their annual dairy and milk needs. Even in rural settlements, the few animals, for example goats, owned by a household could have been gathered together to a larger flock which grazed further away from cultivation areas. Nevertheless, including dairy and meat production into the production plots shows how different land use strategies might have made a substantial difference in the production potential of an area. Pasture space in this case can also be considered as the inclusion of 'wastelands' into the model. The size and share of unused land in the LBA land use strategy is otherwise a rather impossible evaluation to make. Such wasteland could have been put to use as animal pasture, left as such and used for example to collect wild plants and firewood, or serve as area for infrastructure. Thus, including pastureland in the calculations, even if these are calculated through modern standards that do not necessarily reflect well the LBA pastural strategies, serves as the inclusion of any land that was not used for crop cultivation.

As expected, including the adjacent valleys of Berbati and Nemea and the plain surrounding Asine increases the agricultural potential of the Argive Plain region. The increase remains rather constant, *c.* 2000-4000 people in total in both models 1a and 1b when only plant crop production is examined. This range appears low considering that the resources of these areas were possibly exploited by other Argive Plain settlements such as Mycenae (pp.31-36 and Wright 2004). Presumably, each area needed to provide subsistence for its own inhabitants first. When animal pasture is included in the subsistence plot sizes, the increase to the production potential provided by the three adjacent areas is modest, from 1500 to 3000 people, only some 500 people per area. Such figures seem especially low considering that each area was already inhabited by a small population.

Terracing could have perhaps offered a more sustainable option for the intensification of agricultural production and consequently increasing the agricultural potential of the LH III Argive Plain. Earlier in this publication (pp.69-74), terrace use was examined through modern and historical examples. Based on a variety of evidence, terrace land use rate, the rate that describes how much of the slopes that could be terraced were actually put to use, was defined as 30-90 percent. The results of the agricultural potential of terraced areas reflect this range so that the possible impact of terraced fields to the Argive Plain agricultural production can be better observed. Thus, if 30 percent of those Argive Plain slopes that could be terraced were used for crop cultivation which only produced the lowest range of yields, additional 750 people could be supported in submodel 1a. When higher yields are used, a maximum of fewer than 1500 people could be added to the production potential of the Argive Plain. If terraced slopes were also used as animal pasture, they could only support some 500-1100 people with a 30-percent use rate. When terrace usage rate is increased to 90 percent, even with the lowest yields (without pasture) they could support 2000 people. With maximum yields, little more than 4000 people, the population of a large palatial settlement, could be supported by terraced fields only. In fact, terraced fields used to their maximum could have provided a similar addition to the regional agricultural potential than the adjacent valleys and plains together. Since only the space on slopes in the vicinity (max. 2.5km radius) of the major Argive Plain settlements was included in this analysis, the true potential of terracing could have been much higher if slopes further away were also used.

Although it seems less likely that as much as 90 percent of suitable slopes were actually terraced and used for agriculture, the figures above exhibit how terracing could have had a significant role in the LH III Argive Plain subsistence economy. For example, Mycenae could have benefitted from extensive terraced field systems, since it lacks space for flat fields in its immediate surroundings. Furthermore, the calculations above do not include terraces built on the slopes of the adjacent valleys such as Berbati and Nemea. If terracing was used here, the production capacity of these valleys and consequently the wider Argive Plain region could have increased notably. It must be noted, however, that terraced fields do not always produce as well as unlevelled fields. The issues are related to soil consistency and depth, natural watering, erosion, and to the maintenance costs of the fields. Nevertheless, even the minimum subsistence potential of 500-1000 people could have been beneficial to the smaller farming communities located on the edges of the Argive Plain.

Since the LH III administrations had an interest in producing specific food crops, namely olive and figs, it is worthwhile to examine the production potential of terraced slopes for the production of these foodstuffs alone, even if traditionally olive and other tree crops have been grown less systematically (pp.97-99). Table 6.16 (to which Table 6.15 is a key) presents a summary of models 1a and 1b. Some 0.025-0.052ha of space is needed to produce olive oil for one person in submodels 1a and 1b (see also Table 6.13). If terraced fields were only used to grow olive trees, oil could have been produced for 18,800-63,800 people even when the lowest olive yield is used. With higher yields and land use, olive oil production would have been sufficient to provide well above the domestic use of the LH III Argive Plain population. This would have created possibilities to export oil, to use it for industries, or to use it as a form of payment for the palatial workers. Some 0.02ha of land was needed to produce dried figs for the domestic use of one LH III Argive Plain inhabitant in submodels 1a and 1b. If only terraced fields were used to grow fig trees, dried figs could have been produced for 46,000-156,400 people. These numbers are considerably higher than the population numbers created by the previous calculations of the agricultural potential. In models 1a and 1b, dried figs are only consumed *c.* 17.6kg per year, and after storage and other losses, their annual production need would have been *c.* 20.2kg per person. If, however, figs were given 150kg per annum to the palatial workers, their production according to model 1 would have supported about 6200-21,100 people. This is still a considerable amount and it means there could have been enough fruit to support the members of several palatial staffs, for example those of Mycenae, Tiryns and Midea. Fresh fruit produced on terraced fields would have been available in much higher quantities, enough for palatial payments and for domestic use alike, but only for a short period of time every year. Contrary to this, the evidence of the LBA tree cropping being systematic and taking place on orchards, especially those places on terraced fields, can be described as absent. Some level of human-aided tree cropping, or at least monitored extensive harvesting of wild trees must have been needed, however, to ensure a reliable storage of fruit for palatial use if orchards were not a strategy adopted by the Mycenaean communities. Nevertheless, the calculations here reflect the potential of the Argive Plain to produce such bulk in a relatively small area.

All in all, if all available agricultural space, including the Argive Plain, its adjacent valleys and the plain surrounding Asine, and the terraced fields with a 100 percent land use, is used for crop production and animal husbandry, the Argive Plain could have supported a population of *c.* 17,000-34,600 according models 1a and 1b. If all this space was only used for plant crops, the agricultural potential could have ranged from *c.* 21,600-44,100. The first range seems to reflect better the LBA land use. Even if animals were managed mostly in larger communal herds and therefore grazed outside the plain, pasture for cattle and pigs, unused space, or space for infrastructure would have been taken from the potential agricultural space, and therefore it seems impossible that the agricultural land use rate ever reached 100 percent.

The agricultural potential in Model 2 (a and b)

The Argive Plain agricultural potential was also calculated by following the diet composition in model

Table 6.15. Key to yield models in the agricultural potential tables 6.20 and 6.21. All figures represent yields in kilograms.

Yield variation in kg	Cereals	Legumes	Olives	Figs	Grapes	Dried figs	Olive oil	Cattle milk	Sheep milk	Goat milk	Cattle meat	Sheep/ goat meat	Pig meat
Minimum yields	400	300	550	2500	1800	960	110	1000	60	100	100	22	40
Medium yields 1	600	300	550	2500	1800	960	110	1000	60	100	100	22	40
Medium yields 2	600	700	1100	2500	4400	960	230	1000	100	300	200	22	65
Maximum yields	800	700	1100	2500	4400	960	230	1000	100	300	200	22	65

Table 6.16. Summary of the agricultural potential of the LH III Argive Plain, its neighbouring areas, the Nemea and Berbati Valleys and the plain of Asine, and the minimum and maximum areas for terraced fields according to models 1a and 1b. The figures in bold represent population numbers, the main results of the analysis.

Model 1a		**Plant crops**				**Plant crops and pasture**			
		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Definition	Land area/ha	1.39	1.0	0.9	0.7	1.82	1.43	1.12	0.92
Plain	24,000	**17,286**	**24,087**	**26,699**	**34,139**	**13,200**	**16,829**	**21,421**	**25,961**
Plain and adjacent areas	26,800	**19,303**	**26,897**	**29,814**	**38,122**	**14,740**	**18,792**	**23,921**	**28,990**
Plain and terraces, 30% land use	25,000	**18,006**	**25,090**	**27,812**	**35,562**	**13,750**	**17,530**	**22,314**	**27,043**
Plain and terraces, 100 % land use	27,300	**19,663**	**27,399**	**30,370**	**38,834**	**15,015**	**19,143**	**24,367**	**29,530**
All areas	30,000	**21,608**	**30,108**	**33,374**	**42,674**	**16,500**	**21,036**	**26,777**	**32,451**
Model 1b		**Plant crops**				**Plant crops and pasture**			
		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Definition	Land area/ha	1.39	1.0	0.9	0.7	1.77	1.38	1.09	0.89
Plain	24,000	**17,253**	**24,043**	**26,646**	**34,076**	**13,524**	**17,370**	**22,060**	**26,920**
Plain and adjacent areas	26,800	**19,265**	**26,848**	**29,755**	**38,052**	**15,102**	**19,396**	**24,634**	**30,061**
Plain and terraces, 30% land use	26,900	**19,337**	**26,949**	**29,866**	**38,194**	**15,158**	**19,468**	**24,726**	**30,173**
Plain and terraces, 100 % land use	27,300	**19,625**	**27,349**	**30,310**	**38,762**	**15,384**	**19,758**	**25,094**	**30,622**
All areas	30,000	**21,566**	**30,054**	**33,307**	**42,595**	**16,905**	**21,712**	**27,575**	**33,650**

2. In model 2, the share of pulses was increased to 30 percent and the share of cereals lowered to 40 percent to better resemble the diets of the modern rural Greek populations, and to give legumes, which are abundantly found in archaeobotanical samples, a more prominent role. The calculations of the agricultural potential follow the same procedure as in model 1: the production requirement per crop and per person is calculated first, and then turned into need for land. The agricultural land provided by the Argive Plain region is then divided by the area of this 'personal subsistence plot'. Detailed results of these calculations are presented in Appendix 16. Table 6.17 below presents a summary of the agricultural potential of submodels 2a and 2b.

In both submodels 2a and 2b, the individual plot size needed to produce all necessary plant crops for one person ranges between 0.54 and 1.10ha. The size varies according to the size of crop yields - the higher the yields, the smaller the space needed for one's sustenance. With the lowest possible yields (cereals 400kg/ha, legumes 300kg/ha, and olives 550kg/ha) the Argive Plain could have supported some 21,800 people. Variation between the two sub-models is small because only the shares of wheat and barley are changed. If higher crop yields (600kg/ha for cereals, 700kg/ha for legumes, 1100kg/ha for olives) are used, the plain could support *c.* 37,000 people, and with the maximum cereal yield of 800kg/ha, the annual potential of the area could be as high as 44,000 people. Such figures indicate that the Argive Plain could have supported a large population and potentially also produced additional stock of agricultural products that could have been used to gain wealth. However, these estimates are based on 100 percent land use of the plain's agricultural area, and do not include space that was preserved for pasture or for other purposes. The impact of legumes on the agricultural potential, if grown in bulk in garden-type conditions without fallow years, is substantial nevertheless.

When animal pasture is included in model 2, the agricultural potential of the Argive Plain is notably lower than in model 1, *c.* 12,000-24,000 people in

Table 6.17. Summary of the agricultural potential of the LH III Argive Plain, its neighbouring areas, the Nemea and Berbati Valleys and the plain of Asine, and the minimum and maximum areas for terraced fields according to models 2a and 2b. The figures in bold represent population numbers, the main results of the analysis.

Model 2a		**Plant crops**				**Plant crops and pasture**			
		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Definition	Land area/ha	1.42	1.21	0.78	0.68	2.31	2.1	1.24	1.14
Plain	24,000	**16,946**	**19,881**	**30,655**	**35,383**	**10,402**	**11,439**	**19,348**	**21,130**
Plain and adjacent areas	26,800	**18,923**	**22,200**	**34,232**	**39,511**	**11,616**	**12,773**	**21,605**	**23,595**
Plain and terraces, 30 % land use	25,000	**17,652**	**20,709**	**31,933**	**36,857**	**10,835**	**11,915**	**20,154**	**22,010**
Plain and terraces, 100 % land use	27,300	**19,276**	**22,614**	**34,870**	**40,248**	**11,832**	**13,012**	**22,008**	**24,035**
All areas	30,000	**21,182**	**24,851**	**38,319**	**44,228**	**13,003**	**14,298**	**24,185**	**26,412**
Model 2b		**Plant crops**				**Plant crops and pasture**			
		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Definition	Land area/ha	1.42	1.21	0.78	0.68	2.18	1.97	1.16	1.05
Plain	24,000	**16,928**	**19,866**	**30,620**	**35,341**	**10,988**	**12,155**	**20,724**	**22,783**
Plain and adjacent areas	26,800	**18,903**	**22,184**	**34,192**	**39,464**	**12,270**	**13,573**	**23,141**	**25,441**
Plain and terraces, 30 % land use	25,000	**17,633**	**20,694**	**31,896**	**36,813**	**11,446**	**12,662**	**21,587**	**23,733**
Plain and terraces, 100 % land use	27,300	**19,255**	**22,597**	**34,830**	**40,200**	**12,499**	**13,827**	**23,573**	**25,916**
All areas	30,000	**21,160**	**24,832**	**38,275**	**44,176**	**13,735**	**15,194**	**25,905**	**28,479**

submodel 2a, and *c.* 12,800-26,100 in submodel 2b. The variation between the two submodels 2a and 2b is caused by the increased role of cattle as dairy and meat providers in model b. Although cattle as large animals require larger pasture space than sheep and goats, they also produce considerably higher quantities of meat and milk than the smaller ovicaprids. Therefore, a relatively small number of cows are needed to produce the food needed in the model. This is reflected by a lower need for pasture space in submodel 2b. Compared to model 1, however, the agricultural potential including pasture is considerably lower in model 2. The increased dietary need for animal products in sub-models 2a and 2b results in an increase in 'personal plot' sizes.

As with model 1, the space provided by the adjacent valleys of Berbati and Nemea, as well as the plain surrounding the settlement of Asine, increases the agricultural potential of the Argive Plain region in a rather modest way in model 2. If only crop cultivation is examined, these areas could support an additional *c.* 2500-5100 people, not far from the figures in model 1. With animal pasture included only *c.* 1400-3000 people could be supported, thus a little less than in model 1. According to these numbers, very little additional stock could be produced in the neighbouring areas after they provided subsistence to their own communities.

Again, it seems that terraces could provide a feasible option for increasing the agricultural potential in the Argive Plain and its adjacent areas in model 2. If terraces were used for mixed crop cultivation with a maximum land use and yields, the production potential of the Argive Plain could be as high as 50,000 people in submodels 2a and 2b. Such a high figure suggests that terraces could have had great potential to either provide additional cultivation space during population increase, or respond to specific agricultural demands such as tree crop production. If terraced slopes also include animal pasture, the increase to the agricultural potential is modest, only a few thousand people depending on crop yields and land use rate.

Finally, the specific needs of the Mycenaean palatial centres to produce food crops can also be examined for sub-models 2a and 2b: by focusing olive cultivation only on terraced fields, a wide range of people, between 9400 and 58,700, could have been sustained by olive oil (calculated with 30-90 percent terrace use). Dried figs would have sustained a minimum of *c.* 46,000 people. With the 150kg annual consumption mentioned in Linear B sources, dried figs could have been available for *c.* 5400-18,400 people, thus enough for the rations of a large group of palatial employees, but probably not sufficient for domestic use.

Finally, with a 100 percent land use and by combining together all agricultural space available, including terraces and neighbouring valleys, the LH III Argive Plain could have sustained 27,200-46,300 people with crop cultivation alone, and 15,100-29,300 people if animal pasture was included in the model. As with model 1, the latter seems more appropriate as the Argive Plain population range since the pasture space included in the model can also be seen to reflect a lower land use rate in general. Nevertheless, the population range is smaller than in model 1. Therefore, it seems that model 1 with its higher cereal production target produces a better agricultural potential for the LH III Argive Plain. The following section continues by making some concluding remarks of the results of the two models.

Summary: Comparing Models 1 and 2 of the Argive Plain agricultural potential

The agricultural potential between the two main models 1 and 2 exhibits rather modest differences mainly on the higher end of the range. In model 1 (Table 6.16 and Appendix 15), the maximum agricultural potential of the LH III Argive Plain when it is only used for crop cultivation, and when low and medium yields are used, varies between *c.* 17 and 33,000 people. The variation is strongly dependent on the size of cereal yields. On average, model 1 could support some 25,000 people. Model 2 produces a slightly higher agricultural potential than model 1, from 22 to 37,000 people, on average 28,500 people (Table 6.17 and Appendix 16). The higher agricultural potential is caused by the higher the result of an increased production of legumes. These food plants produce slightly better median yields than cereals, but foremost they were probably grown with more intensive strategies than cereal crops, and therefore required less cultivation space. In the lower end of the range, the results of two models vary by some 5000 people. This figure could resemble the population size of a large Mycenaean palatial centre, or a substantial rural population inhabiting several small sites scattered around the Argive Plain. The evidence of such sites is not abundant, but still present (see pp.20-23 and 30-31). In the higher end, the difference is 10,000 people, a notable number if translated into numbers of inhabitants.

This variation shows clearly how crop-growing strategies (intensive versus extensive) could have a notable impact on regional production potential. It seems to emphasize the superiority of intensive methods over extensive. However, in this model legume cultivation is considered to take place as annual cropping because legumes were grown in garden-type conditions and because they do not deplete soil in the same way cereals do. In truth, legume cultivation areas and practices could have changed by year depending on weather predictions and the potential success of cereals (in which case cereals would have been planted in greater amounts). In addition, their 30-percent share in the LBA diet model might be exaggerated, as their share in Mediterranean diets today (from 2010) rarely reaches beyond 2.5kg annually (FAOSTAT Food balance sheets 2023) instead of the modelled 75kg. Examined together, the figures in models 1 and 2 give support to the idea that the Argive Plain could sustain a population not much more than 20-30,000 people. Since these estimates are based on 100 percent land use, this population would likely be closer to the low end of the range.

When pasture space is not included in the models, the agricultural potential fluctuates according to yield sizes. Erdkamp (2022: 416) has recently emphasized how farmers in the past were used to the variability of the weather in the Mediterranean, and able to adjust farming strategies accordingly. This resulted in modest variation in yields. Therefore, farming methods and commute between settlements and fields can be considered to influence more in agricultural production potential. The maximum cereal yield of 800kg used in the analysis is perhaps too high for the type of agriculture practised in the LH III, however. Small farming communities cultivating the land around their dwellings could have possibly been able to achieve such yields by using intensive methods such as manuring, regular weeding, and hand irrigation. However, inhabitants of major settlements likely had to settle for less labour-intensive methods and consequently lower yields. The inhabitants of Mycenae, in particular, would have had to tolerate greater distances since land suitable for fields is not abundant in the surroundings of the site. Similarly, the areas for the palatial production of cereals could have been located further away.

Reaching high cereal yields of 800kg/ha would have likely been challenging without manuring. Manure was only scarcely available if animals were taken to graze elsewhere, as is expected in the agricultural potential models which produce the highest numbers of supportable people. Therefore, the insecurities related to the potential to achieve cereal yields as high as 800kg per hectare suggest that the use of lower yields is more secure. However, since the share of legumes was notably higher in model 2, the dependency on manure in producing sufficient harvests to complete the dietary plan might have been smaller. Therefore, model 2 could have more potential to provide a sustainable subsistence strategy, and a slightly more nutritionally balanced diet (pp.159-166) for the LH III inhabitants. However, the increased production of dairy and meat in model 2, would have increased the need for pasture space and labour force to manage the animals, making model 2 perhaps less manageable than model 1.

