Economic Development and Environmental History in the Anthropocene

Perspectives on Asia and Africa

Edited by Gareth Austin

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This book is dedicated to the memory of Peter Boomgaard, 1946–2017

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Preface

This book stemmed from a belief that, in a time when open-minded citizens around the globe have become more aware than ever of the often unstable interactions between human activity and our physical environment, economic historians and environmental historians, together with colleagues from economics and geography, need to work more closely together in research and teaching. The project was born in Geneva, at the Graduate Institute of International and Development Studies, with a small conference on 26–27 September 2014, generously funded by the Pierre du Bois Foundation for Current History. I am delighted to pay tribute to the support of the board of the Foundation, and especially Irina du Bois, who invited the proposal for the conference, assisted with the arrangements and attended both the conference itself and the accompanying public forum. Valérie van Daeniken and Gabriel Geisler Mesevage of the Institute's Department of International History provided excellent organizational support. While most of the chapters were first presented at that conference, I am particularly grateful to three conference participants who, seeing the way our collective discussions had developed, very kindly decided to write new and very different essays for the book: Tirthankar Roy, Kaoru Sugihara and Julia Adeney Thomas. I am equally grateful to Peter Boomgaard and Emily Osborn, who gracefully agreed to join the project after the conference. Indeed, I am extremely appreciative of the whole team of authors, who contributed so much time in a very self-disciplined manner, and of Bloomsbury Academic, in the persons of Emma Goode and initially also Claire Lipscomb, who encouraged us throughout. I also thank the publishers' anonymous reviewers, who not only made the right recommendation but also provided extremely shrewd and constructive criticism that has helped us improve the cohesion and content of the book. Finally, I pay tribute to my wife, Pip Austin, who did much of the initial copy-editing and the majority of the indexing, and did her best to keep the editor relatively sane.

Gareth Austin

Geneva and Cambridge, December 2016

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Introduction

Gareth Austin

At the beginning of this century the Dutch Nobel-prize-winning chemist Paul Crutzen proposed 'to assign the term "Anthropocene" to the present, in many ways human-dominated, geological epoch', and to date its beginning to the British industrial revolution, starting in the latter part of the eighteenth century (Crutzen 2002; also Crutzen and Stoermer 2001). He highlighted the large and growing rate of burning of fossil fuels (following James Watt's improvement of the steam engine) and the resulting emission of greenhouse gases, and also emphasized deforestation and the accelerated conversion of land to agricultural and urban uses. Other natural scientists insist that it was only with the radioactivity from open-air nuclear tests that our species became an agent of geological change. That would place the origin of the epoch at the beginning of the 1950s, which for Crutzen and co-authors was just after the beginning (1945–50) of what they called 'the Great Acceleration', that period within the Anthropocene when every component of the human impact on the rest of nature intensified, including multiple extinctions of other species (Steffen, Crutzen and McNeill 2007). The Anthropocene Working Group (AWG), reporting to the International Geological Congress in Cape Town in August 2016, endorsed the idea of a 1945–50 beginning for the Anthropocene, featuring not only nuclear explosions but also the proliferation of domesticated chickens and plastic pollution (for an example of the latter, see Osborn's chapter).

The process that accelerated from 1945–50, however, clearly had chronologically deeper roots. The end of the last ice age inaugurated the Holocene, an epoch in which the temperature and rainfall conditions over much of the planet made possible both the original (Neolithic) agricultural revolution and the industrial revolution. The latter was a watershed in human history, in that there now seems little doubt that, in a vicious dialectic, the worldwide – albeit not universal – spread of industrialization has undermined some of the environmental foundations of continuing economic development. For the already 'developed' economies, a continuation of present

This chapter has benefitted from feedback received on seminar presentations in Oxford and Cambridge in November and December 2015. I thank Marc Le Henanf, of the library of the Graduate Institute in Geneva, for assistance beyond the call of duty in accessing online publications.

trends may put at risk the maintenance of existing economic achievements.[1] For late-developing economies, the risk is that there will not be enough physical resources available to allow them to catch up the forerunners, and thus permit the whole world to enjoy the living standards currently confined to a select, though recently much expanded, group of countries.[2]

Ironically, the further economic advance of poorer countries is at risk both from the predicted effects of global warming and from the measures desperately needed to mitigate it. Rising sea levels, resulting from large-scale melting of polar ice, threaten to flood low-lying cities and countries, especially in economies with very limited resources for protective measures. The reduced rainfall predicted for certain regions would imperil crop yields and extend deserts. Meanwhile, different parts of the 'developing world' have specific resource problems, such as water shortages and accelerated depletion of soil nutrients which, in the absence of global warming, could be handled by the acquisition and application of additional inputs in the form of desalinated sea water and chemical fertilizers. Both the latter, however, are fossil fuel intensive to produce; and fertilizers themselves require water. Thus major reductions in fossil fuel use are difficult to combine with solutions to the often more immediate and relatively localized resource constraints. Again, it is likely that any serious global resolution to reduce consumption of fossil fuels would significantly reduce the export earnings of oil producers in middle-income and poor countries as well as rich ones.

This book combines new research and critical overviews that explore the interactions between human populations and their physical environments, in the process of economic development and in the context of the Anthropocene. We focus on four world regions in which industrialization and self-sustained (or so it seemed) economic growth began later than in the West: East Asia, Southeast Asia, South Asia and Sub-Saharan Africa. So far, it is only some of the East Asian countries – Japan long since, more recently Hong Kong, Taiwan and South Korea – and Singapore that have caught up the West in income per head. But much of the rest of Southeast Asia, plus India and, most dramatically, China, have significantly narrowed the gap over the last thirty-five years or so. In Sub-Saharan Africa, as a whole, economic growth seems to have outpaced population growth by about 2 per cent since 1995, when the latest primary commodity-led boom in African history began. Despite some promising signs, it remains to be seen whether this can lead on to industrialization: while growing in absolute terms, manufacturing as a share of GDP actually slipped between 1980 and 2010, to 11 or 12 per cent (Austin, Frankema and Jerven 2017). The four regions have in common that most of their component countries were Western (mainly European) colonies in the nineteenth and early twentieth centuries, or were subject to unequal treaties imposed by Western imperial powers in the nineteenth century. Together, these regions are estimated to have 72 per cent of the world's population, 5 billion out of 7 billion. In mid-2016 this comprised nearly

[1] As a lay person in this area I rely on the Stern report (conveniently, see Stern 2008a,b; and now Stern 2015) and on the updated prognoses of the Intergovernmental Panel on Climate Change (IPCC 2015).

[2] On the implications for historians, see Parthasarathi (2014).

1,620 million in East Asia, over 1,850 million in South Asia, over 970 million in Sub-Saharan Africa and over 630 million in Southeast Asia (Population Reference Bureau 2016).

The following chapters consider human responses, at regional and local levels, to economic and environmental challenges – and opportunities – that arose at a range of scales. At global level, besides climate change, there are international flows of knowledge, commodities and capital, which may offer producers in one area the chance to import some sort of solution to their particular energy or other resource needs, importations which may be adapted to local needs with varying degrees of success. Interactions between the global and the regional or local must be seen in the context of the specific approaches, often reinforced by past experiences and choices, with which local populations and states had reacted to their own environments.

This book is intended to contribute to the discussion of economic development during the transition from the Holocene to the Anthropocene, in three broad ways. First, at a global level, the chapters present perspectives from different disciplines – history, economics and archaeologically informed geography – to the intellectual challenge that the Anthropocene presents to the social sciences and humanities in general: how our thinking needs to respond to the fact of humanity as a major force in changing, not just our landscapes but also our physical environment in general. Second, although the subject is in the intersection set of environmental history and economic history, neither sub-discipline has given it the attention it requires, and each can learn from the other: a cause which this book is intended to advance. Third, in a comparative historical framework, whereas the early historical reflections on the Anthropocene have generally focused on the West, where industrialization began, this book concentrates on the modern history of environment-economy interactions in Asian and African countries which became, or seek to become, 'late-developing' in the sense of engaging in rapid economic development, epitomized by but not confined to industrialization, in a setting fundamentally altered by the fact that other countries had already industrialized.

Before outlining the chapters to come, this introduction presents one economic historian's angle on the natural scientists' debate about the origins of the Anthropocene, and pursues the ambition of combining the insights of economic and environmental historians, by focusing on the implications of the recognition that specific natural resources have very different properties for the analysis of the intersection between economic development and environmental change.

An economic history perspective on the Anthropocene

For some observers, the notion of the Anthropocene has an air of hubris: in current parlance, 'it's all about us'.[3] With so much evidence of anthropogenic change, however,

[3] For general reflections on the concept and its implications, see Bonneuil and Fressoz (2016); for a short late-modern history, see McNeill (2015); for the most detailed history yet of its climate change component, see Brooke (2014).

going far beyond the long history of humans shaping landscapes and soils, it is difficult not to see the coining of the concept as an overdue acceptance of responsibility. The Anthropocene is a disturbing not a comforting idea, especially given that the distribution of the economic gains whose achievement was responsible for most of the human-made environmental change over the last two centuries hardly corresponds to the distribution of the environmental and economic costs, existing and future. Again, recognition of the Anthropocene may be seen as the logical extension of accepting that economic activity and environmental change interact. The alternative is not a realistically modest human sensibility, but, rather, the traditional tendency among some economists and economic historians to assume away any environmental/resource limits to what humans can do (Thomas's chapter).

Crutzen's proposal that the 'Anthropocene' be recognized as a geological epoch launched a debate among natural scientists, which continues at the time of writing, about when anthropogenic environmental change first became sufficiently visible in the geological record to justify the designation of a new era.[4] The debate will certainly continue, despite the recent pronouncement by the AWG. Four major candidates have been put forward so far. The most recent period proposed is the above-mentioned Great Acceleration, the argument being that this is signified geologically by the fall-out from the atmospheric nuclear explosions carried out between 1945 and 1963, before atmospheric tests were inhibited by the Nuclear Test Ban Treaty. Supporters of the original candidate, the British industrial revolution, include the independent scientist James Lovelock (2012). Like Crutzen, he focuses on the harnessing of steam power, and therefore of carbon dioxide emissions, though he dates the Anthropocene not from Watt's improved steam engine but from the first commercially practicable one, designed by Thomas Newcomen in 1712, which was not only fuelled by coal but also raised the productivity of coal mining by pumping water out of mines. Most recently, from the perspectives of climatology and plant ecology, Simon Lewis and Mark Maslin (2015) have proposed an earlier historical watershed as the start of the Anthropocene: the 'collision' of the Old and New Worlds, which not only involved an unprecedented intercontinental exchange of species but also entailed a drastic decline in the indigenous population of the Americas. This depopulation resulted in the reversion to forest of an estimated 65 million hectares. Lewis and Maslin suggest that this led to the marked decline in carbon dioxide concentrations in the atmosphere between 1570 and 1620 (Lewis and Maslin 2015: 174–6). Going back still further, the palaeoclimatologist William F. Ruddiman (2005) argues that humans began to affect the climate long before the industrial revolution or even the Columbian exchange, through the methane-producing effects of the domestication of animals and of the growth of Asian wet-rice agriculture.[5]

The scientific debate focuses on measurement: the search for stratiographic markers, especially those that will be visible in hundreds or thousands of years' time,

[4] A valuable survey is provided by Lewis and Maslin (2015), which has itself provoked debate, notably in the *Anthropocene Review*.

[5] For a very succinct survey of the debate about Ruddiman's hypothesis, see Roberts (2014): 230–31; see also Lewis and Maslin (2015): 174.

as is appropriate in geological terms. What the geologists decide about how they designate geological eras is a matter for them. However, as Christophe Bonneuil and Jean-Baptiste Fressoz write:

> The scientists who invented the term 'Anthropocene' did not simply produce fundamental data on the state of our planet or advance a systemic and fruitful perspective on its uncertain future. They also proposed a history, a story seeking to respond to the question 'how did we get here?' (Bonneuil and Fressoz 2016: 47)

Historians have a duty to comment on this history, especially as the various candidate dates are not necessarily of equal or indifferent significance for students of human history and economic development, when we mobilize more traditional kinds of historical research in the collective attempt to understand how humanity has reached the present environmental and economic-developmental predicament. Conveniently, most of the candidate dates fit well with historians' sense that it is processes, not specific years, that mattered most. Precisely when the growth of paddy-rice agriculture and herding reached the point at which the combination of their resultant methane emissions began to make a distinguishable difference to the atmosphere is much less important than the fact that this occurred, as a result of two of the older and most continual routes of intensification in human use of the land. The decline in the indigenous population of the 'New World' was clearly the result of a longer process of colonial intervention going back to 1492 (and beyond). The development of steam-engine technology, in a series of steps, was part of a broader and longer set of changes that gave rise to, and continued through and beyond, the first industrial revolution.