Modelling the space preserved for animal pasture might better reflect the true agricultural potential of the LH III Argive Plain in both models. When only the space needed for crop cultivation is considered, both models assume that every area suitable for crop cultivation was used for this purpose. Still, natural formations such as ravines and rivers limited cultivation area, but are not included in the mapping of the fertile plain in this study. Infrastructure such as settlements, roads and cemeteries would have taken some space away from fields and pasture. Cultural conventions such as places of ritual, memory, or burial, may have limited use of certain areas for economic purposes. Finally, land use and ownership agreements (pp.15-18), likely had a major impact on land use also in the Argive Plain. Due to this, land that was fertile may have been left uncultivated (see Erdkamp 2022 for further discussion about biases related to carrying capacity analysis). Therefore, even if the additional space needed for animals in these models would have not been used for pasture, it can reflect the space left uncultivated for other reasons. In model 1, the agricultural potential including pasture ranges between *c.* 14 and 22,000 people with medium yields of 400-600kg/ha for cereals. In model 2, the plain alone could support only some 12-23,000 people when pasture areas are included. Based on these figures, it would seem, therefore, that the traditional model 1 with emphasis on cereals provides a higher agricultural potential and would, therefore, provide a better subsistence economic model for the LH III Argive Plain.

The calculations do not consider the potential reduction of pasture area by growing fodder. Animals could have also been kept slightly under their normal weight in times when they were not used for heavy labour (p. 141). Fodder provided to working oxen was the probable way to secure their sufficient maintenance during seasons of heavy labour. Fodder preserved from early sprung legumes, or from crop-processing waste were mentioned as a common means of providing food to domestic animals in the traditional Greek self-sustained farms (p. 141). Although fodder could have reduced pasture space, since less fresh vegetation had to be searched for in the close environment, eventually the economic costs may have increased, as space had to be preserved for fodder crops, reducing other cultivation space. In addition, legumes would have been the probable fodder crops and would probably have needed additional watering. Therefore, fodder cultivation is not included in the agricultural potential models of this study, and it is assumed instead that processing waste and letting animals graze on stubble could provide enough for common household animals. The palatial centres may have used some of the space dedicated to palatial production for fodder cultivation for their most valued draft animals such as oxen. Fodder could have also been acquired from farmers who had a good year of legume of cereal production.

In model 1, the low consumption of animal products results in low fat intake which can be unsustainable in the long term. In model 2 where meat and dairy consumption is higher, the intake of fats is ideal. However, this would likely mean that a relatively large number of animals was maintained in the Argive Plain. Considering the limited space in the plain, there was likely not enough space for both, crop cultivation and large-scale animal husbandry practiced by the local elites. In submodel 2a, one person needs *c.* 0.34-0.65ha of pasture for all cattle that produces dairy and meat for their needs. If the LH III Argive Plain population was some 12,000-21,700 people as the submodel indicates, the pasture for cattle alone would have taken *c.* 420-1410ha of the total agricultural space (space per person defined in Appendix 13). In submodel 2b, the space taken by cattle pasture is higher, *c.* 440-1530ha. Riverbeds and the surroundings of lake Lerna could have provided pasture areas for cattle. However, lake Lerna and the coastline of the Argos Bay only comprise *c.* 1000 hectares (pp.63-65). Stubble fields after harvest was likely one of the few feasible options to find enough pasture space for these large animals if springs, streams or wells could be located close enough to satisfy their water consumption needs.

Only the main food-providing domestic species have been included in the analysis of this book. Other large animals such as horses and asses were also present in the Mycenaean Argive Plain (pp.114-115), and needed to be managed in their specific pastures. In addition, neither the dietary analyses nor the agricultural potential calculated in this study include estimates of the milk provided to new-born calves by their mothers. Instead, all milk provided by cattle and other farm animals is projected only for human use. This is an unlikely scenario and indicates that the number of cattle, and consequently the size of pasture, was probably significantly higher than predicted. Dahl and Hjort (1976: 142-161) point out that usually less than 50 percent of the females of a cattle herd are lactating simultaneously, and that milk yields are strongly related to seasonality and weather changes (e.g. to rainfall and the availability of water). In consequence, the pasture needs of cattle in model 2, especially in submodel 2b, could have exceeded the environmental potential of the LH III Argive Plain. Only in submodel 1a, cattle pasture would stay below 1000 hectares (230-880ha, Appendix 13). Following the model, it is also likely that sheep and goats had a more prominent role in dairy and meat production for average farming families.

Besides dairy and meat producing cattle, large working animals such as oxen, mentioned in Linear B texts, inhabited the Mycenaean palatial landscapes, likely also the LH III Argive Plain. Large-scale construction projects of Cyclopean walls, tholos and chamber tombs, and the local highways would have required animal power. Oxen were expensive to maintain due to their size. Therefore, it is suggested that they were mainly kept by the local palatial centres. An ox would have been bigger in size and weight than a cow. Based on historical and modern data (pp.111-112), the size of a LBA ox was estimated at *c.* 400kg, and a cow between 190 and 375kg. If the cattle stocking rate, 0.2 LU (Live Units, 1 LU equalling to 600kg) per ha is used, one 400kg ox would have needed *c.* 3.3ha of pasture space for its sustenance. The work effort of 25 oxen yokes that were used by Brysbaert (2013: 79) as an example to move the massive Tiryns 'bathroom floor' stone block to its place in the middle of the palatial complex would have needed 165 hectares of pasture, almost seven times the size of the LH III settlement itself. As this task could be performed in a short amount of time, the citadel may have not had the need to maintain so many oxen. Work animals could have been loaned from elsewhere (see also detailed estimates of oxen use in the construction of the Tiryns Lower Citadel wall in Brysbaert 2015). Nevertheless, during heavy labour seasons, large animals used for power would have needed extra attention, and they would have been kept close to the habitation. Finding hundreds of hectares of open pasture for Tiryns, Mycenae, or any of the other major settlements must have been challenging. Fodder was probably necessary to provide additional sustenance to these animals so that pasture size could be reduced. Outside the heavy labour season, lending oxen to local communities located further away could have released some of the maintenance and logistical burden.

Keeping at least a handful of sheep per household would have been a sustainable dairy and meat producing strategy, since, as with cattle, not all milk could be wielded for human use. In model 1a, one adult person would need *c.* 0.23-0.33 sheep to produce milk, cheese and meat for their own use for a full year. The entire LH III Argive Plain population in model 1a, ranging from *c.* 13,600 to 21,900, would have needed 3100-7200 sheep for their sustenance and 1200-3000ha of pasture for their animals. For goats, the need for pasture space was higher, some 1900-5300ha. Because milk had to be saved for the younglings, the need for sheep and goat pasture was probably higher than what is expressed in the model of the agricultural potential. Since these caprids have flexible requirements for their pasture, grazing could have taken place on hillslopes, mountains, and unused spaces on the fringes of the settlements as in recent history. Therefore, it is plausible that even thousands of hectares could have been provided for the use of these animals in the wider Argive Plain region.

The scarce data available suggest that some pigs were kept in pens and fattened for slaughter by feeding them cereal (waste), household waste, and standing water. In addition, faunal remains indicate the preference to produce larger litters towards the end of the LH III (pp.110-111). If the number of pigs in the Argive Plain was high, for example hundreds of heads, it would seem more likely that they were gathered in larger herds which were left to roam free in designated areas at least part of the year, as has been accustomed in the southern Mediterranean. In this case, less evidence would have remained of these herds which were maintained and culled outside the large settlements. The same likely applies to the other domestic species too.

So far, the discussion has only concerned the Argive Plain as limited to the flat plain area of *c.* 24,000 hectares. Including the adjacent areas, the Berbati, Nemea, Kleonai valleys and the plain of Asine, to the Argive Plain production area does not increase its agricultural potential notably. These areas had to firstly support their own populations before any additional stock could be produced for the inhabitants of the Argive Plain settlements (see further discussion on pp.180-182). Therefore, they cannot be considered as a major source of wealth for Mycenae or for other settlements of the LH III Argive Plain. However, if one or many of these areas were harnessed for special use, for example if flocks of sheep were taken to the Berbati Valley or to the Limnes highlands, or if slopes were cultivated for olive trees, some form of wealth-collection could have been enabled. This might have improved the long-term sustenance of the wider Argive Plain region, as less space for tree crops or pasture had to be spared from the plain itself. Road systems located in the vicinity to the major Argive Plain settlements guaranteed that the maintenance and harvesting of crops growing on terraces further away could be completed effectively.

Focusing on orchard cultivation in specific locations would have, however, meant that the organization of crop production and landownership was carefully orchestrated by the palatial administrations. In the models presented above, agricultural production concentrated on small subsistence plots, each providing food for one person. It is rather simple to extrapolate these to household plots, or to spatial needs for larger units such as hamlets or villages with a few dozen inhabitants. However, if the production of one or more food items was controlled by a Mycenaean administration, the availability of these products could have been more complicated to regular farmers, and their production should not be included in the subsistence plot calculations. Such a different system of maintenance, control, and sharing of profits does not have to imply only palatial production, but it can also refer to a system in which households and villages maintained joined orchards, with each household owning a few trees, but the agricultural work tasks being conducted together. There is no evidence of such systems being used, could have been a labour-effective way for small communities to organize their agricultural production.

There is fragility included in the calculations of the agricultural potential. When one variable is changed, the number of people sustained by a land area may change by thousands. In the end, since all the variables presented in the sections above are based on estimations and averages, the results of neither model 1 nor model 2 should be considered to represent absolute ranges of sustainability, nor they should be taken as population numbers. Besides these ranges, the value of this analysis relies on the establishment of more general relationships between land use, diet, crop yields, and the Mycenaean societal organisation.

Chapter 7

Reconstructing Mycenaean agriculture and subsistence

The final chapter of this book discusses the results of the agricultural potential of the LH III Argive Plain in relation to some key questions about the spatial, political, and demographic aspects of the area. The study resulted in a range of 18,000-22,000 people in model 1,[1] and 18,000-29,000 in model 2.[2] Combining these two ranges, an average population of *c.* 22,000 could have been sustained by the LH III Argive Plain (excluding neighbouring areas and terracing). The following sections examine how well these figures compare to previous population estimates given for the plain and its settlements, as well as to the production figures presented in the Linear B texts.

The Argive Plain as an agricultural space

Two major spatial aspects influence the LH III Argive Plain agricultural potential, political geography and land use organization, and the exploitation of terraces and areas adjacent to the plain. The following section presents some ideas on these aspects and their potential influence on the sustainability of the area. Terracing is examined in more detail in the third section of this chapter (pp.185-188).

Individual subsistence areas

Part of the process of formulating the agricultural potential of the Argive Plain was to create subsistence land areas, types of 'personal plots' which measure the size of land needed to grow food for one person's annual requirements. Very few previous estimates of the sizes of subsistence plots for prehistoric and ancient households have been given. Although the "personal plots" are not meant to be taken as indicatives of the LH III Argive Plain farm sizes, they can, nevertheless, be compared with the previous plot size estimates to see if potential differences in size can reveal something about the sustainability of agriculture on an individual and household level. Plot sizes can also be used to examine specific crop and animal husbandry methods, since different farming activities have different spatial needs.

Based on ethnographic and historical evidence of farm sizes and labour costs of harvesting in the Mediterranean, Halstead (1995a: 15–17) suggests that a prehistoric family would have needed 2-3 hectares of intensively cultivated land for their subsistence. This land area could have supported a farming household of about four to five members, since, according to him, it could have produced some 1500kg of cereal. The subsistence land area for one prehistoric farmer would have, thus, been 0.75 hectares at most. Halstead (1995a: 15-17) argues that a prehistoric farming family would not have had access to large animals such as oxen, which could have been used in ploughing or other heavy agricultural tasks. Therefore, plot sizes reflected the capability of the family to perform each crop management task manually. If the family had draft animals at their disposal, for example a pair of oxen, the size of the farm should have exceeded 3-4 hectares so that keeping these animals was worthwhile economically. Five hectares could have produced considerable surplus for the family. In more recent contexts, up to 10 hectares of land have been managed with the help of oxen (Halstead 1995: 15-16).

For similar reasons to Halstead, Boserup (1965: 37) suggests that two hectares were a suitable size for a plot that was ploughed by a draft animal in pre-industrial societies. According to her, fodder cultivation that was necessary to support the large animals caused additional labour costs, which reduced the size of the subsistence land.

Based on census records and previous estimates of grain production in Classical Attica, Garnsey (1998: 191) suggested that about 10,000 hoplites (military personnel) could have been the landowners of Attica, and that they owned about 10 percent of the land available. This would have created plot sizes of 2.4 hectares per hoplite, which with bi-annual fallow would have meant subsistence land sizes of about 4.8 hectares. Garnsey did not think every Classical farmer practiced bi-annual fallow, and even with 4.8-hectare plot sizes, he argues that the hoplites, and thus the Attican population, would have been below their subsistence level. As a solution he (Garnsey 1998: 192-194) argues that more land was, in fact, under cultivation than previously assumed. However, grain imports supported about half of the Attican population.

Traditional land use in Greece was discussed in Chapter 6. Plot sizes of rural communities in the Peloponnese varied on a similar scale to the examples above, depending on which agricultural strategies

[1] This range is formed by the rounded averages of models 1a and 1b, calculated with 400-600kg/ha cereal yields, lower figures reflecting production potential with pasture included, and higher figures production without pasture.
[2] Calculated in a similar way as with model 1.

the farms practiced. Farms which focused on crop cultivation and mixed agriculture had mean plot sizes of 2-3ha (Forbes 1982: 84, Figure 9; van Wersch 1972: 177-78), while farms with emphasis on sheep and goat herding were on average 7ha (Koster 1977: 248).

Linear B texts mention land area sizes on a few occasions, but the units used by the Mycenaean palatial administrations cannot be translated to modern units. According to some interpretations, land areas in these texts vary from small plots of, perhaps, 1 ha to very large units which could indicate the ownership of some 30ha of land (pp.10-15).

According to sub-models 1a and 1b of this study, one LH III person needed a plot of 0.88-1.34ha to grow all crops included in their diet composition. Pasture for the animals which produced them dairy and meat would increase this range to 1.1-1.77ha. In sub-model 2b, which provided the lowest land requirement, the plot ranged from 0.65 to 1.1ha with crop cultivation, and 1-1.99ha with pasture provided from one's own land. For a household of 4-6 members (pp.36-38), the maximum subsistence area could have been 3.52-8.04ha according to sub-model 1a, and the smallest 2.6-6.6ha according to 2b. Most of these estimates exceed Halstead's suggestion of 2-3 hectares for prehistoric households (except the 4 people household and 600kg cereal yields of model 2b), and Boserup's 2 hectares for 'ancient' households. They reflect better the land use of farms managed with the help of oxen or other large animals in the historical examples.

If only cereal land is extracted from the agricultural potential models, one LH III person needed 0.78-1.18ha according to model 1 and 0.42-0.63ha according to model 2 to produce wheat and barley for their personal need, creating household land requirements of 3.12-7.08ha (model 1) or 1.68-3.78ha (model 2). Of these, the latter compares quite well with the previously mentioned 2-3 hectares household requirement. None of the models compare well to Boserup's estimate of a 2-hectare household plot.

Halstead's estimates only consider the production of one or two crops on an intensively managed plot. According to him (1995a:15–17), an intensive cultivation regime included cereal-pulse rotation and weeding, and possibly manuring and hand-watering. If the 2-3 hectares were producing *c.* 1500kg of cereals, the productivity per hectare would have been some 500-750kg, which is not far from the cereal yield estimates of the present study (pp.144-149). Annual consumption would have been *c.* 300kg per household member, which is a rather high figure compared to the diet models in this study, however (pp.159-165). If prehistoric farms used crop rotation as their main cultivation strategy, it means that probably close to half of the arable land was cultivated with legumes each year. Therefore, either the 1500kg per hectare yield should then refer to the joint production of cereals and legumes, in which case the dietary composition of a prehistoric farmer could have resembled diet model 2, or an additional 2-3 hectares was dedicated t legumes besides the already mentioned cereal-land. Either way, more land was probably needed even in the intensive cultivation regime to secure annual subsistence based on a variety of products besides cereals (and legumes).

The subsistence spaces included in this study should not be considered directly as plot sizes for the LH III Argive Plain inhabitants, but seen to reflect the space needed to produce the bulk variety of food items sustaining one individual for one year. Comparing the land area sizes yielded in this study to those given for prehistoric farms indicate that 2-3 hectares for a household were not enough for their full sustenance if prehistoric diets consisted mostly of cereals. As mentioned above, for similar reasons, Garnsey (1998) had difficulty with establishing secure subsistence for rural landowners in Classical Attica with small plot sizes. Hansen and Allen (2011: 885) also arrive at similar conclusions with the agricultural potential of Early Helladic Tsoungiza: the available *c.* 150ha of land was not enough to support a population of about 200 people with a (wheat) grain consumption of 300kg a year, if fallow years had to be included. As a solution, they (Hansen and Allen 2011: 885) suggest that more barley than wheat was cultivated in the hopes of more reliable harvests, or that little or no land was left for fallow. However, they do not give an alternative strategy to fallowing to prevent soil exhaustion. With cereal-pulse rotation and bi-annual fallow, roughly similar share of land would be growing cereals, while the other half would be sown with legumes or left uncultivated. Only if cereal yields were consistently at or above 800kg, which is the maximum used in this study, and annual consumption of cereals was considerably lower than 300kg, for example, the *c.* 180kg used in this study, 2-3ha of land (or rather half of it) could have produced enough cereal for the use of an entire household. Even so, the prehistoric farmers as well as the LH III Argive Plain inhabitants included other foodstuffs in their diet compositions, and these needed to be produced somewhere.

Although fragmentary, there is some evidence that could refer to collective farming and communal activities in the LH III period. Firstly, Linear B texts dealing with land division and land use seem to refer to communally owned or controlled land. People belonging to a *damoi* might have committed collective tasks (for example animal herding, tree cropping, or terrace cultivation, although there is no direct evidence of such tasks in the texts) on their land. Mycenaean palaces also considered the *damoi* as collective units (Deger-Jalkotzy 1983: 91-95; see also pp.14-15). Secondly, some texts suggest one individual could own several smaller plots located away from each other (Uchitel 2007; see also pp.18-20) Such land division could refer to a land ownership system where hired labourers worked the land of a wealthier landowner. In either case, it seems that the Mycenaean land use system was gradually moving away from single farmsteads and household-owned subsistence plots. Thirdly, the settlement pattern of the Argive Plain shows the clustering of small sites within close distances of large settlements. In addition, several small and medium-sized settlements have been located across the plain in more remote locations. Even though many sites are represented by cemeteries rather than houses or other domestic structures, their remote location that cannot be connected with already known sites suggests a settlement was located nearby. Sizes of the cemeteries, and the few domestic structures located, suggest the presence of small to medium-sized communities in the LBA Argive Plain.

Within these villages and hamlets, animal pasture, and the cultivation of certain crops, such as olives or figs, could have been arranged on communal land, as has been customary in recent historical rural communities in Greece (pp.54-56). Individual households could have focused on cereal and legume production on their own plots, and maintained small gardens. With this land use plan, the plot managed by a household could have been smaller. Nevertheless, the space needed for one person's sustenance would not have declined with different land use organization. In addition, the LH III Argive Plain rural household may have needed to produce beyond their own subsistence if additional production targets or taxes were placed upon them by the palatial centres. This would have increased the need for arable land on, or in the close vicinity of the Argive Plain settlements.

The figures above bring forth an important notion about subsistence plot size estimates for ancient farms: there need to be more considerations of the production of other foodstuffs besides cereals in dietary and land use models. Furthermore, prevalent agricultural strategies such as fallowing, cereal-pulse rotation, and grazing need to be better incorporated into plot-size estimates. One can be quite confident that the average LH III Argive Plain household consumed olive oil, fruits, and animal products besides their usual cereal and legume meals. Since there is hardly any evidence of the import of these products from other areas in the LH III period (as opposed to Classical Greece), the space to grow them had to be provided by the Argive Plain or its nearby areas. Therefore, using plot sizes based on the production of one main food item to estimate regional carrying capacities, or household or individual subsistence can be heavily biased. Calculating subsistence spaces for a variety of crops and pasture gives a much better understanding of the space needed for food production, and, consequently, of the agricultural potential.

The adjacent valleys as production areas

The nearby valleys and plateaus could have been included in the agricultural area of the Argive Plain to ease the subsistence needs of at least some of its settlement populations. The total amount of production land provided by these areas (*c.* 2800ha, see pp.63-65 and) was little more than ten percent of the total area of the Argive Plain. Before providing agricultural stock to Mycenae or any of the Argive Plain settlements, these areas had to provide livelihood to their own inhabitants. Comparing the available population estimates (pp.36-38), and the agricultural potential of each of these areas (Table 7.1) it seems they could have not provided major production support beyond their potential.

Amounting to *c.* 1355ha (p.64), the plain north of Asine would have been sufficient to support a small occupation of the two LH settlements located close to the coast (p. 29). According to model 1, the plain could sustain a minimum of 770 and a maximum of 1270 people (rounded from sub-models 1a and 1b) if crops and pasture were both provided by the flat plain land (Table 7.1). According to model 2, the agricultural potential of the area would have been about 680-1300 with pasture included (Table 7.2). As with the Argive Plain itself, there is reason to assume that the figures including pasture reflect the actual land use in the area better (see pp.174-178). If the population of Asine was *c.* 300-00 people, as Bintliff (2019) suggested, the plain could have had a small potential for surplus production.

The Berbati Valley was likely able to support only a small population habiting its central settlement Mastos and the small farmsteads around it (p. 29). If cultivated down to its maximum capacity, the valley bottom could support from 300 to 500 people with pasture in model 1, and less than 550 people in model 2 (Tables 7.1 and 7.2). The population of Mastos has been estimated as *c.* 300-900 in the LH III by Bintliff (2019), and if Wright's high population density estimate is used, up to 1300 people (p. 29). As such, the area would have been at its maximum production capacity and therefore incapable of providing notable surplus production to any of the Argive Plain centres. It is also possible that the valley slopes were heavily terraced in the LH III. Terraces could have been used for pasture, or mixed agricultural activities, for example for olive trees, as has been common more recently (Schallin 1996: 172). The uplands of Limnes, east of Berbati, could have been used as summer pastureland, perhaps releasing some more space for cultivation activities. With crop cultivation

Table 7.1. The agricultural potential of the neighbouring valleys and plains to the LH III Argive Plain in model 1, calculated in a similar fashion to the agricultural potential of the Argive Plain (tables 6.16 and 6.17), and expressed as population numbers.

Valleys and the plain of Asine									
Model 1a		CROPS				CROPS AND ANIMALS			
		Low yields	Medium yields 1	Medium yields 2	High yields	Low yields	Medium yields 1	Medium yields 2	High yields
Region	Size/ha	1.3359	0.9439	0.8765	0.6806	1.76562	1.37362	1.09797	0.90207
Asine	1355	1014	1436	1546	1990.89	767	986	1234	1502
Berbati	544	407	576	621	799.29	308	396	495	603
Nemea and Kleonai	900	674	953	1027	1322.36	510	655	820	998
Model 1b		CROPS				CROPS + ANIMALS			
		Low yields	Medium yields 1	Medium yields 2	High yields	Low yields	Medium yields 1	Medium yields 2	High yields
Land area	ha/ person	1.3386	0.9457	0.8783	0.6819	1.72212	1.32922	1.06553	0.86913
Asine	1355	1012	1433	1543	1987	787	1019	1272	1559
Berbati	544	406	575	619	798	316	409	511	626
Nemea and Kleonai	900	672	952	1025	1320	523	677	845	1036

Table 7.2. The agricultural potential of the neighbouring valleys and plains to the LH III Argive Plain in model 2, calculated in a similar fashion to the agricultural potential of the Argive Plain (tables 6.6 and 6.7), and expressed as population numbers.

Valleys and the plain of Asine									
Model 2a		**CROPS**				**CROPS AND ANIMALS**			
		Low yields	Medium yields 1	Medium yields 2	High yields	Low yields	Medium yields 1	Medium yields 2	High yields
Region	Size/ha	**1.1015**	**0.8924**	**0.648**	**0.5434**	**1.99244**	**1.78334**	**1.10554**	**1.00094**
Asine	1355	1230	1518	2091	2493.56	680	760	1226	1354
Berbati	544	494	610	840	1001.1	273	305	492	543
Nemea and Kleonai	900	817	1009	1389	1656.24	452	505	814	899
Model 2b		**CROPS**				**CROPS AND ANIMALS**			
		Low yields	Medium yields 1	Medium yields 2	High yields	Low yields	Medium yields 1	Medium yields 2	High yields
Region	Size/ha	1.103	**0.8933**	**0.6489**	**0.5442**	**1.86937**	**1.65967**	**1.0232**	**0.9185**
Asine	1355	1228	1517	2088	2490	725	816	1324	1475
Berbati	544	493	609	838	1000	291	328	532	592
Nemea and Kleonai	900	816	1008	1387	1654	481	542	880	980

only, the agricultural potential of Berbati valley may have been some 400-800 in model 1500-1000 in model 2. Overall, the valley food production potential stayed below 1000 people without terracing.

Finally, according to model 1, the Nemea and Kleonai valleys could provide subsistence to some 500 to a maximum of 1000 people with crop cultivation and pasture (Table 7.1). In model 2, this number is slightly smaller, around 450 to 850 people. The central settlement of the LH III Nemea Valley, Tsoungiza, had a considerable size of 7.5ha, which suggests it also had a considerable population. Up to 1500 if Whitelaw's 200 people/ha site density is used. Bintliff gives the site a more modest range from *c.* 300 to 900 people (p.37). Nevertheless, it would have been challenging for the local population to be involved with major surplus production beyond their own subsistence needs. As such, the area seems to have been at its subsistence limits. The valley slopes could have been terraced, but there is no evidence of LH III terracing in this area, nor is terracing extensively displayed in the current landscape. However, the gently sloping hill land may have provided more space for fields, if sharper slopes above the 6 degrees used in this study could be used without terracing.

In conclusion, all three areas connected to LH III Mycenae and the Argive Plain in previous research were able to sustain a small population inhabiting the more sizeable central settlements of Asine, Mastos and Tsoungiza as well as the farmsteads and hamlets scattered around the valley slopes and bottoms. Populations beyond a few hundred individuals would have had difficulties to sustain themselves in these areas, unless their surface was exhaustively turned into fields and the slopes around them were terraced to provide more agricultural space. Thus, it seems unlikely any of these areas could have helped Mycenae, Tiryns or any of the major Argive Plain settlements to expand subsistence production due the population increase in the LH III period, or to produce crops that could be used to obtain wealth and power by the Argive Plain elites. Therefore, the growth of Mycenae as the largest and wealthiest amongst the Argive Plain settlements cannot be attributed to its ability to exploit its neighbouring regions. These areas might have been important to Mycenae in another way, for example in as locations for specialized production, or workforce aid and political alliances, for example as intermediates towards the areas in the north.

The agricultural potential and the Argive Plain population estimates

The results of this study provide the maximum agricultural potential of the Argive Plain and its closest neighbouring valleys. This potential serves as a measure of the region's capacity to sustain a population primarily reliant on farming, and intentionally reshaping their environment for agricultural, economic, cultural, and other purposes. It is important to note that the figures resulting from this analysis represent a range of people sustained by the environment and should not be confused with actual population counts. It is likely that the population of the Argive Plain was lower than its agricultural potential. Nevertheless, it is interesting to compare these results with the previously presented population numbers of the area. This comparison allows for an analysis of regional sustainability, adaptation, and resilience within the Late Bronze Age communities. It also provides an opportunity to critically assess the functionality of the agricultural potential analysis and the methodologies employed in estimating populations in the LBA Aegean context. The following section examines some of these estimates to see how the results of this study align with the established population numbers of the LH III Argive Plain and the broader Bronze Age Aegean.

Unfortunately, population estimates for the LH III Argive Plain are rare, as are estimates for single-site populations (pp.36-38). The few existing estimates for regional and site populations might be biased, due to the scarcity of reference data in the LBA chronological context. Typically, population estimates for Mycenaean or Minoan sites rely on the population densities of large, urban settlements in the Eastern Mediterranean. Notably absent are methods for estimating the population of smaller sites and the rural countryside in the LBA Aegean context.

As presented in the beginning of this work (pp.36-38), only a few population estimates have been given for LH III Argive Plain sites. The most frequently used of these are 6400 people for Mycenae (French 2002; Bennet 2007, 2013) based on a population density estimate of 200 ppl/ha by Whitelaw (2001), and 4900 people for Tiryns (Brysbaert 2013) based on the shotgun method by Hansen (2006), in which the Classical Greek poleis and hinterlands are given population densities based on archaeological material, and adjusted with urbanization rates (a method relatively similar to Whitelaw's 2001 contribution). In total, the population of Mycenae and Tiryns alone would give the Argive Plain an 'urban' population of 11,300.

No estimations for the LH III population of Midea, Nafplion, or Argos have been presented outside Bintliff's suggestion, according to which Midea, Nafplion, Berbati, Asine and Tsoungiza also had a population density of 200 people/ha. Furthermore, hardly any estimates exist of the sizes of these sites. Again, Bintliff is one of the few who has suggested a size of 3 -8ha to each of the major sites (listed above) besides Mycenae or Tiryns. Considering that the most notable settlements in the adjacent valleys, Mastos and Tsoungiza, may have been 7.5ha each (pp.29-30, Table 3.3), it could be suggested that the other notable sites of the Argive Plain were at least equally large. If, thus, 8ha is used for the minimum size of the settlements of Midea, Argos and Nafplion and 200 people/ha is used as the population density for these sites, the LH III Argive Plain would have had an urban population of at least 16,000.[3] Adding other sites with characteristics indicating a notable status and size, namely, the Argive Heraion (p. 28), Kokla (p. 30), and Magoula (p. 30), the Argive Plain could have had an urban population exceeding 20,000 people.

The Argive Plain regional population in the LH III period has been previously studied mainly by Bintliff (e.g.

[3] Including Mycenae 6400; Tiryns 4900; Argos, Nafplion and Midea 1600 each.

1977, 1989, 2020). In his PhD dissertation he (Bintliff, 1977: 697, Table 4) used site catchment analysis to divide the Argive Plain into 19 districts, and then defined a carrying capacity for each cell.[4] He suggested that the total (urban) population of the plain reached *c.* 24,000 people. In his most recent paper (2020), Bintliff established a settlement population density of 112-200 people/ha for the Argive Plain sites. According to him (2020: 19), the urban population of the region totalled *c.* 14,700 people. He further suggested a high urbanization rate of 75-85 percent for the region in the LH III. When the urban population of the plain was multiplied by the urbanization rate, a total regional population of 17,300-19,600 people was achieved. In his other papers (1985; 1989: 96 Figure 8; 2002: 158; 2015a: 16 Figure 2), Bintliff has revised these calculations on several occasions by using recalibrated grain yields and by suggesting that the Bronze Age agriculture was 2-3 times lower than in the Classical and Iron Ages.

Despite of the challenges related to Bintliff's methods (it is not always clear where he gets his estimates of crop yields, site sizes, or settlement patterns) his final estimations of the total population of the Argive Plain, especially those of the 2020 paper, compare quite well with the agricultural potential established in the present study. Here, however, it is suggested that the urbanization level of the plain could have been lower than what Bintliff assumes. Hansen (2006: 66-70) has summarised urbanization rates given to areas in Classical Greece, which generally vary between 60 and 80 percent. It seems unlikely that the rate of urbanization would have been higher in the LBA than in the Classical period when urban settlements were notably larger (see Hansen 2006), although, admittedly, sub-regionally this could still hold true.

Survey data from the Mycenaean mainland points to the presence of small rural settlements, villages, hamlets, and farmsteads in the LH III landscapes (see pp.23-25 for an overview of surveys). Such a settlement pattern is well-attested also in the LBA Messenia, where, besides the Pylian palace, other rather large 'urbanized' sites have been recovered alongside hundreds of known and yet to be recovered small settlements (Davis *et al.* 1997). In their population estimate for the LH III Pylian state, Carothers and McDonald (1979) argued that the settlement pattern of modern Messenia could be used as an analogy to the Mycenaean period, and that the previously suggested LH III settlement population density of 300 people/ha by Renfrew (1972) was too high. The MME survey data indicated that the mean size of a Late Helladic settlement in the area was 1.53 ha and that compared to the population densities of modern villages in the area, it would have hosted a population of *c.* 140 people. Based on this correlation, and the mean LH III site sizes in the survey data, the authors proposed a LH III settlement population density of only 91 people/ha (Carothers and McDonald 1979: 435).

Since the estimates of Carothers and McDonald are based on the MME survey data, their population density cannot be directly used for the Argive Plain, where the lack of surveys has resulted in a scarcity of data on LH III site sizes. Undoubtedly, the Argive Plain could have represented a different type of settlement pattern. With its multiple fortified settlements, it already deviated from the Pylian region and other Mycenaean core areas. However, when survey results from the surroundings of Mycenae and the site data from the plain area are examined together, it seems the LH III Argive Plain did encompass many small settlements, if not as densely distributed. This statement relies on the assumption that those sites where only burials have been found, do in fact reflect the presence of a nearby settlement. Similar to the wider surroundings of Mycenae, independent small settlements could have clustered around other large settlements. Settlements located on the flat plain, as shown by the few examples of Chania, Lerna, Myloi, and possibly Dalamanara. A settlement pattern with small sites distributed outside the urban centres would have resulted in a lower urbanization level, while increasing the total regional population size. Carothers and McDonald (1979: 450) argued that the main workforce of the Mycenaean society lived in dispersed communities outside but within close distance of the palatial centres, and that only the elite and administrative members inhabited the centres themselves. The Argive Plain could have been organized in a comparable way.

If more people did, in fact, live outside the major settlements of the plain in small communities, the total regional population could have been higher than 20,000, which does not compare well with the area's agricultural potential. The lowest agricultural potential of this study resulted in a little over 13,500 people in model 1, and some 12,000 in model 2. In this scenario, the total population of Mycenae and Tiryns would have arrived close at the maximum agricultural potential of the plain. Such a situation would have quickly become unsustainable. However, since the major plain settlements show growth in infrastructure, wealth, and size until the crisis at the end of the LH IIIB2 period, there does not seem to be any major unsustainability related to food production (see pp.25-31 for further details).

[4] The carrying capacities varied from 2250 for Mycenae, 1875 for Tiryns, Prosymna, Berbati, Asine, Midea, and 3000 for Argos, to a few hundred to a thousand people for Lerna and the other unnamed districts (Bintliff 1977: 697, table 4).

Only with the highest crop yields (e.g. cereals 800kg/ha) and including pasture or unused space, food production could have supported some 26-27,000 people according to model 1. Even this may not have been enough to sustain both the populations of the large, densely inhabited settlements, and the smaller population of the rural areas. For example, if five major Argive Plain settlements (Mycenae, Tiryns, Midea, Argos and Nafplion) give a combined population of 16,000 (as suggested earlier), and this is considered to represent the 60 percent urbanization level given to Classical Greece by Hansen (2006: 66-70), the total population of the LH III Argive Plain would have been *c.* 26,700. With such a high population level, the region would have continuously met its maximum potential. Since the spatial limitations of the Argive Plain are rather constant, and the evidence of crop yields, in particular cereals, quite unanimously suggests that yields would have stayed low to medium in mostly non-fertilized and rainfed environments, it can be suggested that the high populations of the major Mycenaean settlements of the Argive Plain can be exposed to further scrutiny.

Another attempt to tackle the regional population can be made by examining the relation between non-agricultural and agricultural workforce, even if this exercise remains rather speculative. Farmers likely formed a large share of the population, and it is possible that individuals who mainly engaged in other activities (e.g. crafters, military and religious personnel) also grew food plants or tended animals part-time or on a small scale. Either way, farming communities had the responsibility for the subsistence production of their households, but possibly also for those members of the society who were needed in other activities, for example in the palatial administrations.

Establishing any estimates of the number of farmers in Mycenaean society is challenging when textual records give no indications to their presence or importance. A few efforts for the LBA Aegean world have been made, however. Chadwick (1972: 112-13) used the number of smiths in the Pylos Linear B texts to extrapolate the size of the total workforce. He further added three family members for each worker, arriving at a population of *c.* 800-1200 for an average-sized 'city' in the Pylos area (see Table 7.3). Hiller (1988) suggested that one third, *c.* 1300 people, of the workers in Pylos tablets were dependent labourers sustained by the palace. Padgham (2014: 100-101) defined the agricultural workforce or the LBA Cyprus as *c.* 73 percent of the total workforce, and about 43 percent of the total population.

In the Argive Plain, the labour force needed for the large-scale construction programs in the LH IIIB Tiryns have been examined through Linear B evidence and labour cost studies by Brysbaert (2013, 2015). She calculates (2015: 100-101) that to build the circa 350-metre Lower Citadel wall at Tiryns during the LH IIIB, it could have taken some three years for an average of a little under 100 men (82 during year 1, 96 during year 2, and 109 during year 3), together with five teams of oxen. These figures represent the minimum number of workforces needed and can vary depending on external factors such as the intensity of agricultural and other subsistence work in a given year, and on the timeframe given for each construction task (quarrying, transporting, hauling up the blocks etc.). In her earlier paper (2013: 82), Brysbaert speculates that if the population of Tiryns was some 4900 people,[5] these 100 men could represent 8 percent of the active workforce of the citadel. Boswinkel (2021) suggests that a construction workforce of 200-500 people was needed to put up the massive LH IIIB fortification walls of Mycenae. This construction workforce comprised no more than 10 percent of the total workforce.

As an exercise, these figures can be added up by following Abrams (1987: 493) who, in relation to the Classical Maya population at Copan, Honduras, suggested that the local the labour pool comprised 20-33 percent of the total population. Thus, if the special workforce of 200-500 for wall construction at Mycenae represented a maximum of 10 percent of the local labour pool, the size of the pool was a maximum of 5000 people, and the total population up to 25,000 people (Table 7.3). Same construction workers could have been used at multiple Argive Plain sites, which is shy this number does not necessarily represent the population of Mycenae, but the wider region (Timonen and Brysbaert 2021).

Estimates of the LH III Argive Plain workforce can be presented by following the suggestions of Boswinkel (2021; after DeLaine 1997), Abrams (1989) and Padgham (2014). If the agricultural potential presented in models 1a and b of this study, 13,600-27,600[6] indicates the maximum number of people inhabiting the Argive Plain, 20-33 percent of this population would total some 2700-9100 workers. Farmers, but also craftsmen and -women, builders, and other workers would have been included in this group. Following Padgham, the workforce of the Argive Plain would have been *c.* 9900-20,0100 people (73 percent of the total population), and the agricultural workforce 4300-8700 people (43 percent of the total workforce). This range could be seen to represent the population inhabiting rural areas.

[5] The number is based on the estimated site size of 24.5ha (after Shermeldine 2008a) extrapolated by Brysbaert by using Hansen's (2006) shotgun method.