It should be added that, as a result of the accumulated research of recent decades, economic historians now see the British industrial revolution (conventionally dated 1760–1850) as having been preceded by an era of proto-industrial, often discontinuous, economic growth in Western Europe and in various other parts of the world, especially in Asia (see, for instance, Jones 1988; Pomeranz 2000; Parthasarathi 2011; de Vries 2013). The phase of atmospheric testing of nuclear bombs may yet turn out to have been an indispensable step in a specific technological and political process culminating in a nuclear Armageddon. Otherwise, it may prove to be rather less central to the broader historical processes of which it was part than, say, the steam engine was to the origins of the British industrial revolution and, thereby, to the start of the worldwide spread of industrialization.

This leads us to the crucial question of how far each candidate process led to the next one: the causal relationships, if any. From this perspective, atmospheric nuclear explosions may be the best-documented human intervention in the geological record, but they began much too late to be the starting point of the human interactions with the physical environment that ultimately included – to take the most obvious example – anthropogenic climate change. The same applies to plastics and domesticated chickens.

Stock-keeping and wet-rice farming is a more complex case. Both were foundations of the polycentric economic world from which the industrial revolution emerged. It has also been argued that the work discipline learnt in the paddy fields contributed to the discipline of the early Japanese factory labour force, thereby assisting the spread of industrialization beyond Europe (Sugihara 2000: 20). But the growth of stock-keeping and paddy fields had been happening for an extremely long time, and much else had to happen before industrialization became possible anywhere.

Lewis and Maslin show that the collision of the Old World and the New has a good claim to meet the measurement criteria for the beginning of the Anthropocene. In the economic historiography, Kenneth Pomeranz (2000) argued that the 'ghost acres' of the Americas, tilled by (in the majority) slaves imported from the southern part of the Old World, Sub-Saharan Africa, played a crucial role in enabling Britain to overcome the resource constraints (of land and energy) that curtailed Chinese economic development, allowing Britain to become the first industrial nation.[6] But the marker identified by Lewis and Maslin – reforestation caused by depopulation – is inversely related to the origins of worldwide industrialization, the process which unambiguously constitutes the driver of modern anthropogenic climate change. Rather than producing carbon emissions and global warming, the human catastrophe of depopulation led to carbon sequestration and global cooling, reinforcing the Little Ice Age. That the latter had major (politically and socially mediated) consequences for societies around the world has been argued in detail in a magisterial study by Geoffrey Parker (2013). But it was hardly the origin of the greenhouse gas crisis of the twenty-first century: it was a move in the opposite direction.

On measurement grounds, Lewis and Maslin downplay the claim of the industrial revolution. From an economic historian's perspective, there is an almost unstoppable dynamic from the Industrial Revolution to the Great Acceleration since 1945 (despite several actual and possible detours and pauses along the way). On my reading of the economic historiography, Crutzen and Lovelock are more convincing because they focus upon steam power and therefore on fossil fuel. Again, it is not the date of an individual invention that matters, but rather the fact that both Newcomen's and Watt's breakthroughs were part of a logical series of inventions, whose application to the economy was favoured by the circumstances of the time[7] and which unleashed the continuous growth in fossil fuel use that we have seen ever since. Thus, while for Lewis and Maslin the years 1610 and 1964 (standing for 1570–1620 and 1945–1963/4, respectively) are the most plausible dates with respect to identifying when humans came to be the major source of contemporary change in the physical environment, and while 1945–50 has attracted the support of the AWG, the decisive process was that which launched what became the incomplete but worldwide spread of industrialization.

[6] Current research by Paul Warde and colleagues points, however, to early-nineteenth-century Britain being a net exporter of 'ghost acres'.

[7] Note, in particular, Allen's (2009) argument that it was profitable to use these inventions, substituting capital for labour, in Britain first because wages were relatively high there. See, further, the exchange between Humphries (2013) and Allen (2015). On the intellectual and cultural circumstances, see Mokyr (2009).

Literatures

Historians generally have begun to think through the implications of the Anthropocene for their own work, perhaps beginning with the intervention of Dipesh Chakrabarty (2009), which starts with the proposition that anthropogenic explanations of climate change collapse the distinction between natural and human history (though see also Thomas 2014). This was followed by the first book-length history of – and commentary upon – the Anthropocene, published in French by Bonneuil and Fressoz in 2013 and now translated into English (2016), and by John Brooke's detailed synthesis of what has emerged as the central element in the Anthropocene, *Climate Change and the Course of Global History* (2014). The present book is intended to build from Chakrabarty's 'collapse', and, in focusing upon Asia and Africa, balance the strongly Eurocentric (or rather, Occicentric) treatment of Bonneuil and Fressoz and also of Brooke. Further, we also see climate change alongside other environmental consequences of economic activity (cf. McNeill 2015). Let us briefly consider the implications for two traditionally separate fields, environmental and economic history; and for environmental and development economics, which have at times been close to economic history.

Environmental history had already become a large and varied field before Crutzen popularized the concept of the Anthropocene, and its growth has continued since. An example of the health of this literature – if not of its subject of study – is that for well over a decade *Environmental History*[8] has been one of the most cited of all history journals. Ironically, though, the systematic examination of the relations between economic and environmental change has often seemed to be only at the periphery of specialist environmental historiography, despite the general acknowledgement that, in John McNeill's words, 'Most of the things people do that change environments count as economic activity' (McNeill 2000: 5). Some years ago, Joachim Radkau asserted that environmental historians 'have tended to avoid core areas of the relationship between humans and their environment' (Radkau 2008: 2). He did not specify the economic among these areas, but if he had, the statement would still appear to be largely true, as the content of recent volumes of *Environmental History* confirms.[9] This may be because environmental historians have a lot else on their plate. Much of the literature in the field addresses the environmental imprints of humans in particular ecosystems, relating to but often not focused upon the economic implications; cultural conceptions of the environment, including clashes between different conceptions; and the politics of pollution and conservation. Indeed, to take a pertinent example, the study of the environmental impacts of European colonialism is about much more than simply the economic calculations of the colonizers and their interactions with those of the colonized (Beinart and Hughes 2007). Still, at least to a sympathetic outsider,

[8] Founded 1996, albeit from a merger.

[9] The 2014 volume of *Environmental History* contains just one article that could be described also as economic history. The same was true of the first volume, in 1996. The 2015 volume had none, but the 2016 has three: a blip or a portent?

the comparative marginality of the economic dimension within environmental historiography is ironic considering the primacy of economic actions in driving environmental change.

There is a corresponding irony in the treatment of the environment in my own field, or sub-discipline, economic history. Neoclassical economics was traditionally defined as the study of optimization under scarcity. Yet much mainstream economic history – within which most arguments owe much, indirectly and often directly, to the economizing logic of neoclassical economics – tends to give causal priority either to the institutions – defined as the rules – surrounding economic activity (e.g. Greif 2006; North 2005) or to the capacity of technological innovation to escape the constraints of nature (Mokyr 2009).[10] Clearly, institutions and technology matter in historical causation, as do culture and politics. But so do specific properties of the physical environment. Without the rise in temperatures that followed the Ice Age, it is unlikely that we would have a society today that could afford professional historians or economists. Without the availability of abundant coal plus raw cotton grown in North America by African slaves, industrialization could hardly have begun where and when it did, in late-eighteenth-century Britain (Pomeranz 2000; O'Rourke, Prados de la Escosura and Daudin 2010). Without coal specifically, it is difficult to see how British industrialization could have been sustained, thereby achieving a historic breakthrough from the old pattern of economic growth stopping and starting in the 'organic economies' that preceded it (Wrigley 2010). In turn, whether that historic breakthrough proves to be permanent is put into doubt in the most pessimistic scenarios for the future of the economy-driven Anthropocene.[11]

There is, however, a tradition in economic historiography which takes the physical environment seriously. Some recent work seeks to disaggregate the category of 'land' (natural resources) or 'natural capital' as a factor of production, recognizing that the specific attributes of particular resources present distinctive opportunities and constraints. This approach is evident, explicitly or implicitly, in many of the chapters that follow.

Several contributors to this book draw on environmental economics, for example for the concepts of resource rent (as in 'forest rent' in the chapters by Ross and Austin) and carrying capacity (in Roy's chapter). In return, as it were, several chapters comment on the notion of the 'Environmental Kuznets Curve' (EKC), which has been the subject of numerous economics papers (Miyama and Managi 2015) but which, to my knowledge, has not been placed in any detailed historical perspective. The original Kuznets Curve was named after a distinguished economic historian, a pioneer of historical national income accounting, who found an empirical regularity between the distribution of income and economic growth over time: as income per head rose, its distribution initially became more unequal (e.g. during industrialization) but then, as income rose further, the inequality diminished, roughly back to the status quo ante.

[10] The institutionalist approach is specifically influential and has been endorsed by a trio of leading growth economists: Acemoglu, Johnson and Robinson (2005) and Acemoglu and Robinson (2012).

[11] See the incisive reflections on the recent historiography of the British industrial revolution in Albritton Jonsson (2012).

While Simon Kuznets' curve is controversial (and is often said to be discredited),[12] the EKC has the same inverted-U shape, with environmental damage rising and then falling as per capita income rises. Aspirationally at least, it is the self-fulfilling basis for the 'grow first, clean up later' approach to the environment, which is discussed in Pomeranz's chapter.

While the EKC fits a lot of the evidence (Miyama and Managi 2015), this book points to three fundamental problems with the concept. First, it treats the various parts of the physical environment as if they are either parallel to each other or can at least be aggregated: as if a single measure can represent all of them. In contrast, several chapters here show that different environmental assets (water, energy, soil nutrients, etc.) are largely discrete, and therefore require separate treatment. Peter Boomgaard's chapter finds an EKC in the context of deforestation and forest regrowth in Southeast Asia (the 'forest transition curve'); but the same does not necessarily apply to all other dimensions of environmental change. The second point is related to the first. Precisely because different parts of 'natural capital' cannot be substituted for each other (either not cheaply or not at all), countries which are very late in industrializing are likely to find that their options for cleaning up have been pre-empted by countries that got in ahead of them. If Mali or Kazakhstan desperately needs more water in 2075, will this be possible and affordable if desalination is still fossil fuel intensive in a world in which fossil fuel emissions have at last been severely restricted? Finally, for many countries the good news reported in the latter part of the EKC is misleading at a global level because reduced domestic emissions of fossil fuels, for instance, may be bought simply by exporting the fossil fuel-intensive production to distant countries with the political capacity to produce fossil fuels.

Perspectives on and from the late Holocene, c.1450 to c.1760/1800

As with the recurring economic growth and proto-industrial expansions in parts of Europe and Asia that preceded the Industrial Revolution and Great Divergence, the Anthropocene was prefigured by a long history of smaller human interventions in the environment, on and immediately below the surface (affecting landscape, vegetation and soils), and even in the atmosphere.

A case could be made for identifying the three centuries or so before the British industrial revolution as the 'transition' from Holocene to Anthropocene, when the scientific, economic and political conditions for the beginning of industrialization *somewhere* fell into place. This is the era conventionally known as the early modern period; now also described, in an equally (but more strongly defensible) Eurocentric way, as the 'First Global Age', with the European circumnavigation of the world and conquest of the Americas, and increased traffic between Asia, Africa and Europe, launched by Portuguese trade-and-gunpowder imperialism, especially in the Indian

[12] But see Feinstein (1998), which effectively revived it in the long-disputed case of the British industrial revolution.

Ocean. It was not only a time of widespread proto-industrialization but also the era in which the Mughal Empire adopted a currency based on silver mined in Peru, in the Spanish Empire. It was a period when technological advances in the ceramics and textile industries of Europe were stimulated by Asian models. Indeed, it was the era when a combination of European colonization and armed trade in the Americas and Atlantic, and scientific and technological advances in Europe, eased the above-mentioned ecological bottlenecks that otherwise made it unlikely that the industrial revolution – and therefore the start of the Anthropocene, in Crutzen's chronology – would have occurred until decades later at least.

In this book, focused on four regions of Asia and Africa, two aspects of the period require and receive particular attention. One is early modern European empires, under which Alfred Crosby's 'biological expansion' of European flora and fauna, including humans, really got going.[13] Exploring the evidence of anthropogenic environmental changes in this context, Amélia Polónia and Jorge Pacheco's chapter challenges the explanatory value of the term 'ecological imperialism', arguing instead that the overall story was one of 'ecological adaptation', reflecting the agency of colonial subjects as well as the ambitions of colonialists. The environments the Europeans entered were cultural rather than simply natural products. The newcomers, the surviving locals and the ecosystems themselves had to adapt to each other. Polónia and Pacheco argue that, for all the destruction and stress wrought by the invaders, both ecosystems and human communities 'showed a surprising adaptability and created alternative patterns of survival through the emergence of syncretic biomes as well as alternative behaviours and cultural patterns' – perhaps an optimistic sign for our own futures. They also emphasize that different colonizations, whether by the same European power in different regions or by different European powers in the same regions, took importantly different patterns. They go on to propose that research in this field can best be carried forward using the theory of cooperation and 'self-organization', previously applied in other social sciences,[14] usually on a scale smaller than colonies or empires.