[6] I take the lowest population number of model 1a calculated for plant crops and pasture, 13,600 people, and the highest population number of 1b, 27,600 people, calculated for crops and pasture. The latter is *c.* 1000 people less than the maximum in model 1a. See further figures in Table 6.16.

Table 7.3. Extrapolation of special workforce (smiths and constructors) of the total workforce, and the amount of workforce of the total population discussed in the text.

Reference	Special workforce	% of total workforce	Workforce of total population %	Settlement population	Location
Boswinkel 2021	200-500	< 10	20-33[7]	6000-25,000	Mycenae
Brysbaert 2013	100	8	25.5	4900	Tiryns
Chadwick 1972	-	-	24.5-36.8	800-1200	'City' in Pylos
Hiller 1988	-	33	(4000 people)	-	Dependent workers in Pylos
Padgham 2014	(farmers)	73	43	-	LBA Cyprus

Viewed from various perspectives, the LH III Argive Plain agricultural potential seems low compared to its previously estimated settlement population sizes. Since no environment can live at its maximum capacity for extended periods, the number of people actually residing in the area should have been notably lower than the maximum to maintain status quo. In their study of Greek and Roman cities in the Classical period, Hanson and Ortman (2017: 319, Table 6) showed that only cities with a size considerably larger than 150 ha had a population density of 200 ppl/ha or more. Two of the smallest cities in their reference list, Pompeii with 60 ha, and Herculaneum with 20ha had population densities of 115-166 people/ha. In this light, the high densities of 200-300 people/ha presented for the LBA palatial centres in general (e.g. Branigan 2001; Renfrew 1972; Whitelaw 2000, 2001) seem rather high.

More data on the presence (or absence) of small settlements in the Argive Plain is needed to further examine the Argive Plain urbanization rate in the LH III period. Further examination of the size of the workforce in Bronze Age societies, for example through labour cost studies, could provide a better basis for demographic examinations in the Argive Plain and elsewhere in the Late Bronze Age Aegean.

Crops, texts, and people

The Linear B texts mention a few staple crop types that were abundant in the LH III Argive Plain (pp.15-18 and p.95). These included the cereals and figs given as rations to specific palatial workers, and t olive, mostly converted into oil. The last section of this chapter examines the potential impact that the production of these crops had on the agricultural potential of the Argive Plain. The discussion emphasizes the potential role of terraced fields in palatial production.

Both cereals and figs were given to the palatial workers in volumes that have been estimated to amount to 20 litres (Nosch 2003; Palmer 1992;). Translated into kilograms, this would indicate *c.* 150kg of dried figs and 180kg of cereal grain a year. While the quantity of grain fits well with the model 1 dietary estimates which suggest *c.* 186kg annual consumption of cereals, the volume of figs seems too high to be consumed by one person. Model 1 of the Argive Plain agricultural potential indicates that cereal production at these levels was possible for tens of thousands of inhabitants in the region. This seems to suggest sparing cereal aside to be handed out as rations to the palatial or other workers did not make a difference in the agricultural sustainability of the region.

However, if it is assumed that the people supported by grain rations from the palace were not responsible for their personal food production, additional production pressure may have been placed upon the farming communities of the Argive Plain. In addition, Foxhall and Forbes' (1982) suggestion for the later Classical ration system is reasonable also in the LBA context: the quantities mentioned in the Linear B texts might have been standardized and therefore exceeding subsistence needs. These shares could have served as a currency that could be exchanged for other products. A ration could have served as a bonus, perhaps given to the employees to be shared with their families. Especially if the cereal rations were handed out as wheat, probably the more esteemed cereal type, the ration would have made a fine gesture towards gathering of wealth. Wheat rations are not included in the agricultural potential models of the present study, but given that the region might have been balancing at the high end

[7] After Abrams 1987.

of its agricultural potential, they could have created a significant pressure of production for those who, likely seasonally, were employed to work on the palatial farms.

In models 1 and 2, a 'normal' consumption of dried figs, 18kg per year, or 5 percent of the diet composition, was assumed. In addition, the diet included another 35.5kg of fresh figs. In total, *c.* 53kg of figs would have been consumed annually. It seems reasonable to assume that the average LH III Argive Plain inhabitant did not consume 150kg of (dried) figs in a year as mentioned in Linear B records, but only palatial workers may have received such large payments. The quantity could have further fluctuated according to the annual production rate of the fruit. Such a high quantity was perhaps given to the employee to also support their families, or, similar to cereals, to be used as a type of currency that could be exchanged for other products. As such, the quantity divided by 4-6 members of the household would result in 25-37.5kg of figs per person per year which fits quite well with the estimate for fresh figs in the diet models of the present study. If, however, the 150kg rations were provided as dried figs, the share of figs produced by the palace would have grown considerably, because more than double would have had to be produced fresh to achieve such quantity in dried form.

Either way, the Mycenaean palatial administrations had to acquire a sufficient stock of figs (and wheat) every year. The palatial fig production targets would have depended on the number of workers included in the ration system. There are many estimates of the number of workers in the LH III palatial settlements (see previous section). The Linear B tablets of Mycenae mention only a few notions related to the number of workers. One tablet (Fo 101) mentions fourteen named women working in the textile industry, and another one (V 659) mentions 25 women working in pairs (Varias Garcia 2012: 159). In Pylos, the number of dependent women and children working for the palace is estimated at 1000, and the total population of the palace a minimum of 2500 (Shelmerdine 2008b: 136). This would indicate that around 40 percent of the population of the palace consisted of workers whose subsistence was provided by the palace. As mentioned earlier, Hiller (1988) suggested that a third of all the personnel listed in the Pylos Linear B tablets were paid in food rations. This would have amounted to *c.* 1300 people. If these figures are used for Mycenae, where the ration payment has been used, and to Tiryns, where craft quarters and linear B texts suggest the presence of a similar palatial system, *c.* 30-40 percent of their populations should have been provided with fig rations. This translates to some 3400-4500 people in total (see pp.36-38 for the population estimates for these settlements).

A convenient place for the Argive Plain palaces to produce additional stock such as tree crops could have been terraced fields. Due to the limited evidence of Mycenaean terraces in the Argive Plain, and the uncertainties related to their dating and use, the areas that could potentially have been terraced were limited by creating a buffer zone of 2.5km around the most notable settlements of the LH III Argive Plain. Terrace cultivation was further examined through terrace usage rate which was defined between 30 and 90 percent. Even with these limitations, the agricultural space of the LH III Argive Plain could have increased by a minimum of about a thousand hectares. This range should, by no means, be observed as an absolute number, but it gives an idea of the scale of agricultural intensification that could have taken place with well-organized terracing.

However, ethnographic data suggest that in Greece, terraces have usually been built by farming households for limited mixed agricultural use rather than by central powers for special uses. According to Foxhall (1996a), building large-scale terraced field systems has not been a widespread practice in Classical antiquity, but only recently gained value as the basis for tree crop cultivation. Cultivated crops and the soil platform of terraced fields require similar care as flat fields. In addition, accessibility to terraced fields may be poorer than to the flat fields. Therefore, the labour costs for maintenance of and cultivation on terraces must be considered in relation to the potential harvest profit. Due to their higher maintenance costs compared to flat fields, an average household maintained only a few terraced fields at the same time. If these examples are applicable to the LH III, for most living within a short distance to the flat Argive Plain, building terraced fields was likely not worth the effort.

When terraced slopes are included in the agricultural space of the LH III Argive Plain, data further suggest that terraced fields did not increase the agricultural potential notably if they were used in a comparable way as fields on flat surfaces, namely for mixed crop cultivation and animal husbandry. However, if they were used to produce specific crops such as olives and figs, they could have probably enabled stock production. This stock could have been used for payment rations, export, or in craft industries (pp.15-18). Therefore, acknowledging the arguments of Foxhall, the following section attempts briefly to examine how well-specialized production on terraced fields would have enabled palatial stock collection.

Fig produces well, at least in modern conditions. With a 30-percent terrace usage rate, fresh figs for almost 60,000 people could have been produced with the 'normal' consumption of 35.5kg per year in both models, 1 and 2

(Table 7.4). Dried figs would have been enough for nearly 46,000 people. According to these figures, there seems to have been enough potential for a considerable fig overproduction. The additional stock of fruit could have been used as rations or as items for export. However, if the same space is used for a 150kg per person annual fig production, only about 5400 people could receive this target figure of dried figs. Terraces could, thus, provide fig rations to the potentially thousands of dependent palatial workers of Mycenae and Tiryns, but not much would have been left for anyone else unless the average farming household produced figs for their own needs elsewhere, for example from scattered, semi-managed trees growing at wastelands as is customary in recent historical Greece.

Olive oil and fresh olives are mentioned in the Mycenae tablets in relation to the same female textile workers as fig rations (as well as to some male employees working with metals, see pp.8-10). The volumes of fresh fruit or oil given to the workers remain unclear. One fragment (Ue 661) mentions 100 units of olives, which has been translated to 1200 litres, or as the total of the rations given to 500 workers in a month (Chadwick *et al.* 1962: 56; Tournavitou 1995: 264). This means one worker would have received *c.* 1.2kg (2.4 litres)[8] of olives, or per month, totalling a 14.4kg annual production requirement. If these rations were used to produce olive oil for personal needs, they would only provide some 2-3kg[9] of oil. Such a quantity would not have been adequate for the annual needs of the palatial employee, if the diet models 1 and 2 of this study are followed. In model 1, the need for fresh olives, including those to be converted to oil, is *c.* 27kg, and in model 2 *c.* 52kg. Especially in model 1, in which animal products consumption is low, the intake of fats would have been severely impaired in case of such low consumption of olive oil.

If olive oil was produced for the needs of the palatial textile and perfume industries, the need to produce it would have been considerably higher than what is presented in the agricultural potential models of this study. Perfumed oil production is well attested in Pylos (Palaima 2014; Shelmerdine 1985), but not securely in the Argive Plain centres, although the Linear B texts recovered at Mycenae do mention several herbs and spices which could have been used for the making of perfumed oils (Sarpaki 2001). The palace could have focussed olive production on terraces. Terraced platforms are extensively used for olive orchards in modern Greece. Terraced fields with a 30-percent usage rate could produce olive oil for *c.* 18,800-39,300 people in model 1 and 9300-19,600 people in model 2, depending on the yield which likely alternated bi-annually. These figures can be compared to the population ranges produced in models 1 (13-27,000) and 2 (12-26,000). According to model 1 in which the annual consumption of an average farmer is low, there is potential for additional olive harvest for palatial needs on 'good years', assuming that olives were exclusively cultivated on terraces which had to provide for the entire Argive Plain population. In model 2, it seems olive oil production on terraces would not have provided enough for the needs of the population, and the palatial industries and possible rations. If, as would be more plausible, some olive production was additionally practiced on flat fields by local farming communities, it would have probably been possible to provide enough for both purposes in model 2 as well. Considering, however, that figs had to be produced extensively as well, and that the palace likely had a demand for wheat grain too, the LH III Argive Plain appears to have provided a rather limited area for agricultural production beyond its populations' subsistence needs. Furthermore, these figures reflect the possible palatial production, farming of specific products, that took place on palatially owned or controlled land (pp.16-18). They do not include calculations of potential production beyond minimum household subsistence due to taxation, for example. If both systems, the palatial direct production of foodstuffs, and taxations of other staples (and non-staples) from local communities were in use in the Argive Plain, its general production should have been notably above subsistence levels.

The results of the calculations indicate that the LH III Argive Plain had the potential to produce cereal, figs and olive oil beyond immediate subsistence needs unless the palatial workforce consisted of thousands of individuals who all needed to be supported by food rations. The additional harvest of these items could have been used to exchange products with foreign powers or consumed during banquets and other festivities. Some of it was likely used for rations. However, if the workforce of each palatial settlement (even if they were just Mycenae, Tiryns and Midea) consisted of thousands of individuals, all of whom were supported by rations, such production would have not been sufficient. Admittedly, the size of rations may have varied according to the employee and their tasks, but even the standard rations of 20 litres of cereal and figs appear to be high if these needed to be produced for thousands in addition to other subsistence items. Such production could have been made more efficient by focusing it on terraced fields, number and size of which could be changed according to environmental conditions and available workforce.

[8] Converted from 2.4 litres with aqua-calc.com conversion tool website, which uses USDA nutrient data to convert food volumes and masses.

[9] Approximately 5kg of olives is needed to produce 1 kg of oil according to modern reports by Aschenbrenner (1972: 163; p.141 in this volume).

Table 7.4. The agricultural potential of specialized production of olives, olive oil, grapevines and figs on terraces in model 1 (a and b).

Model 1 (a and b)		Fresh olives, minimum yield	Fresh olives, maximum yield	olive oil, minimum yield	olive oil, maximum yield	grapes, fresh max	grapes, fresh min	figs, fresh	figs, dried
	ha	0.0043	0.0022	0.0517	0.0247	0.0142	0.0058	0.0177	0.0211
terrace 30	970	**225,581**	**440,909**	**18,762**	**39,272**	**68,310**	**167,241**	**54,802**	**45,972**
terrace 60	1940	**451,163**	**881,818**	**37,524**	**78,543**	**136,620**	**334,483**	**109,605**	**91,943**
terrace 90	2910	**676,744**	**1,322,727**	**56,286**	**117,814**	**204,930**	**501,724**	**164,407**	**137,915**
terrace 100	3300	**767,442**	**1,500,000**	**63,830**	**133,603**	**232,394**	**568,966**	**186,441**	**156,398**

The political distribution of the agricultural space within the Argive Plain affected the potential of each major settlement to provide subsistence to its population. It seems unlikely that one central power would have been in control of the entire agricultural area, and in consequence, responsible for the distribution of the shares of harvest between all other settlements of the plain. Although some have suggested that Mycenae grew to control the flow of goods within the plain, this seems to mainly apply to luxury items and resources instead of subsistence products, and the idea of a centralized, redistributive economic system for Mycenaean core areas has mostly been debunked (pp.16-18). At least for the LH III Argive Plain, the material and textual data refer to relatively independent subsistence systems for each major settlement. This was likely also true for the smaller, more agriculturally focused sites. Therefore, it can be assumed that each settlement and their inhabitants controlled their own share of the total agricultural space available. The people inhabiting areas outside the palaces, and those who were part of the ration system, would have had to arrange their own space for tree cropping. As the calculations of this study show (pp.166-174 and Appendix 12), this would have been possible for a population of no more than 20,000 people in both models 1 and 2, the inhabitants of the palaces taking up more than half of this number.

As noted by Bintliff (1977), a site catchment analysis of the Argive Plain shows how the surroundings of a few major sites had considerably better potential for agricultural production than others. A major difference is seen for example between the landscape around Argos, which had excellent soils, water reserves, and flat land areas around it to support cultivation, and the landscape around Mycenae, which had little of any of these resources. Thus, the construction of terraces, and the exploitation of the neighbouring areas for agricultural purposes could have taken place simply because it was necessary to fill the basic subsistence needs of Mycenae’s large population.

Reconstructing LH III agriculture in the future

It has been established by previous research that crop cultivation and animal husbandry were the main subsistence activities practiced by the LH III Argive Plain people. The selection of the main cultivated crops was established based on the combination of archaeobotanical and textual evidence without much difficulty, although some differences between these two sets were seen in the species variety. What neither set of evidence can produce, however, is the numeric data of how much harvest these crops could produce, and in what kind of quantities these crops were consumed by people (or by their animals). The establishment of the farming practices, physical work conducted by the LH III people, is mainly based on ethnographic analogies instead of material archaeological evidence. It is surprising that in the end we still know so little about these everyday practices of a society that has been researched for two centuries.

Due to the scarcity of evidence, the strong reliance on ethnographic examples is difficult to overcome. However, with targeted research into the available material evidence, this emphasis could change in the future. The issue of crop productivity could be tackled by experiments in which old crop types, such as emmer and einkorn, are grown in different environments. Some experiments have already produced promising results (Bakels 2018; Jenkins *et al.* 2011; Kanstrup *et al.* 2011; Stokes *et al.* 2011), but a larger reference database of the results of these experiments, as well as experiments conducted in the climatic and environmental conditions of the Aegean are needed. Many of these experiments are related to the relationship of isotope values in crop seeds when different cultivation methods, such as manuring and irrigation, are used. More reference data of the isotope values of plants and animals inhabiting Aegean environments are needed to formulate more reliable analyses on the abovementioned topics. So far, the few isotope studies investigating crop husbandry methods in the Aegean derive from Neolithic contexts and cannot be directly used for the LBA. The isotope analysis of the LBA seeds would require the access to charred seed remains from the Mycenaean contexts, which may turn out to be challenging due to the destructive nature of the method.

Some information on the cultivation methods could also be obtained by looking into the selection of tools, such as sickles and hoes. The selection of tools may refer to the selection of cultivation practice, for example whether crops were cut long or short, or whether stubble was left on the fields after harvest (Halstead and Jones 1997). Unfortunately, tools found in the LBA archaeological contexts cannot always be related to agricultural work, since they may have been designed for construction or other purposes (Blackwell 2011). Usewear analysis on the recovered sickle blades and other cutting tools could help to identify possible crop plants and shed light on the ways they were harvested. Moreover, usewear analysis on storage containers could help to connect the harvested crops to human use. Although some analyses have been already conducted (see Chapter 5), more reference data is needed to reach firm conclusions about LBA agricultural practices.

Another way to examine crop growing conditions and their influence on crop yields could be to use more modern data on experiments related for example to the development of drought resistant crop types, or to find crops that can be grown in poorer environmental conditions in developing nations where reliable harvests are crucial to life. Collaboration between archaeologists and agricultural scientists, but also climatologists and nutritional scientists could bring forth new methods to examine past agriculture and sustainability and enable the formation and use of larger reference databases in archaeology. In this study, the databases of the USDA, FAO and WHO were intensively used for the diet reconstruction. Although it is acknowledged that the data is based on modern crop types, which may be genetically different from the ancient crops, the potential of using quantitative data to establish nutritional values of diet compositions is a great advantage in a study such as this which is mostly based on averages of previous estimations.

One of the major aspects that is less frequently discussed in this study is the social and cultural dimension of agriculture. Questions about the rules, customs, and restrictions related to landownership and use, for example whether land was inherited, or if cultural conventions such as closeness to a cemetery or sanctuary limited the use of land for agricultural purposes, are important in the reconstruction of past agriculture. Furthermore, human diet is not just related to what is available, but strongly tied to the societal conventions of what is deemed appropriate. As discussed earlier (pp.129-132), some indications to the dietary differences between the Mycenaean elite and non-elite were seen in the consumption of fish and seafood. The studies of Mycenaean feasts (Dabney *et al.* 2004; Hruby 2008; Lis 2008; Morris 2008; Palaima 2004; Walberg and Reese 2008) have further emphasized the limited access to meat and a larger variety of food which was only available to all during these ritual and celebratory events. Finally, a further interesting direction of research could be the effort to connect the agricultural calendar which inevitably existed in some form since crops grown only in specific times of the year, and to ritual, religious and celebratory behaviour in order to see how much these conventions collided with each other, and how that may have influenced in the everyday practices of the Mycenaean farmers.

Overall, the analysis of the agricultural potential forms an interesting comparison to the analysis of the political relationships of the LH III Argive Plain settlements. The issue of land use distribution between these sites remains unresolved by the present study, and it is certainly a topic that needs further examination. The Argive Plain landscape is versatile, and walking distances to fields may have varied considerably between settlements. This landscape creates challenges to the traditional ways of performing catchment analyses (pp.31-36). New methods to examine the Argive Plain land use have been provided by fuzzy suitability analysis (Knitter *et al.* 2019), and by kernel density analysis (Bonnier *et al.* 2019) of the Berbati Valley. Both methods estimate the suitability of the landscape for different agricultural uses by comparing distance from the site to slope, soil fertility and to other environmental characteristics. These analyses are conducted with GIS tools which can calculate in high accuracy the sizes and locations of the areas in which the best characteristics for agriculture appear in highest densities.