The other aspect of the early modern period that is examined here was the general tendency for an expanding human population to use more of the planet for habitation and sedentary cultivation, notably by clearing forests – a process John Richards called 'intensified human land use along settlement frontiers' (Richards 2003: 4). We have already noted a tragic qualification: that the opposite tendency applied during depopulation in the Americas. After that, land clearances by the new arrivals from the Old World became increasingly evident. Richards' environmental history of the period established the broad pattern for most of the Old World, but did not cover tropical Africa (Richards 2003).[15] It should be noted that 'intensified land use' is a broader category than agricultural intensification, defined as increasing inputs per

[13] Though, as Crosby (1986) insisted, it had begun on a smaller scale earlier.

[14] Also by archaeologists interpreting the phenomenon of urbanization without political centralization (McIntosh 2005).

[15] This landmark book has a chapter on the Dutch colony at the Cape, but tropical Africa features only in a short account of climatic trends in West Africa.

unit of cultivated land. While there was plenty of the latter in the early modern world, notably in Tokugawa Japan, extending the area under cultivation with the same levels of inputs per hectare is 'extensive' growth in economic terms, even though it will also be 'intensified human land use' if it comes at the expense of forests.

Mats Widgren's chapter shows that Sub-Saharan Africa in the 'early modern' period was no exception to either trend of intensification, despite a relatively low average population density. Earlier work by Widgren and colleagues demonstrated that intensive agriculture, manifested in investment in terraces and irrigation, was ancient and ever-present (somewhere) in Sub-Saharan (including tropical) Africa, despite the overall abundance of land. However, the 'islands' of intensive agriculture were seen as exceptions, characteristically found not on plains but on hills, as when a politically decentralized group took refuge from slave-raiding states. His most recent joint research, mapping the development of agriculture worldwide during the last millennium, goes further. Widgren notes examples of intensification on plains as well as hills, including areas under state dominion. Crucially, he argues that, while we already knew that intensive agriculture came and went on many of the sites for which evidence of it exists, the indications now are that there was an overall trend: intensive agriculture became more common in Sub-Saharan Africa during the sixteenth to eighteenth centuries, often stimulated by markets for food to support long-distance trades, including the Atlantic slave trade. Widgren's analysis alters our understanding of African economic and environmental history, and reinforces the sense that, globally, the Anthropocene was the product of processes long in train.

Demands from population and industry under late-modern imperialism, c.1800 to mid-twentieth century

Prasannan Parthasarathi's chapter examines the intensification of resource use in South India in the context of the industrial revolution and, eventually, of the regime of international free trade underpinned and enforced by British (and in East Asia, multilateral Western) imperialism. Whereas the existing historiography of forests in South India focuses on the hills, he maps a rapid deforestation of the plains. This was a response to demand from two core components of nineteenth-century industrial technology, railways and factory-scale iron smelting, plus also from modern sugar mills (engaged in boiling sugarcane juice), all of which were highly energy intensive. The iron and sugar plants could be seen as frontrunners in the (overall, very slow) growth of modern industry in colonial India. A 'new energy economy' emerged, centred on Madras, which itself was rapidly expanding, creating a huge market for firewood. Parthasarathi emphasizes that the early colonial railway engines and other steam-powered machines did not use coal, but rather wood: a hybrid energy system, operating engines designed to burn a fossil fuel with biomass fuel instead. He argues that this early 'bio-mineral' compromise, hugely destructive of local biomass, turned out to be anything but an encouraging sign for such compromises – notably ethanol – in our own time.

A different chronology and origin for deforestation emerges from Boomgaard's analysis for Southeast Asia. He emphasizes the longevity of anthropogenic landscape change, this time in relation to large-scale logging, especially in Java, where the Dutch East India Company used teak for building and repairing ships, expanding in scale upon what was already a Southeast Asian tradition. But, in the region as a whole, he identifies population growth as the main source of land clearance before 1950. In this sense, net deforestation in this historically lightly populated region became widespread only a century or so into the Anthropocene, if the latter is dated from the first industrial revolution.

Even within this, while the spread of industrialization created demands on natural resources around the world, in the case of Southeast Asia, during the colonial period the impact was much less to clear land permanently, and much more to promote its conversion to export agriculture. Here, as in Sub-Saharan Africa, the growth of agricultural exports was often not simply a matter of increased external demand for an established local crop: in some important cases, the crop itself was newly introduced. Southeast Asia and Sub-Saharan Africa have in common long histories of 'land abundance', in the sense that, with certain qualifications (especially seasonal), the expansion of agricultural output was constrained by the supply of labour rather than land. Cocoa and hevea rubber are prime examples of a crop and a crop variety, respectively, whose late-nineteenth and twentieth-century careers epitomize the combination of exotic cultigen and – initial – land surplus. Both originally grew wild in Amazonia. The market for cocoa beans and latex was, respectively, vastly enlarged or created by inventions of the second industrial revolution: milk chocolate, and bicycles and, above all that quintessential agent of the Anthropocene, the internal combustion engine.[16] While their expansion was hindered by the pests and diseases which had long lived with them in their native habitat, especially in the case of rubber, they were adopted on what rapidly became a much larger scale in Southeast Asia (rubber, and more recently also cocoa) and West Africa (cocoa, and, later, to some extent also rubber). Both cultigens, in the two regions in which they were so successfully adopted, were grown, or at least experimented with, by indigenous farmers and on foreign-owned plantations.

In his chapter, Ross examines the case of rubber in Southeast Asia, showing 'how a particular set of biophysical conditions' was a fundamental influence on the development of the industry. Indeed, the success of rubber cultivation in the region was made possible by, and continues to rely upon, the absence of leaf blight, the disease that aborted monocultural cultivation of *hevea brasiliensis* in its native habitat. However, he emphasizes that there were different ways of responding to the same set of conditions; though did not mean that they were equally competitive. Both Ross and Austin have previously worked on cocoa farming in the colonial era, when – ironically – indigenous farmers outcompeted European planters for market share wherever the state allowed the competition to be relatively free. The main reason for this was European planters' persistence in using methods that were much more labour

[16] Unlike rubber, cocoa beans had a much older history as a commodity. See Clarence-Smith (2000).

and capital intensive than those of their local rivals, in conditions that, as the locals understood, favoured more land-extensive methods. Their stubbornness seems to be inexplicable in the categories usually used by economic historians, of economic or political-economic rationality (Austin 1996; Ross 2014). Ross shows here that the story was similar in the case of rubber in Southeast Asia: neatness, at whatever cost, was for European planters a principle more important than profit. He also underlines the environmental cost of clean weeding in a region where rainfall was high and concentrated: the rubber estates (plantations) were a source of soil erosion on a spectacular scale, especially in colonial Malaya.

There is a parallel here with McNeill's argument about the scale of the 'global surge in soil erosion' that came from European expansion and 'the integration of world agricultural markets' (McNeill 2000: 38). While the first of these processes began in the fifteenth century, the second (defined by commodity price convergence) mainly awaited the transport revolution and freer trade of the nineteenth century (O'Rourke and Williamson 2002). McNeill suggested that the fact that 'the conquerors and colonizers of the modern world' came from northern Europe, a region 'very unusual' for its comparative invulnerability to soil erosion, accounts for most of their impact on the soils. The 'same systems of cultivation and grazing' that they used back home, 'when transported to landscapes with lighter soils, steeper soils, and more intense rainfall, led to devastating erosion in the Americas, South Africa, Australasia, and Inner Asia' (McNeill 2000: 39). The European planters who participated in the shift of the centres of cocoa and rubber cultivation to West Africa and Southeast Asia – a response to the integration of world agricultural markets – also brought with them a template based on experience elsewhere (the Caribbean, with different varieties of the crop, in the case of cocoa planting), and refused to adjust it to the unfamiliar conditions. Albeit, in the case of the export crops from the land-abundant humid tropics, it was the economic circumstances (such as the relatively high cost of labour) as well as the environmental setting which induced the problems. Still, cocoa and rubber take less from the soil annually than grains such as maize; and growing tree crops absorb carbon dioxide from the atmosphere. On the other hand, over the life of a cocoa farm the soil nutrients are depleted. François Ruf (1995a,b) has argued strongly that, in the world history of cocoa production, the most profitable country in which to grow cocoa at any given time has always been one in which the land concerned is newly cleared from forest.

While Parthasarathi focuses on the environmental costs and systemic risks associated with the new 'energy economy' he describes, the other India chapter, by Tirthankar Roy, focuses on the agricultural use of land, and particularly soil degradation in the context of agricultural expansion over the last 120 years. Whereas the existing historiography of South Asia has seen environmental history predominately through the lens of colonial interventions, Roy focuses on the dynamic interaction between environment and economy, highlighting the pressure that expanding agriculture put upon 'carrying capacity', in the language of ecological economics. Output expanded in the later nineteenth and early twentieth centuries, led by export crops, largely by extending the area under cultivation. By about 1930, the carrying capacity of land had reached its limits in most parts of the subcontinent, resulting in a near-stagnation of output, and of real agricultural wages, that lasted until carrying capacity was enhanced – sustainably or otherwise – by Green Revolution technology in the 1960s to 1970s. While acknowledging the role of, for example, colonial railways and post-colonial investment in higher-yielding varieties of seedling, he argues that Indian environmental historiography has overstated the impact of the state while underestimating the importance of the physical characteristics of the subcontinent, such as the constraints on profitable investment in water supply for agriculture (canals and wells).

This leads us to the general problem of squeezing more from the land in the context both of the twentieth-century population explosion and of generating sufficient import-purchasing power to permit the import of capital goods and raw materials to launch more late industrializations. Reflecting colonial priorities, the Green Revolution in food crops was preceded by the development of high-yielding varieties of cash crops, especially rubber from the 1930s, followed by cocoa by 1950. All these varieties, including 'miracle' rice and maize, required more water and more (fossil-fuel-based) fertilizers (the overuse of the latter, in some cases polluting the water table). Indeed, after the controversy over Green Revolution technology in the 1960s to 1990s, perhaps the chief remaining blight on its record in South Asia is the question of its environmental sustainability (cf. for example, Shiva 1991; Orr 2012).

Austin's chapter links the themes of Widgren and Roy. He argues that until well into the twentieth century at least, Sub-Saharan agricultural practices, while including elements of intensification, broadly fit a 'land-extensive' path of development, in which returns to labour were given priority over yields per unit area. This was logical in a region where it was usually the supply of labour, not land, which constrained the expansion of output. It was also often a response to environmental constraints such as thin topsoil, which – along with animal sleeping sickness in much of the subcontinent – usually meant reliance on the hoe rather than the plough. Hence cultivation usually relied mainly on fallowing to restore soil fertility; while pastoralism was transhumant, thus also extensive. In this context, the main route to improved food security and higher incomes was the selective adoption of exotic cultigens, from Asia and then from the Americas. Austin goes on to discuss the debate over Sub-Saharan Africa's continuing shift from land extensiveness to land scarcity, a transition that has already occurred in Southeast Asia. The issues in Africa are not only about productivity and the environment; there is also the increasing structural risk of conflicts over land, water and energy. Yet, with a much larger and better-educated labour force than when newly independent African states attempted to industrialize fifty years ago, conditions have become more favourable to labour-intensive industrialization.

Emily Osborn's chapter investigates the global shift from biomass to fossil fuels in a specific setting, by focusing on a particular sector of manufacturing and consumption in West Africa: the making and use of containers. In a move that is highly original, certainly in an African context, she investigates how people have packaged things for storage and transport, and how the technologies and practices have changed. She documents the shift from packages that were made by local artisans and carried mostly by humans, such as clay pots, to the adoption of factory-made, initially imported, containers which were often transported by motor vehicles and trains (which are containers themselves). She identifies the post-1945 period, rather than colonization for example, as the decisive moment in this profound remaking of the 'containerization landscape' of West Africa, particularly because it saw the adoption of plastic containers by African households for a multiplicity of uses. However, she goes on to show that, contrary to what might be supposed, the fossil fuel revolution in containers – containers made with fossil fuels, and moved by further consumption of fossil fuel energy – did not eliminate the artisan from the production of containers. Scrap metal, notably aluminium, has been transformed by local craftsmen into cooking pots and other kinds of storage case. Thus Osborn's chapter brings recycling to the fore.

The resource-saving path of development in Asia?

Perhaps the best starting point for thinking about economic development in the four regions upon which this book focuses is the recognition that the parts of the world which embarked on industrialization after the process had already begun did not pursue their goal, still less achieve it, by simply trying to emulate the first movers. In earlier work, Sugihara developed a framework for analysing these differences in a longer-term perspective, distinguishing different 'paths' of economic development in different world regions that were followed before, during and after industrialization. These paths were defined by responses, in choice of production technique and institutions, to the particular factor endowments of the region concerned. Thus, he contrasted what he calls the 'labour-intensive path' of development, characteristic of the wet-rice economies of East Asia, to the 'capital-intensive' path followed by Britain and the West in general, especially the United States (Sugihara 2003).[17] Whereas Western countries sought to substitute capital for labour, East Asian countries took advantage of their relative abundance of labour by adopting labour-absorbing institutions and using labour rather than capital where and for as long as this was consistent with productive efficiency. That labour intensity could be a 'path', which Japan, and later South Korea, Taiwan and then China (in the 1980s to 1990s) took into industrialization, was partly because (and in so far as) it included enhancement of skills, adding human capital to labour power as such (Sugihara 2013).[18] Sugihara's previous work has suggested that the labour-intensive path was also resource saving, by comparison with the resource (especially energy) intensive way in which the capital-intensive path developed, especially in the United States.

[17] A recent contribution documents the greater use of urban 'night soil' in agriculture in the pre-industrial economies of East and South Asia compared to Western Europe. This was a labour-intensive, biomass-conserving approach to maintaining soil fertility, to which the West eventually found a characteristically capital-intensive response by using chemical fertilizers. See Ferguson (2014).

[18] For the relationship between skill and labour intensity in early modern Europe and Japan, see Saito (2013).

> The pattern of global division of labour since the second half of the nineteenth century suggests that the capital-intensive and resource-intensive technology developed by the use of a disproportionate amount of global resources available to mankind at each stage of development. There was no prospect of a global equalization of income through the direct diffusion of such a technology to the rest of the world. The global diffusion of industrialization was made possible by the development of labour-intensive and resource-saving technology, which provided the majority of [the] world's industrial employment. This labour-intensive route combined cheap labour and Western technology to produce a capitalism aimed at a fuller exploitation of human potential as labour. (Sugihara 2013: 58)

It should be noted that not all Western countries took an especially resource-intensive path. Bonneuil and Fressoz (2016), in a section entitled 'The Anthropocene is an Anglocene', remark that the combined total of British and US carbon dioxide emissions constituted 60 per cent of cumulative global emissions in 1900 and nearly 50 per cent in 1980. As late as 2008, Britain's cumulative emissions stood at 10 per cent of the total, whereas France accounted for only 4 per cent (Bonneuil and Fressoz 2016: 116–17). Although British GDP per capita was slightly higher then, and had been higher for most of the period since the British industrial revolution, the contrast is striking. As the authors comment, it fits the traditional historiographical interpretation of French industrialization as 'soft', long-retaining dispersed, rural-based industry, 'and based on human, animal and hydraulic energy' (Bonneuil and Fressoz 2016: 117; see also Hau and Stoskopf 2013). So, Sugihara's own contrast is definitely generalized: but with that qualification, broadly justified.

In his chapter for this book, focusing on 'monsoon Asia', Sugihara explores the relationships between climate, trade, livelihood and economic development across and between (most of) three of the regions examined in this book. He remarks that since the OPEC oil price shocks of the 1970s there has been a global convergence in energy efficiency, between the traditionally capital-intensive and labour-intensive economies, with a diffusion of best-practice energy-saving technology (cf. Chapter 11). Analytically, Sugihara goes beyond his earlier work by directly confronting and elaborating the relationships between factor bias and resource use. To this end, he disaggregates 'land' into specific local resources, such as supplies of water and energy (including from biomass). Deforestation to supply firewood, for example, by increasing (at least to some extent) the supply of land immediately available for cultivation, may reduce pressure on land; but it depletes the stock of biomass energy, and any expansion of agriculture is likely to increase water intensity, especially where the additional area under cultivation is irrigated. Intra-regional and intercontinental trade may mitigate local shortages, or some of them, while also, as Pomeranz noted elsewhere, enabling 'some people and societies to appropriate resources while insulating themselves from the environmental impact of this appropriation' (Pomeranz 2009a: 11). Sugihara suggests that thinking about the relationship between population and local resource constraints, using the distinction between livelihood security (focused on the individual's access to water, etc.) and resource security (at a more collective level), may help us explain the course of the international division of labour better than thinking about aggregate factor ratios. The same may apply to inter-regional differences in the gender division of labour, which Sugihara discusses in relation to the distribution of the tasks involved in handling the different local resources, and their associated problems.

The chapters by Satoru Kobori and Se Young Jang examine individual industries, both in East Asian, historically labour-abundant economies. Kobori traces the development of an energy-saving (and smoke-reducing) policy in the Japanese iron and steel industry, during the half century or so between the end of the First World War and the OPEC oil price hike of 1973. Japan ceased to be self-sufficient in coal by 1920. Kobori shows that heat conservation in factories originated as a proposal from one of the prefecture governments, and quickly became a shared preoccupation of the state (local and national), private companies and professional energy engineers. In this respect, Kobori's account reinforces the view that Japanese economic development was characterized by a high degree of consensual collaboration between different parts of society, in this case, between political, commercial and – not least – professional elites. Just as Japan had drawn selectively on Western technology to launch its industrialization before the First World War, so, in the interwar years, it considered what the different Western countries had to offer for energy saving in the steel industry, and chose to adopt and adapt German technology. With the 1937–45 war fuel conservation became a military imperative even more than an economic one. Further fuel economies were sought in the post-war years, again with close collaboration between the government, the firms and professional engineers, until the advent of cheap oil removed the pressure for conservation. Fuel efficiency (the ratio of output to fuel inputs) actually continued to rise in the 1960s, maintaining Japan's position as the world leader in energy efficiency, but that was a side effect of other technical advances; until the OPEC intervention restored the imperative of maximizing such efficiency.

Jang tackles the apparent paradox of the government of a labour-abundant economy, South Korea, setting out to adopt an extremely capital-intensive form of energy supply, the generation of nuclear power, relatively early in its industrialization. One consideration was that the country was dependent on imports for the coal and oil on which its electricity supply depended. The government began to prepare for a nuclear future in the later 1950s, hiring US firms to build a research reactor, which opened in 1960. Again, the government invited bids for the contract to build and operate the country's first nuclear power plant in 1968, less than a decade into the spectacular economic take-off that had begun in 1960, and five years before OPEC's oil price hike would have removed any complacency about the long-term reliability of cheap oil. Jang argues that the precocity of the government's interest in, and then commitment to, nuclear power suggests that military considerations were paramount. In the late 1960s and the 1970s the government, doubting the implacability of US military support, ran a covert nuclear weapons programme, which the technology and capacity acquired for civil purposes could support and conceal. As to how a country still in the process of industrialization could afford a nuclear power programme, Jang points to the nature of the technology and the existence, despite restrictions, of an international market in it. The first ten plants were built on the turnkey principle, and financed by foreign loans, so that the initially inadequate domestic supplies of capital and specialist expertise were not a problem. Even in retrospect, and knowing that South Korea has become itself an exporter of nuclear knowhow and equipment, the commercial as opposed to strategic logic of the programme may be questionable; as it is in the minds of the Korean anti-nuclear movement.

Pomeranz examines the environmental constraints on China's contemporary economic growth, in its regional context and in the perspective of earlier episodes of Chinese industrial growth, including the early modern one that, on his *Great Divergence* argument, eventually ran into environmental buffers, leaving the way clear for the other end of Eurasia to be the first to industrialize. Since 1978, China has been converging on the output per head of the earlier industrializers, though there remains a long way to go. Pomeranz emphasizes the spatial unevenness of the rapid economic growth: it is much more a phenomenon of coastal China than, in particular, of the far West. He also stresses the range of China's environmental problems, from air pollution to soil contamination. While the outside world worries most about China's greenhouse gas emissions, Pomeranz insists that water shortage is a much more immediate threat to the continuation of rapid economic growth. He notes that China has a particularly strong reason for wanting to industrialize: moving out of agriculture makes extra sense in a country with so high a proportion of the world's people, and so little of its land and water. Agriculture is generally water-intensive, especially when land shortage and often poor soil quality make it imperative to make much use of irrigation to maximize yields. But the rest of the world could hardly feed China (its own overseas investments in agriculture notwithstanding), and if it did, that would only transfer the water requirement.

Pomeranz's discussion of the specific problem of how to water the arid north of China, with demand pressing upwards – especially if economic growth continues – while the water table recedes rapidly, brings out the exquisite difficulty, domestic and international, of the environmental trade-offs involved in the pursuit of economic convergence in the twenty-first century, at national and international level. The diversion of Himalayan-sourced rivers, in perhaps the most gigantic construction programme in history, is already under way; but to undertake all the diversions mooted would be catastrophic for neighbours, notably Bengal, require huge energy for water pumping and treatment, and entail major risks, including earthquakes (Pomeranz 2009a). Shifting resources to manufacturing and services would aggravate other environmental problems, while the simple, more labour-intensive solution of mending pipes and lining tanks seems beyond the capacity of central government to supervise. Hence, Pomeranz's analysis points to the likelihood that the leadership will continue to favour the mega projects that it can manage itself.

His chapter leaves us, without much confidence about the future of economic convergence, or much else, firmly in the period of the 'Great Acceleration'. To put this acceleration in perspective: the major increase in the human impact on the environment during the early modern age was associated with an estimated doubling of world population in 300 years; whereas about half the population increase since the last ice age is thought to have occurred in the last thirty years (Richards 2003: 1; Pomeranz 2009b: 12).

Writing history and economics in the Anthropocene

Julia Adeney Thomas's epilogue provides an exceptionally thought-provoking set of reflections, drawing together the key themes of the preceding chapters, placing them in the contexts both of the development of the disciplines from which most of the authors come, and using them to address the contemporary debate about how publics and polities should react to the Anthropocene. In a spirit of scholarly self-understanding, she shows how both history and economics were founded as disciplines devoted to the exploration of human freedom: to analysing and narrating choices that were conceived as possible only for humans freed from nature's fetters. By extension, the majority of the world, including the regions discussed in this book, were considered lands without proper history, on the grounds that their inhabitants had not achieved the emancipation from nature necessary for them to make history. As she notes, this conception of freedom actually served as self-imposed blinkers on historians' and economists' capacity to understand the world. It is the source of what she calls 'the often unconscious yet fundamental premise that natural resources are infinitely abundant given the right technologies and therefore external to the linear development of humankind': a premise which, as she shows, is still debilitatingly present in current political debates. More encouragingly, Thomas also delineates ways in which the research presented in this book can be used to rework 'the modernist paradigm of progress'.

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Environmental Impacts of Colonial Dynamics, 1400–1800: The First Global Age and the Anthropocene

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Introduction

Could one apply the concept of the Anthropocene to the First Global Age, understood as the period between 1400 and 1800? Is there enough evidence, qualitative and quantitative, to support such a claim? For the purpose of this debate, this chapter will discuss the dynamics of European colonialism in the First Global Age and how they contributed to environmental changes at a global level.

In a context in which historians hardly dare to apply the expression *Anthropocene* to a period preceding the late eighteenth century, two climatologists, Simon Lewis and Mark Maslin (2015), openly claim the existence of that possibility, based on geological markers. They identify two dates as having left the kind of Global Boundary Stratotype Section and Point (GSSP) generally required as the marker of a new geological epoch. These were 1610 and 1964. Their discussion favours the earlier date.

Appealing as it could be for a historian of the early modern age to identify the markers of this 'new' era in that period, the complexity of the problem is such that it opened a very vivid and intense debate, not to say strong reactions from historians, geologists and ecologists. In the aftermath of their proposal, a plethora of answers and replies arose. The debate clearly shows how contentious this claim can be.

What moves academia and fuels the debate is twofold: first, the definition of the expression (which has already acquired so many meanings – in geology, ecology, philosophy, history and the humanities – that it is becoming difficult to use as a

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concept); and second, the timeline on which one can identify the emergence of an era, or just a period, identified as the *Anthropocene*. It is still contested whether the Anthropocene is a new geologic epoch, subsequent to the Holocene, or part of it (Lewis and Maslin 2015). There is not even consensus on the dates or even the timelines proposed for its inception: the beginning of the Great Acceleration (1945–1954) (Syvitst et al. 2005; Steffen et al. 2007; Syvitst and Kettner 2011; Zalasiewicz et al. 2015) and the beginning of the Industrial Revolution in Europe, taking as a symbolic mark James Watt's steam engine patented in 1776 (Crutzen and Stoermer 2000) are, as explained in the Introduction, the best candidates. In both circumstances the new era is connected with evidence of induced climate change and the rise of CO_2 and CH_4 concentrations in the atmosphere (Crutzen 2002: 23).

Lewis and Maslin are not the first to propose an earlier beginning for significant human impact on the environment (or the functioning of the earth system, as insistently claimed by Clive Hamilton [2015]. Accepting that humans are not outsiders or invaders, but rather an integral part of nature and the ecosystems (still a recent idea in ecology), scientists now argue for an earlier date for the inception of a new era: the one in which the earth system is dominated by humanity.