Nevertheless, although computational methods can produce high-definition quantitative data on distances, sizes and agricultural suitability, the input data used in both of the analyses mentioned above is still mostly the same as what is used in this study. This means that these computational methods cannot overcome the problems related to the scarcity of the archaeological data of the LH III agricultural practices, population, or small farming sites. Besides creating more analyses on the potential locations for best lands for crop cultivation, the future research concerning LBA agriculture in Greece should, thus, focus on creating new data on these essential aspects.

Conclusion

The examination of the subsistence economy in the Mycenaean Argive Plain, situated in the northeastern Peloponnese, Greece, during the Late Helladic III period, relies on a diverse set of sources: archaeological legacy data, ethnographic studies on Greek farming communities, and contemporary data on food consumption and nutrition. By reconstructing the local agricultural practices and their associated land use from this period, this study provides an analysis of the agricultural potential of the region for food production. Furthermore, it allows for estimations of the size of the population that could be sustained within the Argive Plain. Such reconstruction does not only provide valuable insights into the subsistence strategies of the Late Helladic communities but also sheds light on the political and economic organization in the Argive Plain during the Mycenaean peak. This period likely witnessed the imposition of new types of exploitation of the local farming communities by elites. This analysis of Mycenaean farming focuses on the relationship between agricultural production and the socio-economic dynamics of the time.

Methodologically, this study aligns with the research tradition of the paleoeconomic school, employing interdisciplinary approaches to investigate past subsistence strategies, farming strategies, and human-environment relationships. Within this regional and chronological context, the paleoeconomic approach proves particularly fitting. The evidence regarding the LH III Argive Plain subsistence strategies primarily derives from a collection of published datasets which offer predominantly site-specific information if examined in isolation. By cross-referencing data from six fields of investigation (archaeobotanical, zooarchaeological, geographical, artifacts, osteoarchaeological and palaeoclimatological studies), it is possible to achieve a better understanding of the local agricultural strategies and how they connect with the extensive and intensive farming regimes introduced by many of the paleoeconomic scholars (see pp.46-50). In addition to archaeological data, ethnoarchaeological analogies and, to a lesser extent, Classical sources together with recent nutritional data form the foundation for the reconstruction of the Late Bronze Age food production and consumption. These sources provide quantifiable data of variables such as crop yields, diet, and field and pasture sizes. These data enable the transformation of the results into tangible amounts of food production, consumption, and, eventually, people. The results of the present study, thus, broadly express the size of the population that could potentially sustain itself in the Late Bronze Age Argive Plain landscape given the farming practices of the time.

During the data collection for this study, it became clear that a broader, interdisciplinary analysis that can synthesize the data produced by specialized studies can add value to the current state of research of the Mycenaean Argive Plain. BY such synthetization, this study aims at creating more complete picture of the activities of Late Bronze Age communities in this area. However, this study has been challenged by the availability and quality of published data of the Late Helladic societies. Regarding the Argive Plain, surprisingly little is still known of Late Helladic III animal husbandry, local settlement pattern and in particular smaller sites, or the diet and health of the local population. Therefore, while emphasizing the benefits of data synthesis, the value of the literature review used in this study also lies in its ability to reveal the need for more detailed analyses on the LH III Argive Plain subsistence economy.

This study culminates in the analysis of agricultural potential. In this analysis, the reconstruction of the local agricultural practices is used to estimate the potential of the Argive Plain region to produce food. The modelling begins by estimating the space available to practise crop cultivation, by establishing the average yields of the main cultivated crops, and by defining the average food consumption of a LH III Argive Plain inhabitant per annum. These factors are used as the main variables in a series of calculations, which result in a maximum number of people sustained by the Argive Plain agricultural landscape. This number is expressed as a series of population ranges which are based on two different diet models (1 and 2), and four different sub-models (1a, 1b, 2a and 2b). The sub-models are created to better reflect the fluctuation in variables such as crop yields due to climatic and other environmental conditions.

The outcomes of the assessment of agricultural potential in the Late Helladic III Argive Plain, exhibits a relatively close alignment within the two primary models 1 and 2. Model 1 suggests that the region could sustain a population ranging from approximately 17,000 to 27,000 individuals, while Model 2 proposes a slightly higher range of 22,000 to 37,000 people, assuming the optimal use of all suitable space for crop cultivation. When expressed as ranges, both models account for potential variations in land use and cultural aspects, including fallow periods, yield fluctuations, and dietary compositions. However, it is important to note that these estimates do not include the space required by animals kept for meat and dairy products. The agricultural potential outlined here does not reflect real population sizes, but represents the maximum population that could live in the region indefinitely with the available plant food resources. Even in this case, the high end of the range is probably unrealistic, and the 'true' potential is probably closer to the lower end of these ranges. This is due to factors such as certain areas of land remaining unused owing to poor fertility or other environmental constraints, land allocation for infrastructure purposes, or cultural reasons related to land ownership. In other words, considerable amounts of land now included in the model as fields were not in use as such.

Therefore, integrating the space needed for pasture in the agricultural potential model results in a better understanding of land use and resource potential in the Argive Plain. Even if not utilized for pasture, and accounting for potential discrepancies in using modern figures to model pasture requirements of Bronze Age domesticates, excluding this space from crop cultivation areas contributes to a more realistic land use distribution. Consequently, the agricultural potential of the LH III Argive Plain significantly decreases to approximately 13,000 to 21,000 people in Model 1 and 12,000 to 23,000 people in Model 2.

As such, the results of this study suggest that the agricultural potential of the LH III Argive Plain was relatively modest. This is significant especially when the agricultural potential is compared to the existing population estimates for the largest settlements of the plain. The potential of the Argive Plain to support a group of people is not much higher than the combined estimated population of two of its largest settlements, Mycenae and Tiryns (11,000 in total, after Bennet 2007, 2013; Brysbaert 2013; French 2002; Whitelaw 2001). Given that the plain hosted several other major settlements, and likely a notable rural population, there seems to be a discrepancy between regional sustainability and regional population. With such a low agricultural potential, the area could have not provided enough staples such as oil for craft activities, or food rations handed out to palatial workers. In addition, production potential does not rise considerably when the agricultural space of the neighbouring regions of Berbati, Nemea, and Asine are included in the model. Even though many have argued (e.g. Wright 2004: 128; Schallin 1996) that each of these regions were controlled by the Argive Plain centres, in particular by Mycenae, in the agricultural potential model none of them had the capability to produce notable economic surplus that could be used for wealth acquisition by the Argive Plain palatial centres.

Chapter 3 exhibited how existing population density and site size estimates in the Bronze Age Aegean context are often problematic, and that a much wider reference database of settlement and household sizes and density estimates should be used to create further population estimates for the LBA Greek mainland. In the context of the Argive Plain, estimates of site sizes and population densities are not numerous, and the few population figures available for Mycenae (6400 after Bennet 2007; French 2002) and Tiryns (4900 after Brysbaert 2013; Shermeldine 2008b), have been widely accepted without thorough scrutiny. Nevertheless, the establishment of population estimates is often regarded to provide more direct evidence of local societies than the agricultural potential analysis which relies on variables (such as crop yields or food consumption measured in volumes) that may be deemed circumstantial and that can often be changed depending on the used source and perspective. However, the agricultural potential analysis holds value in raising critical questions. This study, for example, has highlighted the need for further investigations into crop productivity and food consumption within the Mycenaean Argive Plain. In addition, differences between the results of this study, which showcase the food production potential of the Argive Plain, and previous population estimates given to the region, highlight the need to look further into the precision of the methodology and data employed to formulate population estimates. Addressing settlement population estimates in the context of environmental resource potential is essential for advancing our understanding of the sustainability and resilience of the Argive Plain people.

Another important result of this study is the establishment of the size of land needed to sustain a LH III Argive Plain individual. Previous estimates of prehistoric and Bronze Age plot sizes for farming households seem rather minor compared to the subsistence land areas modelled in this study. Previous estimates have usually focused on the production of one main crop which is most often defined as (bread) wheat. This study shows that such considerations are rather limited. Up to now, analyses of subsistence plot sizes have rarely considered the consequences of common agricultural practices, such as fallowing or cereal-pulse rotation, for local land use. Thus, when the main subsistence crop is a cereal, the space for its cultivation should be doubled in order to realistically reflect the space which is not used for cereals due to fallowing or crop rotation. In addition, although it is nutritionally just about possible that the main crop formed up to 75 percent of the average diet of a Bronze Age individual, other plant and animal products were nevertheless on their menu as well. Plot size estimates have rarely addressed the spatial requirements for the production of these other essential dietary products.

This is plainly obvious when animal products such as dairy and the spatial requirements to produce it are considered. Simply put, pasture takes up a considerable amount of space. Space is one of the main variables regulating the agricultural potential of an area, and its availability has significant implications for the ways LBA people organized their activities in their immediate surroundings.

Beyond its immediate results of the food production and land use potential of the Argive Plain, this puts emphasis on a topic that has received less attention in the archaeology of the Late Bronze Age mainland – the local farming communities, and the farming practices used by these communities. During more than a century of archaeological research in the Mycenaean core areas in mainland Greece, the main interest has always been focused on the elite activities, their political relations, and in their prominent material culture. Due to the scarcity of material and textual evidence on the presence of farming communities, we still know little of their activities, and how agriculture was able to function in the changing political and economic conditions of the LBA Aegean societies.

The Argive Plain formed an excellent case-study area for such a focus, since it is considered as an important Mycenaean core region, and because the archaeological research here is particularly focused on defining the local political situation in the LH III period and defending the idea of the Mycenaean palace as powerful, controlling centre. This study wanted to show that life in the farming communities must have maintained a level of independence from the local political systems. Furthermore, the established range of population makes it evident that the region was not able to produce much more than the required food stock for daily subsistence. Any additional harvest that could be collected from neighbouring areas such as the Berbati and Nemea Valleys, could have been needed just for the basic subsistence needs for the Argive Plain population, especially if terraced field systems were not actively and intensively used, and if the each of the main centres of the Argive Plain accommodated a population of several thousand people.

On the level of average farming households, agricultural practices likely served everyday needs of the family without producing considerable profits until the Late Helladic period. Emerging palatial needs may have resulted in new challenges to the farming communities, such as demands for increase in production or additional work obligations outside agricultural work. The latter could have included, for example, the participation in the large-scale construction projects of the Argive Plain palatial centres. The building of the Cyclopean style defence walls around the citadels, the road system, and the large chamber tomb cemeteries potentially mobilized a high number of people, either as builders or as support staff. Furthermore, local farmers may have had additional pressure to provide food and other resources to these construction projects. These themes were explored in the ERC-funded SETinSTONE project, to which this study is a contribution.

The analysis of the agricultural potential can provide a critical assessment to existing population size estimates. An examination of a regional subsistence economies can provide useful alternatives in situations where the scarcity of textual records (for example army records), birth and mortality rates, site numbers and their population densities prevent in-depth demographic investigations. Although the analysis does not result in a demographic estimate, the agricultural potential offers a way to use environmental data that might be more abundantly retrievable for the establishment of maximum population capacities. This study has further shown that the value of the method is equally in its ability to use and synthesize large datasets and that this is a sound way to create new insights into old questions. Finally, the concept of agricultural potential has proven to be a valuable tool in creating wider analyses of Late Bronze Age societies, since its focus on subsistence strategies consistently addresses wide thematic issues, such as the organisation of agricultural systems, political and social organisations, and human-environment relationships. The collection, review and analysis of the data on the cultivation and animal husbandry practices, diet, and environmental conditions have opened up new windows to Mycenaean lifeways.

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Appendix 1

Bronze Age chronological systems

Adapted from Shermeldine (2008: low dating), Manning (2010: high dating) and Weiberg and Finné 2018 (BP).

Relative Chronology	Low Dating	High Dating	BP	Period
EH I	3300-2700	3100±3000-		Early Bronze Age (EBA)
EH IIA	2700-2400	2650-2500		
EH IIB	2400-2200	2500-2200		
EH III	2200-2000	2250-2100/2050		
MH I	2000-1900	2100/2050-		Middle Bronze Age (MBA)
MH II	1900-1700			
MH III	1700-1600		3750-3650	
LH I	1600-1500	1700/1675-1635/1600	3650-3585	Late Bronze Age (LBA)
LH IIA	1500-1430	1635/1600-1480/1470	3585-3370 (LH II)	
LH IIB	1430-1390	1635/1600-1480/1470		
LH IIIA1	1390-1370/1360	1480/1470-1420/1410	3370-3280 (LH IIIA)	
LH IIIA2	370/1360-1300	1420/1410-1390/1370		
LH IIIB	1300-1200	1330/1315-1200/1190	3280-3150	
LH IIIC	1200-1100	200/1190-1075/1050	3150-3025	

Appendix 2

Summary table of the ethnographic studies used in the publication

Study	**Research methods**	**Period**	**Village/ Area**	**Topography**	**Rainfall/ mm**	**Economy**	**Fertilizers**	**Population**
Forbes 1982	Participant observation, unstructured interviews	1962-74	Kosona/ Methana, Greece	Volcanic, mountainous peninsula with coastal plateaus	< 400	Self-sufficient mixed farming	yes	40 households
Aschenbrenner 1972	Participant observation, unstructured interviews	1969-70	Karpofora/ Messenia, Greece	Alluvial valleys and gently sloping hills	> 600	Self-sufficient mixed farming	yes	353
Allbauch 1953	Systematic survey with interviews	1948	Island of Crete, Greece	Variety of landscapes	200 - 700	Various professions, but 56 percent of labour force involved with agriculture	yes	Majority of population in villages < 500ppl
Hillman 1973	Systematic individual and collective interviews	1930-40s	Asvan/ Central Turkey	Alluvial plain surrounded by mountainous areas with upland basins	> 400	Self-sufficient mixed farming	no	440
Koster 1977	Participant observation, unstructured interviews	1971-75	Dhidyma/ Southern Argolid, Greece	Mountainous peninsula, coastal and upland plains with alluvial soils	< 500	Self-sufficient sheep and goat herding, cultivation of basic staples	yes	1252
Gibbon 1981	Desktop study of the data collected by ICARDA with systematic survey	1977-78	Aleppo Province, Syria	Variety of landscapes	200-350	Self-sufficient mixed farming	yes	Two villages of 283 and 192ppl

Appendix 3

Modern soil fertility classes

Map and soil descriptions are adapted and translated from Greek to English from Ρίζου (2013), and Yassoglou *et al.* (2019) by the current author.

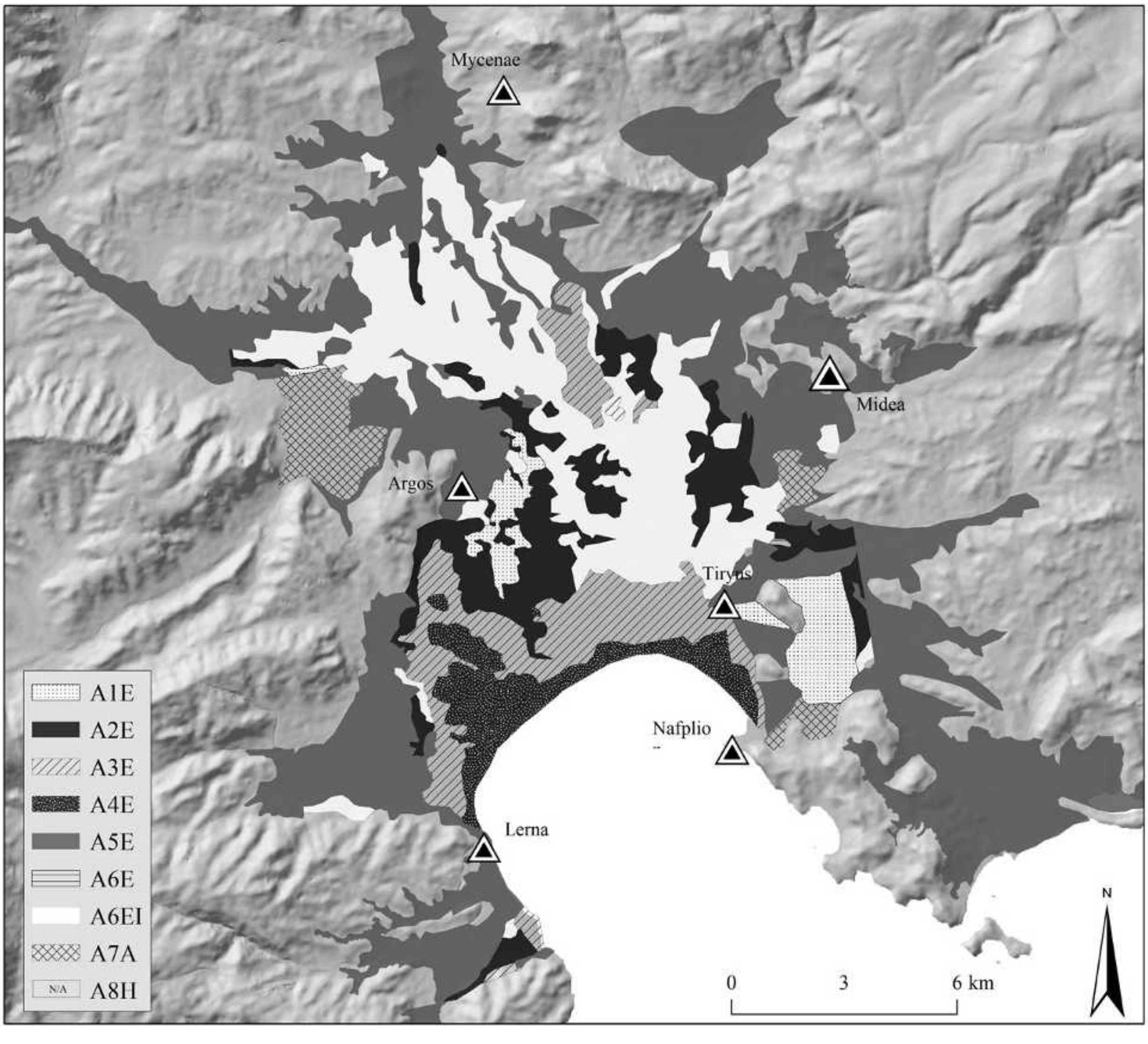
Description of soil types:

AE1

Very well drained *Entisols.* This group forms the coarsest soils of the region. They are characterized by a very well-drained soil profile with average granulometry of loam (L) to clay (CL). The structure is favourable and presents no particular problems for plant growth. Soils are suitable for all cultivated plants growing in the modern landscape. The use of these soils does not have any restrictions other than the need for regular fertilizing. They are found scattered throughout the region.

AE2

Soils are moderately fine, very well or well drained *Entisols.* The granulometry is mainly clay (CL) and sandy clay loam (SCL). The soils exhibit very good drainage conditions. In some cases, they include compact layers. By implementing a standard fertilization program there are no restrictions for the cultivation of modern crops. In the Argive Plain, they are specifically found in the region of Anifi, and Merbaka in the east, and Argos in the west.



AE3

The soils are fine, medium or incompletely drained *Entisols.* Their granulometry is fine, occasionally exhibiting incomplete or poor drainage conditions. Without assisted draining, these soils present severe limitations for the cultivation of moisture-sensitive plants, such as citrus fruit. For annual spring or summer plants, such as vegetables or maize, there is no need to improving drainage conditions. These soils are generally located in the southern reaches of the Argos plain.

A4E

The soils of this group are characterized by a fine grain size, which causes poor drainage conditions. The permanent water level is quite close to the surface (0.50-0.80 cm. Due to proximity to the sea, the soils are typically alkaline. Specifically found in the coastal area and in the location of the former Lake Lerna. They have a generally good structure and hydraulic conductivity, hence if the problem with high water level is solved, they can be used for agriculture. The least affected soils are currently used for cultivating salt-resistant vegetables, such as artichoke, which gives high yields.

A5E

These soils are moderately fine, very well drained *Entisols.* They contain gravel on the soil surface and in deeper horizons. Comparing the other soil characteristics, they are similar to those of group A2E. Gravel increases the water filtration rate and can help to balance the effects of the otherwise fine granulation.

A6EI

The soils are fine, very well or well drained *Entisols* or *Inceptisols.* The granulometry varies from clay loam (CL) to clay (C). The soil texture shows great variability but is generally medium to moderately coarse. This soil class is favourable for cultivation, except when layers more compacted than average occur. The existence of the compact layers and the clayey granulometry are limiting factors that require special attention regarding the irrigation, especially with crops like citrus. This soil group is found especially in the areas of Lalouka, Heraion, Merbaka and Anifi in the central and eastern parts of the plain.

A7A

These soils are fine, very well drained *Alfisols.* They are found in the upper reaches of the alluvial fields, and in terraced alluvial deposits. The soils consist of a surface of clay loam (CL) or sandy clay loam (SCL) and lower layers of sandy clay (SC) or clay (C). There are clay horizons quite close (0.30 – 0.60 cm) to the soil surface, and often erosion has brought the horizon to the surface. The compact consistency of these clay horizons is challenging for cultivation. The soils of this group are found in the region of Panariti in the east, and Akova in the west of the plain.

A8H

This soil group occupies the mountainous and hilly terrain, in other words the periphery of the Argive Plan. They are autochthonous and have been formed mainly on limestone, calcareous conglomerates and marl, which have not undergone diagenesis. These soils are shallow, and strongly eroded. These features, combined with dry climate and unfavourable topography, create serious limitations for cultivation. They are usually found at altitudes above 100 masl

Appendix 4

Bronze Age macrobotanical finds from the Argive Plain sites

Crop	Species	Date	Tsoungiza	Midea	Mycenae	Tiryns	Lerna	Synoro
CEREALS								
einkorn	*Triticum monococcum*	EH	x				x	
		LH	x	x	x	x		
bread wheat	*Triticum aestivum*	EH	x					
		LH		x		x		
emmer	*Triticum dicoccum*	N	x				x	
		EH	x				x	
		MH						
		LH	x		x	x		x
naked barley	*Hordeum vulgare var. nudum*	N					x	
		EH					x	
		MH					x	
barley	*Hordeum vulgare*	EH	x				x	
		MH	x					
		LH	x	x		x		x
barley	*Hordeum sativum*	LH			x			
spelt	*Triticum spelta*	LH				x		
broomcorn millet	*Panicum miliceum*	LH				x		
rye	*Secale cereale*	LH				x		
LEGUMES								
bitter vetch	*Vicia ervilia*	EH	x				x	
		MH	x					
		LH	x	x	x	x		
Vetch/grass pea	*Vicia lathyrus sp.*	LH	x					
lentil	*Lens culinaris*	LN					x	
		EH	x				x	
		MH	x				x	
		LH	x	x	x	x		
chickpea	*Cicer arietinum*	LH		x		x		
pea	*Pisum sativum*	LN					x	
		EH					x	
		LH	x	x		x		
fava bean	*Vicia faba*	LN					x	
		EH					x	
		MH					x	
		LH	x	x	x	x		x
grass pea	*Lathyrus sativus*	LN					x	
		EH					x	
		LH	x	x	x	x		

Crop	Species	Date	Tsoungiza	Midea	Mycenae	Tiryns	Lerna	Synoro
FRUIT, VEGETABLES, OIL PLANTS								
fig	*Figus carica*	EH	x				x	
		MH	x					
		LH	x	x	x	x		x
grapevine	*Vitis vinifera*	EH	x					
		MH		x	x	x		
		LH		x	x	x		
melon	*Cucumis melo*	LH				x		
pear	*Pyrus amygdaliformis*	LH				x		
FRUIT, VEGETABLES, OIL PLANTS								
olive	*Olea europaea*	EH	x					
		MH	x					
		LH	x		x	x		
flax	*Linum usitatissimum*	EH					x	
		LH	x			x		
WILD PLANTS								
bugloss	*Echium sp.*	LH				x		
cotton thistle	*Onopordum acathium*	EH					x	
		MH					x	
malva	*Malvaceae* sp.	EH	x					
		LH				x		
	Medicago	EH	x					
		LH				x		
NUTS								
almond	*Prunus amygdalus*	EH	x					
		LH				x		
acorn	*Quercus* sp.	EH	x				x	
		MH					x	
pistachio	*Pistachia*	EH	x					
		LH	x					
Walnut	*Juglans regia*	LH	x					
Hawthorn	*Cratageus sp.*	MH	x					
CORNS, ROOTS, TUBERS								
garlic	*Allium sativum*	LH	x					

Appendix 5

Tree and maquis species present in the pollen cores of the Bronze Argive Plain (Lake Lerna and Kleonai) and the Southern Argolid (Limni Thermisia and Kiladha)

Name	***Species/Family***	**Lake Lerna**	**Kleonai**	**Kiladha Bay**	**Thermisia**
fir	*Abies*		x	x	
alder	*Alnus*			x	x
strawberry tree	*Arbutus*	x	x		
birch	*Betula*			x	x
box	*Buxus*	x			
hornbeam	*Carpinus/Ostrya*	x	x		x
chestnut	*Castanea*		x		
rockrose	*Cistaceae*	x			
hazel	*Corylus*	x		x	
cypress-family	*Cupressaceae*				x
	Erica	x			x
walnut	*Juglans*		x		
olive	*Olea*	x	x	x	x
	Phillyrea	x	x		x
pine	*Pinus*	x	x	x	x
Aleppo pine	*Pinus halepensis*		x		
	Pistachia	x	x	x	
deciduous oak	*Quercus cerris/pubecens*	x	x	x	x
kermes oak	*Quercus coccifera*	x	x	x	
evergreen oak	*Quercus Ilex*	?		x	x
willow	*Salix*				x
linden	*Tilia*		x	x	x
elm	*Ulmus*			x	x

Appendix 6

Domestic and wild mammals, fish, and bird species present in the LH III deposits of the Argive Plain sites of Mycenae, Lerna, Midea, Tiryns, Asine, and Tsoungiza

Name	Species	Mycenae	Lerna	Midea	Tiryns	Asine	Tsoungiza
Ass	*Asinus asinus*		x				x
Aurorch	*Bos primigenius*		x	x			
Cattle	*Bos taurus*	x	x	x	x	x	x
Dog	*Canis familiaris*		x	x	x	x	x
Goat	*Capra hircus*	x	x	x	x	x	
Horse	*Equus caballus*		x			x	x
Horse/mule/ass	*Equus*			x	x	x	
Donkey	*Equus asinus*					x	x
Pig	*Sus domesticus/scrofa*	x	x	x	x	x	x
Sheep	*Ovis aries*	x	x	x	x	x	x
Sheep/goat	*Ovis / Capra*		x	x	x	x	x
WILD MAMMALS							
Badger	*Meles meles*				x		
Bear	*Ursus arctos*				x	x	
Cape hare	*Lepus capensis*			x	x		
Cat	*Felis sp.*			x			
Deer			x			x	x
European hare	*Lepus europaeus*		x			x	x
European pond turtle	*Emys orbicularis*				x		
Fallow deer	*Dama dama*				x	x	
Fox	*Vulpes vulpes*		x	x	x	x	x
Hedgehog	*Erinaceus europaeus*			x	x		x
Hermann's tortoise	*Testudo hermanni*				x		
House rat	*Rattus rattus*				x		
Lesser mole-rat	*Spalax leucodon*				x		
Lion	*Panthera leo*				x		
Lynx	*Lynx lynx*				x		
Marginated tortoise	*Testudo marginata*				x		
Marten	*Martes foina*				x		
Mediterranean monk seal	*Monachus monachus*				x		
Otter	*Lutra lutra*				x		
Red deer	*Cervus elaphus*		x	x	x	x	x
Roe deer	*Capreolus capreolus*				x	x	x
Shrew	*Sorex*						

Name	Species	Mycenae	Lerna	Midea	Tiryns	Asine	Tsoungiza
Tortoise/turtle	*Testudine*			x	x	x	x
Weasel	*Mustela nivalis*			x	x		
Wild boar	*Sus scrofa*		x		x	x	
Wild cat	*Felis silvestris*				x		
FISH							
Amberjack	*Seriola dumerili*				x		
Common pandora	*Pagellus erythrinus*				x		
European bass	*Morone labrax*				x		
Grouper	*Epinephelus guaza*				x		
Mullet	*Mugilidae*				x		
Smooth hammerhead	*Spyrna zygaena*				x		
Thicklip grey mullet	*Mugil chelo*				x		
Tub gurnard	*Trigla lucerna*				x		
BIRDS							
Chicken	*Gallus gallus domesticus*				x		
Common coot	*Fulica atra*				x		
Common crane	*Grus grus*				x		
Common pochard	*Aythya ferina*				x		
Common raven	*Corvus corax*				x		
Eurasian buzzard	*Buteo buteo*				x		
Europan herring gull	*Larus argentatus*				x		
Garganey	*Anas querquedula*				x		
Goose	*Anser anser (domesticus)*				x		
Grebe	*Podiceps cristatus/grisegena*				x		
Hooded crow	*Corvus corone cornix*				x	x	
Lark	*Alauda arvensis/Galerida cristata*				x		
Little owl	*Athene noctua*				x		
Mallard	*Anas platyrhynchos (domesticus)*				x		
Mute swan	*Cygnus olor*				x		
Rock dove	*Columba livia (domestica)*				x		
Rock partridge	*Alectoris graeca*		x		x		
Rook	*Corvus frugilegus*				x		

Appendix 7

Comparative data of ovicaprid sizes and milk yields

Table 1. Bronze Age cattle, sheep and goat wither heights in reference data.[12]

Animal	Average wither height in cm	Location	Date	Reference
Cow	100-115	Tiryns	LBA	von den Driesch and Boessneck (1990: 100)
Bull	110-120	Tiryns	LBA	von den Driesch and Boessneck (1990: 100)
Domestic cattle	112.5 and 124.2	Platia Magoula Zarkou, Thessaly	EBA	Becker (1991: 23)[1]
Domestic cattle	110.5-12.,6	Sitagroi, northern Greece	EBA[2]	Bökönyi (1986: 72, Table 5.3)
Male sheep	60-65	Tiryns	LBA	von den Driesch and Boessneck (1990: 101)
Female sheep	50-72	Tiryns	LBA	von den Driesch and Boessneck (1990: 101)
Male goat	72-82	Tiryns	LBA	von den Driesch and Boessneck (1990: 101)
Female goat	55-65	Tiryns	LBA	von den Driesch and Boessneck (1990: 101)

Table 2. The average wither heights and weights of modern indigenous cattle, sheep and goat of Greece based on the fact sheets of the Ministry of Rural Development and Food (Georgoudis *et al.* 2011).

Animal	Average wither height in cm	Weight in kg	Milk yield per year in kg
Cattle breed			
Brachykeratiki male	115	210	-
Brachykeratiki female	106	190	-
Katerini male	123	375	-
Katerini female	113	280	-
Sykia male	123	375	-
Sykia female	113	280	-
Sheep breed			
Boutsiko male	55-60	45-50	-
Boutsiko female	52-55	35-45	108
Thraki male	62-65	45-55	-
Thraki female	45-55	35-45	60-100
Kalarrytiko male	67	64	-
Kalarrytiko female	58	45	90
Sarakatsaniko male	65	69	-
Sarakatsaniko female	56	41	60
Goat breed			
Greek goat (general) male	73-74	40-65	-
Greek goat (general) female	65-66	30-50	100

[1] The data is based on two fully preserved specimen only.
[2] The specimen date to Sitagroi Phase V, which according to Renfrew (1986: 24, table 2.1) is c. 3100-2200 BCE.

Table 3. The estimations of Dahl and Hjort (1976: 144–45, 164–65) for the average milk yield of small African indigenous cattle.

Breed	Region	Weight	
Boran	north Kenya	262-314	
Maasai	East African Maasai tribes	108-180	
Average milk yield per day in kg	**Average milk yield per year in kg**	**Human consumption per day in kg**	**Cows needed for family of 6**
1.5	500-1100	2	9

Appendix 8

Stocking rates for (modern indigenous) cattle, sheep, and goats

Cattle

Modern requirements for the area of pasture are usually measured in livestock units (LU or LSU). According to EU standards (European Commission 2013; Hellenic Statistical Authority ELSTAT 2018), one LU equals the grazing area of and adult dairy cow that can produce an annual milk total of 3000kg without food supplements. The weight of such cow is *c.* 600kg (Poncheki *et al.* 2015: 189).

In a recent survey of the grazing systems in the Mediterranean, the amount of land used for pasture in south-eastern Peloponnese (including the prefectures of Arcadia and Laconia) was estimated as 2800km2. The stocking rate, the number of individual livestock per grazing area,[1] inside this pastureland is 0.20 LU/ha (Caballero *et al.* 2009: 68). This means that, today, the grazing density of cattle in the south-eastern Peloponnese is 0.2 cows (that produce 3000kg milk annually) per hectare (0.01km2), or one adult cow per 5ha.

As show in Appendix 7, the Greek indigenous cattle weights range between 190kg and 375kg, and their wither height matches well with the wither heights of the EBA-LBA cattle of Greece. Calculating with modern stocking rate, such weights would result in 0.32-0.61LU/ha. One individual LBA (assuming similar weight to the modern indigenous cattle) cow would have, thus, needed a grazing area of 1.6-3.1ha (0.0164-0.031km2). The calculation process is simplified below:

LU = 600kg
Modern stocking rate = 0.20LU/ha
Cow pasture = 0.2 cows/ha => 1 cow/5ha
LBA cattle weight = 190-375kg
LBA cow pasture = 0.32-0.61 cows/ha => 1 cow/1.64-3.1ha

Sheep and goats

The modern stocking rate for sheep and goats in the eastern Peloponnese is 0.2LU/ha (Caballero *et al.* 2009: 68). The LBA sheep in Tiryns had withers heights of *c.* 50-72cm for females, and 60-65cm for males. Compared to modern indigenous sheep in Greece (Appendix 7), these heights result in weights of 40kg for females and 50kg for males.

LU = 600kg
Modern stocking rate = 0.20LU/ha
LBA sheep weight = 40-50kg
LBA sheep pasture = 2.4-3 sheep/ha => 1 sheep/0.33-0.42ha

Female goats in LBA Tiryns have the average withers height of 55-65cm, and males 72-82cm (von den Driesch and Boessneck 1990: 101). Compared with modern indigenous ovicaprids of Greece the average weight settles in the same range of 40-50kg with sheep (Georgoudis *et al.* 2011: 33–34). Thus, sheep and goats have similar pasture requirements.

These estimations can be compared to ethnographic data of sheep pasture sizes in Greece. In higher altitudes in the Pindos Mountains, Central Greece, stocking rates for sheep and goats varied between 3.2 and 7.5 heads per ha (0.13-0.31ha/individual) (Chang 1992: 81). In 1971-2 the mean land holding for shepherds in Didyma in the Southern Argolid was 7.07ha of which 3.13ha was kept as fallow. In winter, the only the fallow was used for grazing, resulting in a high stocking rate of 15.1 sheep per hectare (0.06ha/individual). However, on average, the sheep rarely remained strictly on this land, and were spread out to communal land, resulting in more comfortable stocking rate of 0.85 sheep/ha (1.18ha/individual) (Koster 1977: 248).

[1] Definition by Koster (1977: 436, table 77).

Appendix 9

The number, age, and sex of the Bronze Age human individuals whose skeletal material are used in this publication

The number of unidentified (unsexed) individuals indicates only the number of unidentified adults. The category <18 includes subadults, adolescents, children, and infants. The category N/A includes unsexed adults. In some cases, the number of individuals is not clearly expressed in the reviewed publication and a question mark has been added with the number.

Location	Dating	Method	Total	Adult	M	F	N/A	<18	Reference
Agia Triada, Peloponnese	LH III	C and N isotopes	80	80					Petroutsa and Manolis 2010
Almyri, Peloponnese	LH III	C and N isotopes	34	34					Petroutsa and Manolis 2010
Armenoi, Crete	LM IIIA-B	C and N isotopes	39	39	22	16	1		Richards and Hedges 2008
Asine	MH	C and N isotopes	19	10	5	3	2	9	Ingvarsson-Sundström *et al.* 2009
Aspis, Argos	MH	C and N isotopes	4	4					Triantaphyllou *et al.* 2006
Kalamaki, Achaia	EH/LH	C and N isotopes	32	31				1	Richards and Vika 2008; Kwok 2015
Kalapodi, Fiotida	LH IIB-IIIA1	C and N isotopes	14	14					Petroutsa and Manolis 2010
Karitsa, Pieria	EIA	C and N isotopes	2	2	2				Triantaphyllou 2015
Kladeri, Pieria	EIA	C and N isotopes	5	5	3	2			Triantaphyllou 2015
Knossos, Crete	MMII-LMI	C and N isotopes	62	59	23	27	9	3	Nafplioti 2016
Kouphovouno	MH	C and N isotopes	4					13	Lagia *et al.* 2007
Lerna	MH I-III	C and N isotopes	39	22	15	7		17	Triantaphyllou *et al.* 2008
East Lokris	LH IIIB-C	C and N isotopes	16	16	8	8			Iezzi 2015
Mycenae, chamber tombs (Batsorachi, Loupouno and Monastiraki)	LH I-III	C and N isotopes	11	11			11		Richards and Hedges 2008
Mycenae, Grave Circle A	MH III-LH I	C and N isotopes	18	18	8	4	6		Richards and Hedges 2008
Pylos	MH-LH IIIC	C and N isotopes	63						Papathanasiou *et al.* 2012
Pylos	MH-LH IIIC	C and N isotopes	39	39					Schepartz *et al.* 2011
Spaliareka, Achaia	LH	C and N isotopes	8	8					Richards and Vika 2008
Spathes, Mt. Olympus	LH III	C and N isotopes	6	6	1	5			Triantaphyllou 2015
Sykia, Laconia	LH III	C and N isotopes	6	6					Richards and Vika 2008