One point seems consensual: all authors refer to Western societies as the catalyst of such an epoch. Those who believe in 1945 as the symbolic beginning of the Anthropocene even specify that it signals 'unambiguously the dawn of the era of global economic domination by the United States of America, which was intimately tied to the economic boom of the post-war years and so [to] the rapid increased [*sic*] in greenhouse gas emission and associated warming' (Hamilton 2015: 105). Maslin and Lewis follow the same reasoning when trying to interpret the data revealed by the 1610 GSSP marker as the impact of Europeans upon the Americas, as if one could, within the worldwide dynamics created by European colonization, isolate specific factors affecting one continent and discard all the balances and imbalances involving the others. The concept of 'connected worlds' seems to be strange to scientists who otherwise maintain that measurements are only valid if observable at a global level.

History is by tradition a good auxiliary in exercises put forward by scientists who would normally disregard its existence as a discipline. It is perceived as a useful tool to contextualize and justify assumptions and policy goals (Linnér and Selin 2013; Uhrqvist and Linnér 2015: 159). Hardly precise or strictly rigorous in the data submitted for evaluation by the 'real' scientists (especially for the pre-statistical era), driven by heavy source criticism as a standard methodology, focusing on particulars rather than on general rules, and denying the existence of general laws as regulating societies over time, historiography is an easy resource available either to be used as a mere contextual framework or to be manipulated as a data provider. Both sides in the Anthropocene debate are evidence to this. Between them, however, they have opened a clear space for historians to enter the debate.

Reacting to Lewis and Maslin's proposal of 1610 as a chronological marker to the Anthropocene, Hamilton claims:

> When other scientists and historians begin to examine more closely the historical correspondences and the scales of the various claims about colonization, population decline, the spread of crop varieties from Europe to South America and back the other way, pollen in marine sediments, rates of forest regeneration, atmospheric CO_2 and the course of the "Little Ice Age" the Lewis-Maslin story will surely fall apart. (Hamilton 2015: 3)

This may very well be so, but validating or invalidating this new claim is an enterprise that requires active cooperation between history, ecology, geology, earth system sciences and other disciplines. History has to be taken as a partner to clarify hypotheses, rather than to be used as a weapon in a fight between academic currents.

At the risk of stating the obvious, what is expected from any discipline is to define concepts, to debate hypotheses according to clear theoretical assumptions, to collect empirical evidence and to submit conclusions to further debate. This chapter will try to do just that by debating the concept of the Anthropocene as applied to the First Global Age 1400–1800.

Let us begin by asking whether it is even worth debating the applicability of the concept to that period. If one takes the Anthropocene as an era in which the earth system is driven by human action, the latter having an impact as massive as other forms of nature, such as meteorite strikes or volcanic eruptions (Lewis and Maslin 2015: 138), then the signals of such an era can only be read at a global level and supported by global dynamics. In this framework, the pertinence of this kind of analysis for this period is clear, if one keeps in mind that we are dealing with a period that tends to be consensually interpreted as 'The First Global Age', when global economic systems and global circulation of men, commodities, ideas and technologies prevailed.

But can one subscribe to the idea that, during that period, the omnipresence of humans and their actions over the ecosystems affected the earth system in such a way that human performances overcame 'Nature' (for better or worse) as an influential element of the earth system? It can only be discussed if one takes, layer by layer, the dimensions that define the Anthropocene.

Traditionally, there are some basic parameters by which one can measure the impact of man upon nature. One is soil exploitation. During the First Global Age, a colonial economy, ruled by European markets, introduced new patterns of territory management, property regimes and soil exploitation. Colonial plantations, based on monoculture and *latifundia*, tended to dominate or overlap other ways of soil appropriation or use. That is a proven fact, at least in some parts of the planet. Another parameter is energy consumption: during this period the massive cultivation of products designed for European markets consumed tropical forests and fertile soils in a quest for arable land and for the energy needed to operate sugar mills or smelt metal, for instance. This is largely acknowledged, even if its real scale and differential geographical representation still require further research.

A third aspect is species extinction. The disappearance of vegetable species during this period is well documented, as is the elimination of some animals from both the land and the oceans. One should add to this panorama, however, the emergence of new hybrid species, resulting from the transfer of organisms across oceans and continents disconnected until then (Thomas 2013; Polónia 2014), which resulted in a global homogenization of the earth's biota. Such trans-oceanic exchanges are considered unique since Pangaea, and taken as not having any geological analogy (Lewis and Maslin 2015; Maslin and Lewis 2015: 110).

This period saw a large-scale exchange of animals, plants, seeds, and also of bacteria, viruses and diseases. This points both to the global ecological flows between continents, across oceans, and the problem of their impact upon local environments in Africa, Asia, America as well as in Europe.

In view of this, discussing the application of the concept to this period is justified. In fact, there was an ongoing and vivid historiographical debate, well before the Anthropocene concept arose, and an anthropocentric scrutiny of that biological exchange at a global level took place: well-established analyses emphasize the importance of the actions and intentions of the colonizers over nature, assuming from the outset their supremacy in all respects, as well as their responsibility for developments which led to depletion or exhaustion of resources, frontier conflicts, damage to ecosystems, introduction of invasive species, bacteria and germs, and the destruction of species, to the very point of their extinction at an unknown level – most of them coinciding with the described effects of the Anthropocene.

This view assumes that part of what happened was the result of imperial-oriented policies and colonial agendas, including the unintentional and uncontrolled actions of European colonizers trying to replicate their own way of living in foreign geographies. Typically, it adheres to the concept of 'ecological imperialism', seen as 'The Biological Expansion of Europe' (Crosby 1986). According to Crosby, ecological imperialism is the ultimate expression of colonialism. Let us revisit this core proposal.

Ecological imperialism

The 'early modern age' (1400–1800) is consensually seen as a time of growing interconnectivity among several continents and oceans. This opened the door for the creation of a world economy (and a world system) as much as for environmental impacts resulting from global transfers, from which new syncretic biomes emerged. During this period, Europeans invaded old and new worlds aiming for a quick, effective and profitable use of their resources. The Europeans moved towards the other old-world continents, Africa and Asia, and projected themselves into newly discovered continents and subcontinents, the Americas, Australia and Oceania. The invasions were organized through state-run monopolies (sponsored by the crowns of Portugal and Spain), and chartered trading companies (sponsored by England, France, the Netherlands, Sweden and Denmark). Overseas settlements and long-distance trade were established, and economic emporia and political empires were created, changing the world systems for good.

According to the ecological imperialism perspective, Europeans tried to replicate, as much as possible, their way of living in the new territories, implying an intense projection of their influence upon them. A colonial economy, ruled by European markets, introduced new patterns of territory management, property regimes (Prem 1992) and soil exploitation.

In America, colonial plantations, based on monoculture and *latifundia*, tended to dominate. Along with cattle breeding, they unbalanced old equilibria and the profile of autochthone economies (Poppino 1949). Sugar, coffee, cocoa, tobacco, tea and rice were transplanted to regions where they had never existed, replacing old plantations or totally invading unexploited lands. Their cultivation consumed fertile soils, together with timber and tropical forests, in a quest for arable land and for the energy necessary to run sugar mills.

Native societies and communities, along with their cultures and economies (agrarian or not), were first pushed back, then partly or totally shattered by the new plantation regimes, the new patterns of land exploitation and the new norms of landed property, imposed by force or deception. The uses of land and environmental management became driven by new requirements and rationalities. Africa and America were continents heavily affected by these new rationalities.

In the Americas, first mining and then extensive colonial plantations of tobacco, cotton and sugar invaded the Antilles and extensively contributed to the annihilation of local tribes and their environment and economies. During the short period between 1492 and 1542, the Tainos of Hispaniola, the most numerous indigenous group, nearly became extinct (Crosby 1967: 321–37; Guerra 1988: 305–25; Guerra 1993: 313–27; Richards 2003: 306, 315–33). Famine, cultural depression and infectious diseases, mostly influenza, resulted in high mortality rates. In some of the Antilles, what mining and colonial plantations did not accomplish in terms of environmental impact and ecosystems, cattle breeding and ranching did (Gordon 1993: 65–121).

On the Spanish American mainland, gold and silver exploitation, extensive livestock rearing and epidemic outbreaks, side by side with the impact of indentured or enslaved labour through the *Encomienda* and the *Repartimiento* system, provoked both the depletion of ecosystems and human depopulation as high as 90 per cent in some Mexican regions (Reff 1991: 9–32; Cook 1998).

Increasingly, formerly unexploited lands were taken by Spanish settlement and ranching, changing the natural and environmental equilibria (Richards 2003: 334–79). Mining in Spanish America emerges as similarly responsible for the exhaustion of resources (Powell 1952) and, more than that, for long-lasting pollution exacerbated by the use of mercury (Bakewell 1990, 2: 131–53; Martínez-Cortizas et al. 1999).

Portuguese settlement in Brazil followed similar patterns even if with less immediate and extensive effects. Apart from the shoreline and the more intensive exploitation of the coastal fringes of Portuguese captaincies, there were the substantive activities of the *bandeirantes*, informal expeditions searching for precious metals and capturing indigenous people, acting without frontiers all over South America. More than anything, it was the period of gold and diamond exploitation, from the end of the seventeenth century, that was responsible for a more extended and aggressive predation of Brazilian territory and ecosystems.

Even where, in the East and Far East, Europeans were one group among many others who had settled in the region for centuries, imposing different empires and political rules or just adapting to a trade regime in which plurality of partners was the norm (Chaudhuri 1978, 1985; Subrahmanyam 1990), their footprint was substantial, for example, by the transportation of new seeds and germs from other regions and the introduction of plantations of other species within the Indian Ocean world. That is the case, for instance, with some kinds of Southeast Asian spices the Portuguese introduced to the Indian subcontinent, more specifically in the Goa region and on the Malabar Coast. The British imperial impact in India, especially after 1800, seems to have been more extensive still. Under British imperial rule, India's forests were depleted not only by the expansion of cultivated land, but also by both commercial timber operations and plantation cropping for European markets (Tucker 1988: 118–40; and see, further, Parthasarathi's chapter in this book). The same could be said about the impact of Spanish colonialism, in particular in the Philippines, as shown in the work of Greg Bankoff for a later period (Bankoff 2007).

Before 1800, a comparable impact of European systems of exploitation is acknowledged for South Africa and latterly for Australia, initiated respectively by the Dutch and the British. In the Cape region, the southern corner of Africa, opportunistic plantations, first aiming to provide European crews with food, wine and supplies in order to guarantee trans-oceanic navigations, then directed to export, transformed local ecosystems into agrarian landscapes. As stressed by John Richards, by the end of the Dutch period (1795), nearly all the larger fauna of the entire Cape region had been depleted by inexorable hunting, even more lethal once the new settlers used firearms. Elephants, rhinoceroses, hippopotamuses and other large, vulnerable animals tended to disappear. As the European frontier expanded, wildlife diminished (Richards 2003: 274–306).

At the same time seas were changing in a direct relation with European colonialism, and some species of fish and mammals were threatened by large-scale catches. Those were imposed by the demands of distant consumption markets, ruled by European needs, and commanded by European merchant rationalities. Cod, tuna and whales were just some of the species targeted by this aggressive predation. Massive catches of mammals, particularly cetaceans and other marine species (Brito and Costa 2011), were undertaken from the very first moment of contact, in Africa or on the Brazilian coasts.

Portuguese, Breton, Norman and Basque fishermen dominated New World cod fisheries throughout the sixteenth century (Pope 1997; Abreu-Ferreira 1998: 100–15) as much as did the English (Lounsbury 1934; also Jansen 2012). If the impact of such activity is not comparable to recent times, due mostly to technological changes, the pattern of exploitation was already settled in the sixteenth century. The same applies to hunting sea lions for their skins; the catching of civet cats for the secretion of their glands; the near-extinction of American beavers, to dress fishermen in Northern Europe and for the leather industry all over Europe; and the killing of whales for their oil, which was used to illuminate large European cities such as London (Haines 2011: 159–75). Those behaviours, driven mostly by economic causes, entailed significant costs for environmental and ecological stability.

The new explorers are seen as taking the inexhaustibility and everlasting existence of species for granted or not even considering it. Just as indigenous people did not have legal status in the eyes of most of the European colonizers, autochthone ecosystems did not have any kind of regulation (unlike in Europe) designed to prevent their exhaustion and extinction, at least until the eighteenth century, when ecological concerns begin to be discernable among both European scientists and colonists (Grove 1995). Botanic species were totally destroyed in the Atlantic archipelagos which had, until then, been uninhabited, as in Madeira, the Azores and the Canary Islands; in the same way, the original human inhabitants of the Canary Islands disappeared together with their ecosystems (Crosby 1986: 104–31).