Location	Dating	Method	Total	Adult	M	F	N/A	<18	Reference
Tres Elies, Mt. Olympus	LH III-EIA	C and N isotopes	6	6	6				Triantaphyllou 2015
Voudeni	LH IIB-IIIA	C and N isotopes	24	24	12	7	5		Petroutsa *et al.* 2009
Zeli, Fiotida	LH IIIA2-IIIC	C and N isotopes	20	20					Petroutsa and Manolis 2010
Athens	LH IIB- LH IIIB/C	oral pathologies	63		33-34	21-22			Kirkpatrick Smith 1998
East Lokris	LH/PG	oral pathologies	22?	22?					de Gregory 2012
Kouphovouno, Laconia	MH	oral pathologies	26	13				13	Lagia *et al.* 2007
Lerna	MH I-III	oral pathologies	50						Triantaphyllou *et al.* 2009
Pylos	LH IIIA (-C)	oral pathologies	108	93	34	33	26	15	Schepartz *et al.* 2009
Pylos	MH-LH IIIC	oral pathologies	179	160				19	Papathanasiou *et al.* 2012
Pylos	MH-LH IIIC	oral pathologies	179	160				19	Schepartz *et al.* 2011; 2017
Argos	LH IIIC-G	skeletal analysis	113	81	49	28	4		Pappi and Triantaphyllou 2007
Asine	MH	skeletal analysis	44	28	16	12		16	Angel 1982
Asine	EIA-G	skeletal analysis	19	8	5	3		11	Angel 1982
Aspis, Argos	MH	skeletal analysis	13	9	1	6	2	4	Triantaphyllou *et al.* 2006
Athens	LH IIB LH IIIB/C	skeletal analysis	118	80	40	39	1	38	Kirkpatrick Smith 1998
Ayios Vasilios, Laconia	MHIII-LHI	skeletal analysis	49	36	13	13	10	13	Moutafi and Voutsaki 2016
Kouphovouno, Laconia	MH	skeletal analysis	26	13				13	Lagia *et al.* 2007
Lerna	MH	skeletal analysis	209						Voutsaki *et al.* 2013
East Lokris	LH IIIB-C	skeletal analysis	186	143	62	61	20	43	Iezzi 2009
Midea	MH/LH/ Roman	skeletal analysis	3	3				3	Ingvarsson-Sundström 2007
Mochlos, Crete	LM IIIA-B	skeletal analysis	32	26	11	12	3	6	Triantaphyllou 2011
Mycenae, Grave Circle A	MHIII-LHI	skeletal analysis	17	15	11	3	1	2	Papazoglou-Maniodaki *et al.* 2009; 2010
Mycenae, Grave Circle B	MHIII-LHI	skeletal analysis	23	21	16	5		2	Angel 1973; Musgrave *et al.* 1995
Sykia, Laconia	LH IIIB-LH IIIC	skeletal analysis	36						Efstathiou 2008
Mycenae, Grave Circle A	LH	Str isotopes	11	11	7	2	2		Nafplioti 2009

Appendix 10

The nutritional values of foodstuffs used in the dietary analysis of this publication

These values are based on USDA data, and present mostly uncooked, raw, and lightly or non-processed forms. The values are expressed as calories and grams per 100 grams.[1]

Food/100 grams	Energy (kcal)	Protein (g)	Fat, total (g)	Carbohydrate (g)	FDC ID
Almonds, unsalted	607	20.3	54	20.4	1100511
Barley, flour or meal	345	10.5	1.6	74.52	169739
Barley, hulled	354	12.5	2.3	73.5	170283
Beef, cooked, fat eaten	235	27.06	13.44	0	1098160
Bulgur, cooked without fat	83	3.08	0.24	18.6	170287
Cow's milk cheese (cheddar)	370	26	27	6	1819277
Cow's whole milk	61	3.15	3.27	4.78	172217
Einkorn, organic	333	16.7	2.08	64.6	2106521
Einkorn, whole wheat flour	312	12.5	3.12	53.1	1883166
Emmer, whole grain, farro[1]	362	12.77	2.13	72.34	1852515
Fava beans, dry, cooked	110	7.6	0.4	19.6	173753
Fava beans, in pod, raw	88	7.92	0.73	17.6	168574
Fava beans (broad beans), mature seeds, raw	341	26.1	1.53	58.3	175205
Fig, raw	74	0.75	0.3	19.18	1102663
Figs, dried, uncooked	249	3.3	0.93	63.87	1102632
Flat bread, whole wheat	262	10	3.12	47.5	2035212
Goat milk, whole	69	3.56	4.14	4.45	1097531
Goat, boiled	142	26.9	3	0	1098358
Goat, fried	153	26.46	4.52	0	1098359
Goat's feta cheese	321	17.9	25	3.57	1866220
Grape juice	60	0.37	0.13	14.8	173042
Grapes, raw	69	0.72	0.16	18.1	1102665
Lamb chop, cooked, lean and fat eaten	313	24.96	22.89	0	1098342
Lentils, dry, cooked	116	9.02	0.38	20.01	172421
Lentils, raw	352	24.6	1.06	63.4	172420
Olive oil	884	0	100	0	1103861
Olive, ripe, Greek	105	0.88	9.54	6.06	1103680
Peas, green, cooked	84	5.36	0.22	15.6	170420
Peas, green, raw	81	5.42	0.4	14.45	170419
Peas, split, mature seeds, raw	364	23.1	3.89	61.6	172428
Pistachio, unsalted	581	20.42	47.44	27.43	1100552
Pork loin, cooked	242	28.2	13.5	0	167826
Sheep milk	108	5.98	7	5.36	170882
Sheep's milk cheese	357	25	28.6	3.57	1945420
Wheat flour, whole grain	340	13.2	2.5	72	168893
Wheat, durum	339	13.7	2.47	71.1	169721

[1] Farro is cooked soft with water.

Appendix 11

Food consumption, and the production need of different food items according to Diet model 1

Table 1 represents the variables in diet model 1, and the two sub-models a and b. Table 2 represents first the annual food consumption and production need in sub-model 1a. Table 3 represents the annual food consumption and production need in sub-model 1b.

Table 1. Variables in diet model 1, and in sub-models a and b. The numbers can be best explained by using cereals as an example: in diet model 1, cereals form 75 percent of the dietary energy. The total daily energy need is 2400kcal per person (section 6.2), of which 75 percent is 1800kcal. Of the 1800kcal, 70 percent, or 1260kcal consists of barley, and 30 percent, or 540kcal, of wheat in sub-model 1a. In sub-model 1b, these figures are reversed. The resulted energy need per foodstuff can be used to calculate how much (in weight) of said foodstuff needs to be consumed annually to reach the needed energy targets. This figure equals to the minimum annual food production target per person.

DIET MODEL 1				SUBMODEL A		SUBMODEL B	
Foodstuff	**Share in %**	**Share in kcal**	**Of which**	**%**	**share in kcal**	**%**	**share in kcal**
Cereals	75	1800	barley	70	1260	30	540
			wheat	30	540	70	1260
Legumes	5	120	-	-	-	-	-
Dried fruit	5	120	-	-	-	-	-
Fresh fruit	5	120	-	-	-	-	-
Oil	5	120	-	-	-	-	-
Meat	2.5	60	sheep	30	18	20	12
			goat	30	18	20	12
			pig	30	18	40	24
			beef	10	6	20	12
Milk	1.25	30	sheep	40	12	25	7.5
			goat	40	12	25	7.5
			cow	20	6	50	15
Cheese	1.25	30	sheep	40	12	25	7.5
			goat	40	12	25	7.5
			cow	20	6	50	15
Total	100	2400					

Table 2. The consumption requirements of different foodstuffs per person in diet sub-model 1a. Share in g/d represents daily consumption of food expressed in grams, and share in yr/kg annual consumption in kilograms, calculated according to the percentual shares of sub-model 1a. Need after seed loss represents the production need of cereals and legumes after reseeding stock (10 percent of total) is added multiplying the annual consumption need by 1.10. Need after storage loss represents the total production need of foodstuffs for one person after reseeding stock and storage losses (multiplying factor 1.15) are added to the consumption needs.

DIET MODEL 1a						
Food/10 g	**Average energy kcal/100g**	**kcal/g**	**Share in g/d**	**Share in yr/kg**	**Need after seed loss 10%**	**Need after storage loss 15%**
Barley	354	3.54	355.93	129.91	142.9	164.34
Wheats	352	3.52	153.41	55.99	61.59	70.83
Legumes	352	3.52	34.09	12.44	13.68	15.73
Olive, ripe, Greek	105	1.05	5.71	2.08	n/a	2.39
Fig, raw	74	0.74	97.3	35.51	n/a	40.84
Grapes, fresh, raw	69	0.69	60.87	22.22	n/a	25.55
Dried figs	249	2.49	48.19	17.59	n/a	20.23
Olive oil	884	8.84	13.57	4.95	n/a	5.69
Sheep’s milk	108	1.08	11.11	4.06	n/a	4.67
Goat’s milk, whole	69	0.69	17.39	6.35	n/a	7.3
Cow’s milk, whole	61	0.61	9.84	3.59	n/a	4.13
Cow’s milk cheese	370	3.7	1.62	0.59	n/a	0.68
Goat’s feta cheese	321	3.21	3.74	1.37	n/a	1.58
Sheep’s milk cheese (kefalotiri)	357	3.57	3.36	1.23	n/a	1.41
M Mutton/lamb	313	3.13	5.75	2.1	n/a	2.42
M Goat	142	1.42	12.68	4.63	n/a	5.32
M Pig	242	2.42	7.44	2.72	n/a	3.13
M Beef	235	2.35	2.55	0.93	n/a	1.07

Table 3. The consumption requirements of different foodstuffs per person in diet sub-model 1b. As with Table 2 and sub-model 1a, the 'Need after storage losses' represents the total production need of foodstuffs for one person after reseeding stock and storage losses are added to the consumption needs.

DIET MODEL 1b						
Food/100 g	**Average energy kcal/100 g**	**kcal/g**	**Share in g**	**Share in yr/kg**	**Need after seed losses 10%**	**Need after storage losses 15%**
Barley	354	3.54	152.54	55.68	61.25	70.44
Wheats	352	3.52	357.95	130.65	143.72	165.28
Legumes	352	3.52	34.09	12.44	13.68	15.73
Olive, ripe, Greek	105	1.05	5.71	2.08	n/a	2.39
Fig, raw	74	0.74	97.3	35.51	n/a	40.84
Grapes, fresh, raw	69	0.69	60.87	22.22	n/a	25.55
Dried figs	249	2.49	48.19	17.59	n/a	20.23
Olive oil	884	8.84	13.57	4.95	n/a	5.69
Sheep's milk	108	1.08	6.94	2.53	n/a	2.91
Goat's milk, whole	69	0.69	10.87	3.97	n/a	4.57
Cow's milk, whole	61	0.61	24.59	8.98	n/a	10.33
Cow's milk cheese	370	3.7	4.05	1.48	n/a	1.7
Goat's feta cheese	321	3.21	2.34	0.85	n/a	0.98
Sheep's milk cheese	357	3.57	2.1	0.77	n/a	0.89
M Mutton/lamb	313	3.13	3.83	1.4	n/a	1.61
M Goat	142	1.42	8.45	3.08	n/a	3.54
M Pig	242	2.42	9.92	3.62	n/a	4.16
M Beef	235	2.35	5.11	1.87	n/a	2.15

Appendix 12

Food consumption, and the production need of different food items according to diet model 2

As in Appendix 11, Table 1 represents the variables in diet model 2, and the two sub-models a and b. Table 2 represents first the annual food consumption and production need in sub-model 2a. Table 3 represents the annual food consumption and production need in sub-model 2b.

Table 1. Variables in diet model 2, and in sub-models a and b. See further explanation in Appendix 11, Table 1.

DIET MODEL 2				SUBMODEL A			SUBMODEL B	
Foodstuff	**Share in %**	**Share in kcal**	**Of which**	**%**	**Share in kcal**	**Of which**	**%**	**Share in kcal**
Cereals	40	960	barley	70	672	barley	30	288
			wheat	30	288	wheat	70	672
Legumes	30	720	-	-	-	-	-	-
Dried fruit	5	120	-	-	-	-	-	-
Fresh fruit	5	120	-	-	-	-	-	-
Oil	10	240	-	-	-	-	-	-
Meat	5	120	sheep	30	36	sheep	20	24
			goat	30	36	goat	20	24
			pig	30	36	pig	40	48
			beef	10	12	beef	20	24
Milk	2.5	60	sheep	40	24	sheep	25	15
			goat	40	24	goat	25	15
			cow	20	12	cow	50	30
Cheese	2.5	60	sheep	40	24	sheep	25	15
			goat	40	24	goat	25	15
			cow	20	12	cow	50	30
Total	100	2400						

Table 2. The consumption requirements of different foodstuffs per person in diet sub-model 2a. See further explanation in Appendix 11, Table 2. The 'need after storage losses' represents the total production need of foodstuffs for one person after reseeding stock and storage losses (multiplying factor 1.15) are added to the consumption needs.

DIET MODEL 2a						
Food/100g	**Average energy kcal/100g**	**kcal/g**	**Share in g**	**Share in yr/ kg**	**Need after seed losses 10%**	**Need after storage losses 15%**
Barley	354	3.54	189.83	69.29	76.219	87.65
Wheat	352	3.52	81.82	29.86	32.846	37.77
Legumes	352	3.52	204.55	74.66	82.126	94.44
Olives, fresh	105	1.05	5.71	2.08	n/a	2.39
Fig, raw	74	0.74	97.3	35.51	n/a	40.84
Grapes, fresh	69	0.69	60.87	22.22	n/a	25.55
Dried fruit	249	2.49	48.19	17.59	n/a	20.23
Oil	884	8.84	27.15	9.91	n/a	11.4
Sheep's milk	108	1.08	22.22	8.11	n/a	9.33
Goat's milk	69	0.69	34.78	12.69	n/a	14.59
Cow's milk	61	0.61	19.67	7.18	n/a	8.26
Cow's milk cheese	370	3.7	3.24	1.18	n/a	1.28
Goat's feta cheese	321	3.21	7.48	2.73	n/a	3.82
Sheep's milk cheese (kefalotyri)	357	3.57	6.72	2.45	n/a	2.56
M Mutton/lamb	313	3.13	11.5	4.2	n/a	4.83
M Goat	142	1.42	25.35	9.25	n/a	10.64
M Pig	242	2.42	14.88	5.43	n/a	6.24
M Beef	235	2.35	5.11	1.87	n/a	2.15

Table 3. The consumption requirements of different foodstuffs per person in diet sub-model 2b. See further explanation in Appendix 11, Table 2.

DIET MODEL 2b						
Food/10 g	**Average energy kcal/100g**	**kcal/g**	**Share in g**	**Share in yr/ kg**	**Need after seed losses 10%**	**Need after storage losses 15 %**
Barley	354	3.54	81.36	29.7	32.67	37.57
Wheat	352	3.52	190.91	69.68	76.648	88.15
Legumes	352	3.52	204.55	74.66	82.126	94.44
Olives, fresh	105	1.05	5.71	2.08	n/a	2.39
Fig, raw	74	0.74	97.3	35.51	n/a	40.84
Grapes, fresh	69	0.69	60.87	22.22	n/a	25.55
Dried fruit	249	2.49	48.19	17.59	n/a	20.23
Oil	884	8.84	27.15	9.91	n/a	11.4
Sheep’s milk	108	1.08	13.89	5.07	n/a	5.83
Goat’s milk	69	0.69	21.74	7.94	n/a	9.13
Cow’s milk	61	0.61	49.18	17.95	n/a	20.64
Cow’s milk cheese	370	3.7	8.11	2.96	n/a	3.4
Goat’s feta cheese	321	3.21	4.67	1.7	n/a	1.96
Sheep’s milk cheese (kefalotyri)	357	3.57	4.2	1.53	n/a	1.76
M Mutton/lamb	313	3.13	7.67	2.8	n/a	3.22
M Goat	142	1.42	16.9	6.17	n/a	7.1
M Pig	242	2.42	19.83	7.24	n/a	8.33
M Beef	235	2.35	10.21	3.73	n/a	4.29

Appendix 13

The individual subsistence production areas for different foodstuffs according to model 1

Table 1. Key to yield models. Medium yields 1 consists of 600kg cereal yields and the minimum yields of all other foodstuffs. Medium yields 2 consists of 600kg cereal yields and the maximum yields of all other foodstuffs.

<table>
<tr><th>Yield variation in kg</th><th>Cereals</th><th>Legumes</th><th>Olives</th><th>Figs</th><th>Grapes</th><th>Dried figs</th><th>Olive oil</th><th>Cattle milk</th><th>Sheep milk</th><th>Goat milk</th><th>Cattle meat</th><th>Sheep/ goat meat</th><th>Pig meat</th></tr>
<tr><td>Minimum yields</td><td>400</td><td rowspan="2">300</td><td rowspan="2">550</td><td rowspan="4">2500</td><td rowspan="2">1800</td><td rowspan="2">960</td><td rowspan="2">110</td><td rowspan="2">1000</td><td rowspan="2">60</td><td rowspan="2">100</td><td rowspan="2">100</td><td rowspan="4">22</td><td rowspan="2">40</td></tr>
<tr><td>Medium yields 1</td><td>600</td></tr>
<tr><td>Medium yields 2</td><td>600</td><td rowspan="2">700</td><td rowspan="2">1100</td><td rowspan="2">4400</td><td rowspan="2">960</td><td rowspan="2">230</td><td rowspan="2">1000</td><td rowspan="2">100</td><td rowspan="2">300</td><td rowspan="2">200</td><td rowspan="2">65</td></tr>
<tr><td>Maximum yields</td><td>800</td></tr>
</table>

Table 2. Spatial requirements to produce the plant crops of diet model 1a. If cereals can be produced 400kg per hectare, and per annum they are needed 164.34kg (including reseeding and storage losses), it takes to produce the needed volume of cereals when fallow fields (50 percent of the field space) are included.

Model 1a					
PLANT CROPS	Annual production need/kg	Spatial need in ha with minimum yields	Spatial need in ha with medium yields 1	Spatial need in ha with medium yields 2	Spatial need in ha with maximum yields
Barley	164.34	0.8217	0.5478	0.5478	0.4109
Wheats	70.83	0.3542	0.2361	0.2361	0.1771
Legumes	15.73	0.1049	0.1049	0.0449	0.0449
Olive, ripe, Greek	2.39	0.0043	0.0043	0.0022	0.0022
Fig, raw	40.84	0.0163	0.0163	0.0163	0.0163
Grapes, fresh, raw	25.55	0.0142	0.0142	0.0058	0.0058
Dried figs	20.23	0.0211	0.0211	0.0211	0.0211
Olive oil	5.69	0.0517	0.0517	0.0247	0.0247
Total spatial need to produce plant crops/ha		**1.3884**	**0.9964**	**0.8989**	**0.703**

Table 3. Spatial requirements to produce the animal products of diet model 1a. If 4.67kg of sheep's milk is needed per year, and one sheep produces a minimum 60kg of milk per year, share of that sheep is needed to produce the needed milk. The maximum pasture area to sustain one sheep is 0.4ha. The 0.078th of a sheep thus needs of pasture space for one person's milk production at its maximum.

Model 1a							
ANIMALS	Annual food production need/kg	Share of animal needed: minimum milk/ meat yield	Share of animal needed: maximum milk/meat yield	Min pasture needed per animal	Min pasture needed to produce food	Max pasture needed per animal	Max pasture needed to produce food
Sheep's milk	4.67	0.0778	0.0467	0.3	0.01401	0.4	0.03112
Goat's milk, whole	7.3	0.073	0.0243	0.3	0.00729	0.4	0.0292
Cow's milk, whole	4.13	0.0041	0.0041	1.6	0.00656	3.1	0.01271
Cow's milk cheese	0.68	0.0068	0.0068	1.6	0.01088	3.1	0.02108
Goat's feta cheese	1.58	0.2633	0.158	0.3	0.0474	0.4	0.10532
Sheep's milk cheese	1.41	0.141	0.0705	0.3	0.02115	0.4	0.0564
M Mutton/ lamb	2.42	0.11	0.11	0.3	0.033	0.4	0.044
M Goat	5.32	0.2418	0.2418	0.3	0.07254	0.4	0.09672
M Pig	3.13	0.0783	0.0482	-	-	-	-
M Beef	1.07	0.0107	0.0054	1.6	0.00864	3.1	0.03317
Total spatial need to produce animal products/ha					**0.22147**		**0.42972**

Table 4. Spatial requirements to produce the plant crops of diet model 1b.

Model 1b					
CROPS	Annual food production need/ kg	Spatial need in ha with minimum yields	Spatial need in ha with medium yields 1	Spatial need in ha with medium yields 2	Spatial need in ha with maximum yields
Barley	70.44	0.3522	0.2348	0.2348	0.1761
Wheats	165.28	0.8264	0.5509	0.5509	0.4132
Legumes	15.73	0.1049	0.1049	0.0449	0.0449
Olive, ripe, Greek	2.39	0.0043	0.0043	0.0022	0.0022
Fig, raw	40.84	0.0163	0.0163	0.0163	0.0163
Grapes, fresh, raw	25.55	0.0142	0.0142	0.0058	0.0058
Dried figs	20.23	0.0211	0.0211	0.0211	0.0211
Olive oil	5.69	0.0517	0.0517	0.0247	0.0247
Total spatial need to produce plant crops/ha		**1.3911**	**0.9982**	**0.9007**	**0.7043**

Table 5. Spatial requirements to produce the animal products of diet model 1b.

Model 1b							
ANIMALS	Annual food production need/kg	Share of animal needed: minimum milk/ meat yield	Share of animal needed: maximum milk/ meat yield	Min pasture needed per animal	Min pasture needed to produce food	Max pasture needed per animal	Max pasture needed to produce food
Sheep's milk	2.53	0.0485	0.0291	0.3	0.00873	0.4	0.0194
Goat's milk, whole	3.97	0.0457	0.0152	0.3	0.00456	0.4	0.01828
Cow's milk, whole	8.98	0.0103	0.0103	1.6	0.01648	3.1	0.03193
Cow's milk cheese	1.48	0.017	0.017	1.6	0.0272	3.1	0.0527
Goat's feta cheese	0.85	0.1633	0.098	0.3	0.0294	0.4	0.06532
Sheep's milk cheese	0.77	0.089	0.0445	0.3	0.01335	0.4	0.0356
M Mutton/lamb	1.4	0.0732	0.0732	0.3	0.02196	0.4	0.02928
M Goat	3.08	0.1609	0.1609	0.3	0.04827	0.4	0.06436
M Pig	3.62	0.104	0.064	-	-	-	-
M Beef	1.87	0.0215	0.0108	1.6	0.01728	3.1	0.06665
Total spatial need to produce animal products/ha					**0.18723**		**0.38352**

Table 6. Summary table of the land areas needed to produce foodstuffs in diet sub-models 1a and 1b. Colour coding refers to the individual foodstuffs in tables 2-5 which form the food groups 'cereals', 'fruit crops', 'dairy', and 'meat'.

SUMMARY				
Diet 1a				
Foodstuff	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Cereals	1.1759	0.7839	0.7839	0.588
Legumes	0.1049	0.1049	0.0449	0.0449
Fruit crops	0.0559	0.0559	0.0454	0.0454
Olive oil	0.0517	0.0517	0.0247	0.0247
Dairy	0.22323	0.22323	0.10729	0.10729
Meat	0.17389	0.17389	0.11418	0.11418
TOTAL	**1.78552**	**1.39352**	**1.12037**	**0.92447**
Diet 1b				
Foodstuff	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Cereals	1.1786	0.7857	0.7857	0.5893
Legumes	0.1049	0.1049	0.0449	0.0449
Fruit crops	0.0559	0.0559	0.0454	0.0454
Olive oil	0.0517	0.0517	0.0247	0.0247
Dairy	0.22323	0.22323	0.09972	0.09972
Meat	0.16029	0.16029	0.08751	0.08751
TOTAL	**1.77462**	**1.38172**	**1.08793**	**0.89153**

Appendix 14

The individual subsistence production areas for different foodstuffs according to model 2

Table 1. Spatial requirements to produce the plant crops of diet model 2a. See key to yield models in Appendix 13, Table 1.

Model 2a					
CROPS	Annual food production need/kg	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Barley	87.65	0.4383	0.2922	0.2922	0.2191
Wheats	37.77	0.1889	0.1259	0.1259	0.0944
Legumes	94.44	0.6296	0.6296	0.2698	0.2698
Olive, ripe, Greek	2.39	0.0043	0.0043	0.0022	0.0022
Fig, raw	40.84	0.0163	0.0163	0.0163	0.0163
Grapes, fresh, raw	25.55	0.0142	0.0142	0.0058	0.0058
Dried figs	20.23	0.0211	0.0211	0.0211	0.0211
Olive oil	11.4	0.1036	0.1036	0.0496	0.0496
Total spatial need to produce plant crops/ha		**1.4163**	**1.2072**	**0.7829**	**0.6783**

Table 2. Spatial requirements to produce the animal products of diet model 2a. See key to yield models in Appendix 13, Table 1.

Model 2a							
ANIMALS	Annual food production need/kg	Share of animal needed: minimum milk/ meat yield	Share of animal needed: maximum milk/ meat yield	Min pasture needed per animal	Min pasture needed to produce food	Max pasture needed per animal	Max pasture needed to produce food
Sheep's milk	9.33	0.1555	0.0933	0.3	0.02799	0.4	0.0622
Goat's milk, whole	14.59	0.1459	0.0486	0.3	0.01458	0.4	0.05836
Cow's milk, whole	8.26	0.0083	0.0083	1.6	0.01328	3.1	0.02573
Cow's milk cheese	1.28	0.0128	0.0128	1.6	0.02048	3.1	0.03968
Goat's feta cheese	3.82	0.6367	0.382	0.3	0.1146	0.4	0.25468
Sheep's milk cheese	2.56	0.256	0.128	0.3	0.0384	0.4	0.1024
M Mutton/lamb	4.83	0.2195	0.2195	0.3	0.06585	0.4	0.0878
M Goat	10.64	0.4836	0.4836	0.3	0.14508	0.4	0.19344
M Pig	6.24	0.156	0.096				
M Beef	2.15	0.0215	0.0108	1.6	0.01728	3.1	0.06665
Total spatial need to produce animal products/ha					**0.45754**		**0.89094**

Table 3. Spatial requirements to produce the plant crops of diet model 2b.

Model 2b					
CROPS	Annual food production need/kg	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Barley	37.57	0.1879	0.1252	0.1252	0.0939
Wheats	88.15	0.4408	0.2938	0.2938	0.2204
Legumes	94.44	0.6296	0.6296	0.2698	0.2698
Olive, ripe, Greek	2.39	0.0043	0.0043	0.0022	0.0022
Fig, raw	40.84	0.0163	0.0163	0.0163	0.0163
Grapes, fresh, raw	25.55	0.0142	0.0142	0.0058	0.0058
Dried figs	20.23	0.0211	0.0211	0.0211	0.0211
Olive oil	11.4	0.1036	0.1036	0.0496	0.0496
Total spatial need to produce plant crops/ha		**1.4178**	**1.2081**	**0.7838**	**0.6791**

Table 4. Spatial requirements to produce the animal products of diet model 2b.

Model 2b							
ANIMALS	Annual food production need/kg	Share of animal needed: minimum milk/ meat yield	Share of animal needed: maximum milk/ meat yield	Min pasture needed per animal	Min pasture needed to produce food	Max pasture needed per animal	Max pasture needed to produce food
Sheep's milk	5.07	0.0972	0.0583	0.3	0.01749	0.4	0.03888
Goat's milk, whole	7.94	0.0913	0.0304	0.3	0.00912	0.4	0.03652
Cow's milk, whole	17.95	0.0206	0.0206	1.6	0.03296	3.1	0.06386
Cow's milk cheese	2.96	0.034	0.034	1.6	0.0544	3.1	0.1054
Goat's feta cheese	1.7	0.3267	0.196	0.3	0.0588	0.4	0.13068
Sheep's milk cheese	1.53	0.176	0.088	0.3	0.0264	0.4	0.0704
M Mutton/lamb	2.8	0.1464	0.1464	0.3	0.04392	0.4	0.05856
M Goat	6.17	0.3227	0.3227	0.3	0.09681	0.4	0.12908
M Pig	7.24	0.2083	0.1282				
M Beef	3.73	0.0429	0.0215	1.6	0.0344	3.1	0.13299
Total spatial need to produce animal products/ha					**0.3743**		**0.76637**

Table 5. Summary table of the land areas needed to produce foodstuffs in diet sub-models 2a and 2b. Colour coding refers to the individual foodstuffs in tables 2-5 which form the food groups ‘cereals’, ‘fruit crops’, ‘dairy’, and ‘meat’.

SUMMARY				
Diet 2a				
Foodstuff	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Cereals	0.6272	0.4181	0.4181	0.3135
Legumes	0.1049	0.1049	0.0449	0.0449
Fruit crops	0.0559	0.0559	0.0454	0.0454
Olive oil	0.1036	0.1036	0.0496	0.0496
Dairy	0.44574	0.44574	0.22933	0.22933
Meat	0.34789	0.34789	0.22821	0.22821
TOTAL	1.68523	1.47613	1.01554	0.91094
Diet 2b				
Foodstuff	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Cereals	0.6287	0.419	0.419	0.3143
Legumes	0.1049	0.1049	0.0449	0.0449
Fruit crops	0.0559	0.0559	0.0454	0.0454
Olive oil	0.1036	0.1036	0.0496	0.0496
Dairy	0.44574	0.44574	0.19917	0.19917
Meat	0.32063	0.32063	0.17513	0.17513
TOTAL	1.65947	1.44977	0.9332	0.8285

Appendix 15

The agricultural potential of the LH III Argive Plain in Model 1

Table 1. The agricultural potential of the LH III Argive Plain according to sub-model 1a, expressed as numbers of population. The number of people that could be sustained by a specific land area is achieved by dividing the land area (ha) by the individual subsistence areas needed to produce the foodstuffs included in diet model 1a. See Appendix 13 for the formulation of the subsistence areas. Land that could be terraced is added to the land area available in the Argive Plain (= 'plain') and neighbouring valleys and the plain of Asine (= 'valleys').

AGRICULTURAL POTENTIAL, MODEL 1									
Sub-model 1a		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
Yield models		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	**ha**	**1.3884**	**0.9964**	**0.8989**	**0.703**	**1.8182**	**1.42612**	**1.12037**	**0.92447**
plain	24000	17286.08	24086.71	26699.3	34139.4	13199.87	16828.88	21421.49	25960.82
valleys	26800	19302.79	26896.83	29814.22	38122.33	14739.85	18792.25	23920.67	28989.58
terrace 30% use (970ha)	25000	18006.34	25090.33	27811.77	35561.88	13749.86	17530.08	22314.06	27042.52
terrace 60% use (1940ha)	25900	18654.57	25993.58	28812.99	36842.11	14244.86	18161.16	23117.36	28016.05
terrace 90% use (2910ha)	26900	19374.82	26997.19	29925.46	38264.58	14794.85	18862.37	24009.93	29097.75
terrace 100% use (3300ha)	27300	19662.92	27398.64	30370.45	38833.57	15014.85	19142.85	24366.95	29530.43
All areas (100% terrace use)	30000	21607.61	30108.39	33374.12	42674.25	16499.84	21036.1	26776.87	32451.03

Table 2. The agricultural potential of the LH III Argive Plain according to sub-model 1b, expressed as numbers of population.

AGRICULTURAL POTENTIAL, MODEL 1									
Sub-model 1b		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
Yield models		Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	**ha**	**1.3911**	**0.9982**	**0.9007**	**0.7043**	**1.77462**	**1.38172**	**1.08793**	**0.89153**
plain	24000	17252.53	24043.28	26645.94	34076.39	13524.02	17369.66	22060.24	26920.01
valleys	26800	19265.33	26848.33	29754.64	38051.97	15101.82	19396.11	24633.94	30060.68
terrace 30% use (970ha)	25000	17971.39	25045.08	27756.19	35496.24	14087.52	18093.39	22979.42	28041.68
terrace 60% use (1940ha)	25900	18618.36	25946.7	28755.41	36774.1	14594.67	18744.75	23806.68	29051.18
terrace 90% use (2910ha)	26900	19337.22	26948.51	29865.66	38193.95	15158.17	19468.49	24725.86	30172.85
terrace 100% use (3300ha)	27300	19624.76	27349.23	30309.76	38761.89	15383.58	19757.98	25093.53	30621.52
All areas (100% terrace use)	30000	21565.67	30054.1	33307.43	42595.48	16905.03	21712.07	27575.3	33650.02

Table 3. The agricultural potential of tree crop cultivation on terraced fields in the Argive Plain in models 1 and 2. The population numbers here express the number of people to whom tree crops could be produced on terraces only. Since fruit yields, consumption, and production shares are the same in models 1 and 2, these figures apply to both models.

AGRICULTURAL POTENTIAL, MODELS 1 & 2								
Tree crop cultivation on terraces								
	olives, minimum yield	olives, maximum yield	olive oil, minimum yield	olive oil, maximum yield	grapes, minimum yield	grapes, maximum yield	figs, fresh	figs, dried
ha	**0.0043**	**0.0022**	**0.0517**	**0.0247**	**0.0142**	**0.0058**	**0.0177**	**0.0211**
terrace 30% use (970ha)	225581.4	440909.09	18762.09	39271.26	68309.86	167241.38	54802.26	45971.56
terrace 60% use (1940ha)	451162.79	881818.18	37524.18	78542.51	136619.72	334482.76	109604.52	91943.13
terrace 90% use (2910ha)	676744.19	1322727.27	56286.27	117813.77	204929.58	501724.14	164406.78	137914.69
terrace 100% use (3300ha)	767441.86	1500000	63829.79	133603.24	232394.37	568965.52	186440.68	156398.1

Table 4. The agricultural potential of dried figs on terraced fields for palatial payment rations where the need per person is 150kg per annum. Since fruit yields, consumption, and production shares are the same in models 1 and 2, these figures apply to both models.

AGRICULTURAL POTENTIAL, MODELS 1 & 2		
Production of dried figs to palatial rations		
Annual need per person/kg	Yield per ha	Space per person/ha
150	960	0.15625
ha		**People**
terrace 30% use (970ha)		6208
terrace 60% use (1940ha)		12,416
terrace 90% use (2910ha)		18,624
terrace 100% use (3300ha)		21,120

Appendix 16

The agricultural potential of the LH III Argive Plain in Model 2

Table 1. The agricultural potential of the LH III Argive Plain according to sub-model 2a, expressed as numbers of population.

AGRICULTURAL POTENTIAL, MODEL 2									
Sub-model 2a		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	Yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	**ha**	**1.4163**	**1.2072**	**0.7829**	**0.6783**	**2.30724**	**2.09814**	**1.24044**	**1.13584**
plain	24000	16945.56	19880.72	30655.26	35382.57	10402.04	11438.7	19347.97	21129.74
valleys	26800	18922.54	22200.13	34231.7	39510.54	11615.61	12773.22	21605.24	23594.87
terrace 30% use (970ha)	25000	17651.63	20709.08	31932.56	36856.85	10835.46	11915.32	20154.14	22010.14
terrace 60% use (1940ha)	25900	18287.09	21454.61	33082.13	38183.69	11225.53	12344.27	20879.69	22802.51
terrace 90% use (2910ha)	26900	18993.15	22282.97	34359.43	39657.97	11658.95	12820.88	21685.85	23682.91
terrace 100% use (3300ha)	27300	19275.58	22614.31	34870.35	40247.68	11832.32	13011.52	22008.32	24035.08
All areas (100% terrace use)	30000	21181.95	24850.89	38319.07	44228.22	13002.55	14298.38	24184.97	26412.17

Table 2. The agricultural potential of the LH III Argive Plain according to sub-model 2b, expressed as numbers of population.

AGRICULTURAL POTENTIAL, MODEL 2									
Sub-model 2b		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	ha	**1.4178**	**1.2081**	**0.7838**	**0.6791**	**2.18417**	**1.97447**	**1.1581**	**1.0534**
plain	24000	16927.63	19865.91	30620.06	35340.89	10988.16	12155.16	20723.6	22783.37
valleys	26800	18902.53	22183.59	34192.4	39464	12270.11	13573.26	23141.35	25441.43
terrace 30% use (970ha)	25000	17632.95	20693.65	31895.89	36813.43	11446	12661.63	21587.08	23732.68
terrace 60% use (1940ha)	25900	18267.74	21438.62	33044.14	38138.71	11858.05	13117.44	22364.22	24587.05
terrace 90% use (2910ha)	26900	18973.06	22266.37	34319.98	39611.25	12315.89	13623.91	23227.7	25536.36
terrace 100% use (3300ha)	27300	19255.18	22597.47	34830.31	40200.27	12499.03	13826.5	23573.09	25916.08
All areas (100% terrace use)	30000	21159.54	24832.38	38275.07	44176.12	13735.19	15193.95	25904.5	28479.21

Appendix 17

The agricultural potential of the three Argive Plain neighbours; the Berbati and Nemea Valleys and Asine plateau

Table 1. The agricultural potential of the three Argive Plain neighbours; Berbati and Nemea valleys, and Asine plateau in model 1. The results have been achieved with the same individual subsistence area sizes as in model 1 of the Argive Plain agricultural potential (see Appendix 13).

Food production in the neighbouring valleys and plain, Model 1									
Sub-model 1a		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	ha	**1.3884**	**0.9964**	**0.8989**	**0.703**	**1.8182**	**1.42612**	**1.12037**	**0.92447**
Asine	1355	975.94	1359.9	1507.4	1927.45	745.24	950.13	1209.42	1465.7
Berbati	544	391.82	545.97	605.18	773.83	299.2	381.45	485.55	588.45
Nemea and Kleonai	900	648.23	903.25	1001.22	1280.23	495	631.08	803.31	973.53
Sub-model 1b		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	ha	**1.3911**	**0.9982**	**0.9007**	**0.7043**	**1.77462**	**1.38172**	**1.08793**	**0.89153**
Asine	1355	974.05	1357.44	1504.39	1923.9	763.54	980.66	1245.48	1519.86
Berbati	544	391.06	544.98	603.97	772.4	306.54	393.71	500.03	610.19
Nemea and Kleonai	900	646.97	901.62	999.22	1277.86	507.15	651.36	827.26	1009.5

Table 2. The agricultural potential of the three Argive Plain neighbours; Berbati and Nemea valleys, and Asine plateau in model 1. The results have been achieved with the same individual subsistence area sizes as in model 2 of the Argive Plain agricultural potential (see Appendix 14).

Food production in the neighbouring valleys and plain, Model 2									
Sub-model 2a		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	Yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	ha	**1.4163**	**1.2072**	**0.7829**	**0.6783**	**2.18267**	**1.97357**	**1.1572**	**1.0526**
Asine	1355	956.72	1122.43	1730.74	1997.64	620.8	686.57	1170.93	1287.29
Berbati	544	384.1	450.63	694.85	802.01	249.24	275.64	470.1	516.82
Nemea and Kleonai	900	635.46	745.53	1149.57	1326.85	412.34	456.03	777.74	855.03
Sub-model 2a		CROPS	CROPS	CROPS	CROPS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS	CROPS & ANIMALS
	Yield models	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields	Minimum yields	Medium yields 1	Medium yields 2	Maximum yields
Land area	h	**1.4178**	**1.2081**	**0.7838**	**0.6791**	**2.18417**	**1.97447**	**1.1581**	**1.0534**
Asine	1355	955.71	1121.6	1728.76	1995.29	620.37	686.26	1170.02	1286.31
Berbati	544	383.69	450.29	694.05	801.06	249.06	275.52	469.73	516.42
Nemea and Kleonai	900	634.79	744.97	1148.25	1325.28	412.06	455.82	777.13	854.38