Environmental colonialism seems, in this context, much more important than any other. Ecological and environmental equilibriums were unbalanced, not in a long-term process, but in a short and invasive onslaught of transformation and depletion. The exploitation of indigenous natural resources on the one hand, and the introduction of European animals, seeds, plants and diseases, on the other, were two sides of the same coin (Crosby 1988: 114–15).

Summing up, the 'ecological imperialism' thesis claims that the aggressive behaviour of European agents towards pre-existent environments led to a heavy appropriation of primary products for human use by land appropriation against the needs of other species and other cultures; the depletion of natural resources; the extinction of vegetable and animal species; the destruction of ecosystems and the drastic changes in landscape.

'Ecological imperialism' versus 'Ecological adaptation'

The 'ecological imperialism' perspective reflects a Eurocentric, or else Western-centric model, according to which the local agents, the colonized, are usually excluded from the dynamics of colonial processes, with the global interpretations centring almost exclusively on the determining performance of European powers, agents and policies. In doing so, it ignores the important processes of adaptation and evolution that result precisely from the entanglement of nature and nurture, which necessarily accrued to all those peoples and environments involved.

Therefore the ecological imperialism perspective needs to be reviewed. Examples are provided by the outputs of the so-called post-colonial studies, developed since the 1980s. The more recent perspectives centred on a connected history of the colonial empires (Subrahmanyam 2007) or the agenda of a highly prolific world or global historiography[1] have been contributing to a revision of Eurocentric interpretations of colonial phenomena (e.g. Boyajian 2008; Darwin 2008; Andrews 1984; Polónia 2012),

1 See the abundant publications, for example, in the *Journal of World History,* the *Journal of Global History, Itinerario* and the *Asian Review of World Histories*.

as reflected in recent publications (Antunes and Polónia 2016), and the organization of scientific panels and conferences on the subject.[2]

Such a historiographical revision is also settled on the adoption of concepts and models of analysis stemming from self-organization and cooperation theories (Nowak 2006a,b; Santos, Santos and Pacheco 2008; Ribeiro 2016), first developed in economics, biology, anthropology, psychology, physics and mathematics (Ostrom 1990; Fehr and Gächter 2000; Hammerstein 2003; Fischbacher 2004; Richerson and Boyd 2005; Hagen and Hammerstein 2006; Herrmann, Thöni and Gächter 2008) and now applied to history. In the language of cooperation, the fact that interactions are generally repeated and bidirectional in time offers to those interacting the opportunity to reciprocate, thus sharing the benefits and costs that accrued to both entities involved, in our case, colonizers and colonized.

The application of this theory and model of analysis by environmental historians clearly has something to offer to a reanalysis of the environmental effects of European colonialism in Asia, Africa, America or Oceania during the First Global Age. Indeed spatio-temporal models of cooperation, which go well beyond strict collaborative efforts between equal parties, will allow one to assess how far the unequal roles played by the parties involved affected cooperation, adaptation and reciprocity. New directions can be defined in order first to question how local actors and Europeans interacted in order to use and manage available natural resources and, second, which mechanisms of adaptation existed, both for Europeans to survive in totally different and frequently adverse environments and for autochthonous people and environments to react, resist or voluntarily adapt to the new ecological elements. This new trend, already happening in the economic, social and cultural analyses of empires, remains to be applied in the framework of environmental history.

In this analytical approach, self-organization theories may provide an adequate complementary perspective of analysis (Vasconcelos, Santos and Pacheco 2013), as they reflect processes where some form, order or coordination arises out of the interactions between the components of an initially disordered system.

George Modelski employed the concept of self-organization to discuss long-term processes in global politics and economics, and world macrodynamics generally (Modelski 2000; Modelski, Devezas and Thompson 2008). According to him, 'Dynamic physical, biological, and social systems evolve in such ways that order increases so that several parts are mutually adapted in what are evolutionary processes' (Modelski n.d.; Barabási and Albert 1999). Another connotation of self-organization, for the understanding of historical processes, lies in the realm of so-called evolvability: the capacity of certain collectives, groupings, areas or ensembles

2 'The power of the commoners: informal agent-based networks as source of power in the First Global Age', org. Amélia Polónia at the Social Science History Conference 2010 (Chicago); 'Beyond Empires: Self-Organizing Cross Imperial Networks vs Institutional Empires, 1500–1800', coord. Amélia Polónia and Cátia Antunes', European Social Science History Conference 2012 (Glasgow; 'Fighting Monopolies, Building Global Empires', coord. Amélia Polónia and Cátia Antunes in conference on 'Colonial (mis)understandings: Portugal and Europe in global perspective (1450–1900)' Lisbon, 2013); 'Cooperation under the Premise of Imperialism', coord. Tanja Bührer, Flavio Eichmann and Stig Förster (Bern, 2013).

to produce spontaneous order, at least in the form of organized patterns. Evolution, innovation (or mutation), cooperation and conflict, which act under selection (natural or cultural), are key elements of an evolutionary paradigm. Away from the assumptions of the Darwinian natural selection, this understanding coincides with current trends of evolutionary ecology (see Russell 2011).

Self-organization theories emerge thus as a possible contribution to a renewed analysis of the colonial processes, including its environmental impacts (Polónia 2010). Self-organization occurs and can be studied in a variety of social and cognitive systems, but also in the realm of physical, chemical and biological processes (Watts 1999; Sawyer 2005). This can be a powerful tool to re-examine the processes conventionally considered in the framework of 'ecological imperialism'.

Frequently the 'ecological imperialism' perspectives neglect that European powers and settlers interacted with an environment that, far from constituting a 'natural' blank slate, had already been created by pre-installed cultural systems. Such an approach further disregards the way ecosystems reacted to the invaders and become themselves builders of different environments – in other words, it overlooks the evolution and adaptability of ecosystems, as well as the adaptation of Europeans to pre-existent environments.

Aware that, just as there is no natural determinism to human action, there is also no human determinism to nature or to the configuration of ecosystems, it has been claimed that 'the role of European policy should not be overemphasized in discussing eco-history, even if it is true that the indirect and often unintended impact of the European presence profoundly and permanently altered the direction of the ecological evolution of [a] region. In short, the interaction between political form and ecological transformation has always been reciprocal and dialectical' (Weiskel 1988: 145–46).

Evolutionary ecology contributes also new insights to this revision of 'ecological imperialism', stressing that through the millennia there were no stable environments: evolution and transformation are permanent trends and essential ingredients of living systems. When describing evolution and adaptation of ecosystems, modern thinking and modelling in ecology includes nature and nurture (Keller 2010; Goldhaber 2012), and treats space and time on an equal footing, including their interdependence (Levin 1992; Santos, Pacheco and Lenaerts 2006).

Instead of the classic perspective that defines European colonialism as a single, all-encompassing process, understood as 'the Columbian exchange', this chapter argues, within the current discussion on the Anthropocene, that one has to clearly differentiate among colonial experiences. The 'Columbian exchange' tends to be taken simplistically, as if the nature of the contacts and exchanges was limited to the encounters with new worlds (to the Europeans), whether in the Americas, Oceania or the *Tropical Island Edens* (Grove 1995). Instead, much of the European colonization and colonial exchanges happened in Africa (Morocco and Ethiopia, already known to the Europeans, as well as the Sub-Saharan, 'new' Africa), as much as in Asia – part of it an old world and an old partner of the Europeans. Nobody could claim that the new scale of exchanges did not have environmental impacts, but it certainly did not have the same effects as those recognized in America or Oceania – parts which tend to be taken for the whole.

Establishing a linear cause-and-effect correlation between the claimed (and debated) loss of 50 million American inhabitants as a result of colonial-driven outbursts of violence and a GSSP geological marker (Lewis and Maslin 2015) implies disregarding the population dynamics operating at a global level during this period. By that time not only was America demographically strengthened by the arrival of millions of African slaves, but the world population levels give evidence of the migration of species that contributed to food regimes capable of feeding growing populations. The evolution, roughly estimated as an increase from 350–400 million as of 1450 to 900 million by 1800 (McNeill and McNeill 2003: 155–211), resulted from exactly this trend, due to the action of humans as transporters of new species, but also to the role of nature as an integrative force, creating new natures. Here, adaptation, syncretism, hybridism and evolution are key concepts that apply both to men and nature, to ecology and culture.

Adding to this, the first contacts and settlements led by the Portuguese and Spanish in the fifteenth century cannot be perceived as equivalent to those spawned by the Dutch or the British in the seventeenth and eighteenth centuries, or even the Iberian ones in the eighteenth or nineteenth centuries. Instead of linear perspectives according to which the colonized territories were blank sheets where European wrote their history, led by their own agenda, one must investigate the different periods in light of their aims, capacities and market demands, and the existing and changing ecosystems, economies and societies, where topography, geomorphology, biodiversity and climate were as paramount as culture – the local cultures. If one agrees to apply the concept of an Anthropocene to this time period, it will have to include the performance of all mankind.

Not only were environments different between and within Australia, Asia, Africa and the Americas, one has to consider explicitly the different models of colonization and the different arrangements within each colonial empire. Let us take the example of mining. Portuguese settlement in Brazil followed quite different patterns from that of the Spanish in Latin America. Even if the amount of gold extracted in Quito and Potosi (Castillan Indias) and in Minas Gerais (Brazil) was comparable, the social and ecological pattern was not the same. Not only were the extraction techniques different (open, through hydric extraction, or by mining) but also the transformative processes (the smelting processes, the use or non-use of mercury) brought quite different impacts. Moreover, the means by which the labour force was obtained, whether by massive forced migration (the slave trade), as in Brazil, or by extracting labour from the indigenous population (by the *Encomienda* and *Repartimiento* systems), as in Peru, had different implications.

Even in the same colonial context, for instance Potosi, the extraction and smelting techniques underwent developments to increase production. This included the adoption of local techniques to separate metal through a casting system with lead, wherein the Amerindians would grind the ore in stone mills and then fuse it in clay ovens and also the replacement of that method by the amalgam system using mercury. This process, introduced from 1554 in Pacoa and from 1572 in Potosi, allowed increased and improved output, and faster separation of the ore. This implied the need to increase the workforce for metal extraction, higher levels of health risk and pollution, and thus more striking environmental impacts (Richards 2003: 366–72). Although this is well known, the historiography tends to neglect the fact that, on the other hand, as far as copper transformation is concerned, traditional indigenous techniques still prevailed until the late eighteenth century. This was, due both to the Spaniards' inexperience with that kind of metal transformation and to less pressure on a market for copper commodities, quite different from that of gold or silver. In fact, very little has been written on the environmental impacts of mining in Spanish America. Among it the 2010 Studnicki-Gizbert and Scheter contribution stands as a state-of-the-art paper. However, even this only deals with silver production (Studnicki-Gizbert and Schecter 2010).

Africa offers a very different picture yet. Here, gold mining still followed traditional patterns of exploitation until 1800, despite Portuguese domination of the export trade, both in the Mina region on the west coast and in the Monomopata (or Mutapa) Kingdom in Zimbabwe, which exported via the Zambezi. On the western coast, the Portuguese increased demand. They opened different markets with different conditions of exchange and tried to divert trade from the caravans to the caravels. But they did not interfere directly in the gold exploitation system, largely because they did not penetrate African territory or take extensive possession of the raw material primary sources before the late eighteenth and early nineteenth centuries. Even then they would still depend on local populations and extraction techniques.

As for the eastern coast, the Portuguese brought Monomopata territories, villages and metal resources under their influence by integrating and trying to control the local social, economic and territorial organization, with the 'Prazos do Zambeze' as a clear example (Isaacman 1972; Newitt 1973). Zambezia came under Portuguese influence and was ruled by the captain of Mozambique. The intention was to integrate under Portuguese rule the administration and agrarian exploitation of the huge properties granted by the Bantu chiefs. Those were *latifundia* transformed into royal Portuguese properties and granted by the Crown for three successive generations, in return for an annual fee paid in gold dust. This territory became relevant after the 1607 and 1629 treaties with the Monomotapa Kingdom, which acknowledged the Portuguese Crown as owner of vast areas in exchange for military support. These grants not only involve the use of the land but also jurisdiction over the African people living there. However, though the demand for gold extraction increased and the circuits tended to be controlled by the Portuguese, neither the techniques nor the extraction methods seem to have changed enough to make a noticeable and structural environmental impact, such as that caused by the use of mercury in the Spanish Americas.

Summing up, from the sixteenth to the eighteenth centuries, mining was quite different in West Africa, East Africa or Brazil. This is relevant if one seeks to evaluate ecological impacts – because nature and culture (the local cultures) matter in the processes of empire building.

Similarly, it is well known that the Portuguese, Dutch or British models of settlement on the Indian Ocean world differed from each other and that they used varying degrees of imposition and adaptation to local economies, societies and cultures – all interwoven with environmental dynamics. Studies, for instance, of the role of women as intermediaries in the Portuguese colonial world (Polónia and Capelão forthcoming) suggest high degrees of transfer not only of land but also of food regimes, implying ecological interactions between indigenous women and Europeans who, in fact, had to adapt to the locals. In a different political and social context, the same could apply to Amerinidan women and to African women in the diaspora. The Africanization of the archipelagos of Cape Vert and Sao Tome by the massive presence of African women (enslaved or free) in social and family structures did not prevent the introduction of sugar plantations into Sao Tome, for instance, but was certainly responsible for a different cultural (and economic, and political) appropriation and use of the soil and the natural resources, quite diverse from the Antillean archipelagos, for example.

A quite different model of colonization; a quite different way of empire building; a quite different degree of regulation were responsible for diverse ecological and human impacts. Such an approach is equally important in analysing the spread of diseases and epidemic outbreaks. Different models of interaction with local populations, different models of urbanization, nucleation or aggregation of autochthone inhabitants (stimulated by induced or forced migration patterns), affected disease transmission by the spreading of virus and bacteria. *Encomiendas, repartimientos, congregaciónes* in Spanish America, Jesuit missions in Brazil; nucleation of population in Africa (Garcia Bernal 1978; Weiskel 1988; Neto 2012; Bernier, Donato and Lüsebrink 2014); different degrees of cohabitation and sexual intermingling between colonized and colonizers are essential variables in these complex and dynamic processes. Their form and extent depends on colonial models. A complex equation has to be put forward in which variables and corresponding nominal values are to be determined, but in which population dynamics prove as essential as the epidemiological characteristics of the diseases (Guerra 1988; Reff 1991; Guerra 1993).

One must, indeed, realize the fundamental differences that accrued to different models of colonization. In Brazil, for instance, the survival of Amazon forests can be directly correlated with the weakness of the Portuguese crown. Similarly, the environmental heritage disputed nowadays on the fringes of wild Brazil – where the possibility of preserving indigenous cultures is still under debate – results from the (fortunate) Portuguese incapacity to match the efficiency of their Spanish, British or even Dutch and French counterparts. The intensity of soil exploitation, the territorial expansion and the appropriation of land are fundamentally different when we disentangle the ecological impact of colonialism. Indeed, these are ingredients that change the dynamics of evolving populations, in a way that precludes the rationalization of colonialism into a single and unified model.

For instance, when Douglass North, William Summerhill and Barry Weingast (2000) argue that the differences in development between Latin America and Anglo-Saxon America derived from the inefficiency and inadequacy of Iberian institutions to promote modern growth, they inadvertently demonstrate the important role that time and the environment of contact plays in the genesis of institutional systems and property models. Daron Acemoglu, Simon Johnson and James Robinson went further with their claim that economic development in former colonies is a function of the institutions imposed by the colonists (2001). However, the equation is much more complex than that. One can easily accept that very different models of colonization involving quite different ways of state and empire building, different degrees of regulation and different property regimes, necessarily and naturally led to very different ecological dynamics and to diverse ecological and human impacts. This does not mean, however, that the determining force of institutions is to be taken as read. One must take into consideration that environmental differences between the regions largely accounted, reciprocally, for the institutional differences (Engerman and Sokoloff 2012). To conclude: overstating the clarity of state intentions and the capacities of the colonizers sets a bias in the historical discourse that obscures – more than reveals – the identification of the processes that occurred; thus, no single, general model of analysis seems adequate in this domain. On the other hand, this does not preclude the identification of those principles that are common to (and those that distinguish) different models of ecological dynamics.

Another central argument in favour of the existence of an ecological adaptation instead of the ecological determinism associated with 'ecological imperialism' arises when we argue that the European cultural patterns in colonial spaces were not the only ones operating in the field, and not even necessarily the predominant ones. The Europeans had to adapt, intermingle and survive in a world totally unknown to them. Indeed, they frequently depended on the knowledge and the assistance of local populations to deal with new, wild and dangerous endeavours, features that surely were in place in the tropics and rainforests. *The Mosquito Empire* (McNeill 2010) certainly gives evidence to that. Resource exploitation was not an immediate outcome, neither was appropriation a guaranteed result. One has to remember that, at a basic level, facing totally different worlds, in Asia, Africa and the Americas, the survival of Europeans depended on the efficacy of their adaptation to new environments and cultures from which intense material transfers resulted. Europeans had to be receptive to new patterns of food, hygiene, daily agendas, new techniques of exchange and new linguistic and cultural paradigms. The history of science has produced enough examples of those transfer patterns and intermingling, essential to the understanding of the globalization processes at stake. Recent literature points to the importance of the concepts and dynamics of both locality and circulation (Livingstone 2003; Raj 2007), being themselves dependent on processes of complex cultural translation. While those strands were largely cultural, similar mechanisms might be found for ecological trends. The strength of locality – as a producer and as receptacle – was as important as the pressure for circulation, and thus for globalization.

Interdependencies between worlds necessarily went further, disrupting the static view that is often offered. Instead, adaptation prevailed, both from the colonized to the presence and methods of the colonizers and vice versa. Survival in such different worlds as Asia, Africa and the Americas inevitably implied adaptation and acculturation, for Europeans too. In other words, the lives of the first settlers, or group of settlers, would most probably accelerate reciprocal acculturation processes, different from those expected or described by the traditional imperial historiography. These circumstances should have led, in fact, to inevitable mechanisms of exchanges, namely in the processes of resource identification, location and appropriation.

More often than not, colonizers depended on autochthones to provide them with the resources they sought, sometimes counting on their own methods, sometimes transferring technologies that would unbalance the ecological standing equilibrium. Hunting and the use of firearms are just an example. Trade was definitely established between colonizers (together with other competitive traders) and the colonized, which implied adaptation. Registers of fur trading in North America (Marin 1979; Yerbury 1986) and Brazil indicate amounts traded that are incompatible with the view of autochthonous tribes as seldom communicating and never trading (Teixeira and Papavero 2009, 2010).

Those are, however, domains in which we often lack measurable testimonies, precisely because they occurred out of the frame (or at least the focus) of the conventional 'empires'. Only a systematic analysis of these dynamics will be able to provide an appraisal of the long-term ecological impact of such cooperation between colonizers and colonized, with the former benefitting from the environmental knowledge of the latter. A one-sided view focusing on the action of colonizers alone is far from sufficient for such understanding.

Concurrently, we need studies of the way colonial species 'colonized' European worlds and how they reciprocally affected other European overseas settlements. In fact, transfer flows, interaction, adaptation and assimilation processes were never unidirectional. In this sense, there is a range of tropical and Asian products which should be of particular interest because of their massive and structural impact on the food regimes of Europe and Africa. Corn (maize) and potatoes became the basis of the European food regime and helped prevent famines; maize and cassava (manioc), from America, became the basis of the diet of a large part of the African population (for a more detailed analysis of the travel of seeds and plants, see Ferrão 1992; Patiño-Rodriguez 2002; Dean 1991; Widgren's and Austin's chapters in this book). These are just the most prominent examples, with rice, sugar, tobacco, coffee, cocoa and tea being other cases in point.

Seen from this perspective, 'this' Anthropocene generated much more than destruction, pollution, depletion and imbalances. In fact, new balances emerged, transforming land use, property regimes, protein availability and population dynamics in Europe as well. The 'corn revolution' is just one of the most well-known processes (Dubreuil et al. 2006; Mir et al. 2013).

This process was thus far from being unidirectional, as stressed before. We can easily understand this argument taking the more recent example of the 'Green Revolution', as analysed by Jonathan Harwood. The Green Revolution is usually portrayed as an agricultural development programme in which crop varieties and expertise were transferred essentially from North to South. Against this background, according to which the earliest programmes were initiated by US foundations and a US government agency, based on a technological revolution that had begun in Western Europe and the United States in the late nineteenth century, the author argues that this picture is highly misleading. According to him, many varieties, practices and people central to these programmes in fact originated in the South and important approaches to improvement have been developed through the fusion of knowledge and expertise from *both* hemispheres. From this point of view, the Green

Revolution is better characterized as a collaborative achievement of North and South (Harwood 2012).

Summing up, two main ideas should be stressed: reciprocity, syncretism and evolvability are paramount to understand ecological processes (no species survives without assimilation by the receiving ecosystem and cultures) and, besides destruction patterns and stressful mechanisms projected onto the ecosystems as led by colonial actions, one should also look at the mechanisms of adaptation, both by humans and by the environment, and analyse the degrees of resilience of ecosystems and human communities to different kinds and degrees of stress. They showed a surprising adaptability and created alternative patterns of survival through the emergence of syncretic biomes as well as alternative behaviours and cultural patterns. This kind of analysis might even contribute to vital questions of the present: how to adapt to different climatic and biological conditions, and how to create sustainability in a world which tends inexorably to be unsustainable? When worlds collide they also intermingle, creating new worlds.

The main issue is still whether the consequences and the impact of these exchanges went far enough, in scale and in spread, to have transformed the world as a whole and to have interfered with the earth system itself. This leads us to discuss the linkage between the local and the global and the extent of the identified structural and irreversible impacts, sufficient to leave geological marks on the globe. Methodological considerations are necessarily implied in this discussion.

Anthropocene in the First Global Age?

In accordance with our claim that time and space matters when analysing colonial environmental impacts, did the local and regional phenomena described have a global expression? Since we are not geologists, only concrete empirical enquires would be able to provide an answer to this question. We claim that such collection of aggregate data needs to be pursued at local, regional and inter-regional scales. Accepting this rationale implies, as a consequence, that no historical phenomenon, even if recognizable worldwide, can be understood without observations at a deeply observable scale. No glacial register will provide the historian or the social scientist with more than a hint of the kind of answer able to close this debate. Furthermore, evaluating, on a stable basis, long-term changes and environmental processes for the pre-statistical era seems frequently an impossible task. That is also why local inquiries and micro-analyses facilitate evaluations in a context in which macro-level approaches cannot be pursued, at least from a historical point of view. 'Think globally, act locally', expresses this exact conviction (Vasconcelos, Santos and Pacheco 2013; Polónia 2015). You may think globally, but for your analysis, local is the available scale of scrutiny, in early modern History. David Armitage, responsible for some of the major trends in Atlantic History, Digital Humanities and Big History, calls precisely for a micro-macro interplay as a fundamental dialectic to provide meaning to historical analysis (Armitage and Guldi 2014).

But how to identify those impacts objectively, even on a local scale? The answer seems simple for economic historians: measure them. But how to measure when one does not possess serial, systematic and coherent data to work with? This is the reality both for the European pre-statistical era and for the kind of registers provided by other cultures, based on other systems and criteria of registers. The answer requires interdisciplinary methods and interdisciplinary teams.

Since the 1990s, studies in environmental history have attempted to bring to the fore an all-encompassing perspective, instead of embracing the ideologically driven discourse that prevailed before. Our approach tries to bring the analysis to a new level, by combining historical information with anthropological knowledge of the communities of contact and mathematical modelling, based on evolutionary ecology and reciprocal cooperation. This new paradigm intends to combine historical sources of information, dating from the pre-statistical era, with predictive models of ecology, cooperation and evolution. These will hopefully provide the scaffolding within which scattered historical information will fit into a coherent structure.

Monographic and monodisciplinary approaches have been the rule in environmental history studies. Some of the previously mentioned topics of analysis were dealt with by historians, biologists, epidemiologists, demographers, anthropologists, economists – separately. Given the demonstrated usefulness of these concurrent yet often separate approaches, what if we bring these disciplines together, promoting the interplay between their concepts, their methods and their knowledge (both from the social and the natural sciences), thus providing a new paradigm of approaching this topic?

One may argue that this quest is not entirely new. Indeed, it has been acknowledged by recent scientific associations, research teams, group discussions and publications, and has been implemented in research areas other than environmental history, where this goal remains unreached, although recent publications acknowledge the principle (for instance, Emmett and Zelko 2014). Today more than ever, academics are encouraged to work across disciplines. The consensus seems to be that, while disciplinary research has its merits, the future lies in cooperation across disciplines. Rigid adherence to the borders of academia is a twentieth-century relic, scholars are told; the challenges of the twenty-first century (and beyond) will require historians to talk to botanists, literary critics to talk to physicists, and anthropologists to talk to astronomers. Nowhere is this attitude more evident than in environmental disciplines (Emmett and Zelko 2014: 5).

The renewal of environmental studies does not depend, in fact, only on new theoretical positioning: it also depends on the concrete application of new methodologies to historical analysis. The use of quantitative methods is not new in history. Economic history and even econometrics possess a full range of tools able to pursue a measurable analysis of some historical data and realities: except for the fact that those statistical, quantitative analyses depend on availability of serial, statistical data. On the other hand, the combination of mathematical modelling (resulting from complex systems analysis) with pre-statistical data gathered from historical sources to define possible evolving scenarios impossible to obtain from historical analysis alone is certainly new, in particular in the scope of historical environmental studies in the

First Global Age. This is precisely the aim of the 'Circulating Natures' team project, an ongoing research project based on interdisciplinary bases.

We witness, at present, the enormous success and predictive capacity of mathematical models in forecasting local and global behaviours as diverse as the weather and the spatio-temporal unfolding of new epidemic threats (Colizza, Pastor-Satorras and Vespignani 2007; Grenfell 2004). However, the success of these models relies on the availability of precise, and coherent, spatio-temporal data. Thus, mathematicians, physicists, computational biologists and ecologists will have to face the following challenge: how to ensure predictive capacity of forecasting models given that inputs are sparse and scattered in space and time? As harsh and challenging as these constraints may be, they have a seductive power to practitioners of the natural sciences that should not be overlooked. Challenged by these questions and prerequisites, natural scientists will have to develop means of testing and anticipating the robustness of their predictions given the limited data available.

On one hand, historians have to identify sources able to provide a consistent base for modelling exercises, or rather question traditional sources in a different and more innovative way. On the other hand, models will guide historians in what kind of data they must seek. In the end, new scenarios can be scrutinized by historical analysis. Given the limited availability, and the non-linearity of the models involved, it is crucial to be able to get point-like information in the vicinity of what experts designate by 'tipping points' – decisive moments in space and time where small variations may lead to large divergences (Scheffer et al. 2012). This implies interplay between researchers from different fields which will foster a new generation of researchers. It also requires a new paradigm for facing the challenges of understanding history. Finally, history will gain from the attempt to quantify the scale of environmental impacts, while it will check the historical functioning of diverse variables, such as time, space, territory, climate, cultural arrangements and colonial models of settlement and dominion. From a historiographic point of view this constitutes an opportunity; from a modelling approach, it is a fascinating challenge. Three examples will illustrate the potential of this approach.

One could resume the subject of the impact of mining and metal smelting processes on ecosystems. As stated above, early modern mining in the colonies has received extensive attention by historians, but there existed no serious studies of its environmental dimensions. The contribution by Daviken Studnicki-Gizbert and David Schecter established rhythms and scales of fuel wood consumption, the main source of energy for silver smelting and refining, for mining districts located along the length of New Spain (Chihuahua to Taxco) from the beginning of colonial mining (1522) to the turn of the nineteenth century (Studnicki-Gizbert and Schecter 2010). This was made possible by the survival of good serial data for silver production in Mexico, recorded by the *Cajas Reales*. They had been already used by Richard Garner (Garner 1988) to calculate the historical evolution of the New Spanish silver industry and are now analysed from a totally new perspective (data published by TePaske, 1982–90 and available at Richard Garner's webpage, http://www.insidemydesk.com/hdd.html). Those data, combined with account books of two *Haciendas de Beneficio* containing the amount of charcoal consumed in the course of producing silver in two periods of time, 1611–12 and 1782–3, allowed the authors to develop a fascinating approach, not only to the energy consumption required by mining but also to its connection with an emerging pastoralism and agriculture, and its social and ethnic dimensions (Studnicki-Gizbert and Schecter 2010).

Their conclusions mostly apply to silver production, driven by a colonial agenda and highly demanding external markets. The study of copper exploitation and transformation offers, apparently, a different case and promotes different impacts, because this process adapted, integrated and depended on indigenous technological knowledge. The smelting facilities were located near the fuel sources, on the high plateau of central Michoacan, some 120–200 kilometres away from the mines, basically because local vegetation was not considered suitable for preparing the right type of charcoal (Garcia Zaldua forthcoming). The idea of locating the facilities in these areas went hand in hand with the policies for the creation of *congregaciones de indios* nearby. The *congregaciones* displaced and relocated a significant social mass of specialized metallurgists, operating side by side with the charcoal makers (*carboneros*). Both were active agents who, forcefully or through negotiation and cooperation, were responsible for manufacturing new landscapes. The need for wood thus worked as a lever for multiple ecological transformations and adaptations. The comparison of both models of forest use, based on effective data source and/or on mathematical modelling, would probably make a case for a comparative approach and a provocative debate about to what extent higher degrees of adaptation of colonizers to colonized technological patterns implied less negative impacts in ecological systems (or not).

The second example can be provided by the sugar cane exploitation in island environments. Here a more circumscribed territory and a higher propensity for the exhaustibility of resources would make a case for the study and measurement of the impact of sugar cane cultivation on a large scale. Taking the example of Madeira Island and Martinique, for instance, one could proceed with a comparative approach involving different ecosystems, different colonial economies (in Madeira sugar was never a monoculture) and different colonial systems: Portuguese and French. In both cases, there are fiscal sources allowing us to calculate the yearly production of sugar cane. The impact upon soil depletion, deforestation, soil drainage and human migration of free or enslaved labour includes variables whose interference could be examined. Again, mathematical modelling could offer an opportunity for a promising analysis of the possible outcome in terms of environmental impact of the same colonial product exploitation. The scarce approaches to this issue (Smith 2010: 51–77) give evidence that historians alone cannot succeed when more complex processes are at stake. Conversely, without a historian, or a team of historians, natural scientists cannot grasp the correlation data between human and other components in the ecosystem, when the human past is involved.

The last example is the fur trade.[3] A French ship, *La Pélerine*, was sailing back to Europe from the coast of Pernambuco, where she had stayed from March to July 1531,

[3] We thank Fabiano Bracht for the suggestion to take this as a case study and for our discussions over the subject.

when she was captured by the Portuguese in September of that year, near the Canary Islands, still with all its load (Guedes 2002: 156): 5,000 quintals of Brazil wood; 300 quintals of cotton; 300 quintals of grain; 600 parrots, who already knew a few words of French; 3,000 skins of leopards and other animals; gold ore; and medicinal oils. All in all, the freight was valued at 62,300 ducats (Guénin 1901: 44).

The numbers are considerable. The 600 parrots who arrived alive in the Canary Islands suggest that a substantially higher number were loaded aboard in South America. Even more amazing than that is the number of animal skins: 3,000. Of these, according to Nelson Papavero and Dante Martins Teixeira (Teixeira and Papavero 2010), at least 2,800 were jaguar (*Panthera onça*), the largest cat in the Americas. This data sheds light on a very interesting problem, which can be mathematically modelled. To do this, we have to add to this data some complementary information. Like all cats, the jaguar is a carnivore. While the average weight of the animals varies greatly in relation to the territory in which they live, females can reach about 75 kilograms and males 100 kilograms. In some regions where food is readily available, 140-kilogram cats were measured. Individual adults of approximately 80 kilograms need approximately 5 kilograms of meat per day, although they can eat up to 30 kilograms at once, after a long period without food.

Jaguars do not live in groups. They meet in small groups of one male and two or three females during the mating season. Females are sexually mature after two years and have an average of two cubs (though usually only one reaches adulthood), who live with their mother for about a year and a half to two years. Outside this period, they are solitary animals. Studies indicate they are extremely territorial. Females usually hunt in a semi-exclusive territory of about 25–40 square kilometres. The territories of two females may eventually overlap, although this is uncommon. Males reserve for themselves territories whose average varies between 50 and 80 square kilometres, usually encompassing the territories of the females. They defend their areas against other males. Current figures show a wide variation in population density. In the Pantanal, there are currently about six individuals per 100 square kilometres, and on the Amazon, two animals in an area the same size. For the sixteenth century, issues such as the lack of cattle ranches and farms must be taken into account.

From this data, the first question that can be raised relates to the extension of the area where the animals were captured. Even taking into account the possibility of the locals having skins stocked, and given the breeding habits of the animal, a small area would take too long to be resettled to provide such a great number of skins. Knowing the distribution of native peoples in the area (in 1530 the Portuguese occupation was restricted to trading posts scattered along the coast), their hunting grounds could be estimated, given the fact that the food-gathering areas of those tribes, although semi-nomadic, did not overlap. That would help to calculate the area involved.

Once the density of jaguars has been estimated, and in view of their territorial and hunting habits, one can conjecture projections of the impact of those captures upon the density of their prey. The same applies to the estimate of the whole energy balance impact over the area concerned, as well as for the establishment of assumptions concerning the levels of optimal foraging for the period studied. Needless to say, this will tell us something about the negotiating capacities of the tribes involved, in order to provide sufficient supply, in time, for the French merchants arriving at the coast.

The possibilities go far beyond that, and present rich, innovative and enticing challenges to all involved. The above are just some examples to illustrate the potentialities deriving from the integration of historical data, ecology and mathematics.

Epilogue

The aim of this chapter was not to prove or disprove to what extent one can apply the concept of the Anthropocene to the First Global Age. Rather, we took the opportunity offered by an ongoing debate in order to show the complexity of the variables involved. We also claim that, including in the equation historical as well as biological, chemical and geological data, none of these disciplines should have the presumption to try to resolve the issue alone. It is not the Lewis and Maslin observation of a GSSP in 1610 that will reinforce the conviction of the historian that definitively his time period of analysis can be claimed as a landmark to the beginning of the Anthropocene. Likewise, we take the assumptions of a quite simplistic view of 'Ecological Imperialism', attractive and appealing as it could be, as misleading, even if we concur with some of the conclusions drawn within it.

We took the opportunity to draw attention to two basic ideas presumed by the discussion around the Anthropocene: the complexity of the framework until now simplistically seen as the 'Columbian Exchange' and the need for an active interdisciplinary dialogue, of which – besides historians – ecologists, biologists, geographers and geologists, mathematicians and specialists on modelling complex systems should be part.

Summing up, assuming that the cultural systems of colonizers and indigenous peoples were mutually interdependent, this chapter discussed three ideas: (1) When worlds collide they also intermingle. As opposed to the unidirectional perspective of 'ecological imperialism', we argue that syncretism, mutual adaptation and assimilation were integral parts of a transformative process of environment; (2) European cultural patterns were not the only ones responsible for altering landscapes. These did not change drastically in colonial spaces alone and, last but not least, if there is an 'Anthropocene' in the First Global Age, this was not a mechanical result of the agency of Europeans; and (3) Human actions alone cannot determine the evolution of nature or the configuration of ecosystems. Through the millennia culture was a permanent feature to be taken into account, but nature always found new ways of reinventing ecosystems, as stressed by evolutionary ecology. Thus, both social and ecological systems should not be treated independently, but as a single, interconnected system (Levin 2012).

The possible input of this new approach to environmental history for the period under scrutiny, if any, is twofold: in one way, it might contribute to the comprehension of human dynamics and human behaviours responsible for environmentally stressful changes and their long-term consequences; in another way, it might help to understand the limits of ecosystem survival and the ability to adapt to changing environmental frameworks. Understanding environmental dynamics in the long term is a key aim of environmental studies, but it is maybe even more important to understand the costs and the mechanisms which can lead, in the long term, to a point of environmental unsustainability. European colonialism is far from the only variable in these complex ecological equations.

Human-induced environmental change also occurred where European impact was muted and indirect. While change before 1500 tended to be evolutionary and slow, in the period under analysis there was a dynamic of economic growth (with rising productivity in industry and agriculture) which resulted in demographic increase, intensified international trade, combined with estate-building processes based on a professionalized military strength (Richards 2003: 24). Except that those states were not only European. The seventeenth-century Mughal Empire in India, for instance, was one of the most populated territories of its time, with a productive economy, and counted among the most successful states in the world (Richards 1993).

Environmental history should not present human-induced environmental change as 'an unrelieved tragedy of remorseless ecological degradation and accelerating damage' (Richards 2003: 13), as it is currently seen by most of those who refer to the Anthropocene as the era of the humans. In this sense, to underestimate the resilience of ecosystems and to overestimate human-induced impacts as opposed to natural processes is to risk producing an analysis that may prove too simple in the long run. Climate, geomorphology and culture also forcefully intervene with evolutionary ecosystems. Concurrently, ecosystems affected by human action during the period of colonialism are not necessarily sterile, unbalanced or degraded. They changed then, as they keep changing now, and will remain changing – an attribute of living systems. Eventually, an environmental history that contents itself with deploring the many negative impacts of European colonization upon the non-European world neglects the role played by ecological and cultural dynamics of adaptation during the process, as much as the role of the non-European populations and the other cultures – and this is a perspective which needs to be overcome. Any discussion over the Anthropocene has to go beyond European and Western societies and transcend the technological and development topics. Clean and green technologies are possible and available; sustainable ways of living and interacting within complex ecosystems are offered by a multiplicity of cultures. The connection between the Anthropocene debate, economic development and environmental history is certainly pertinent and a highly relevant topic of discussion but not the only one when debating the Anthropocene, particularly when applied to the First Global Age.

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3

Agricultural Intensification in Sub-Saharan Africa, 1500–1800

Mats Widgren

Precolonial African agricultural history is notoriously under-researched and the research that actually exists is poorly synthesized. Therefore, it is still possible to publish research aiming to explain the growth or lack of growth in precolonial Africa without much consideration of the actual development of farming on the continent during the precolonial period. Whether environmental constraints (Gallup and Sachs 2000) or institutional failure (Acemoglu and Robinson 2010) are advanced as explanations for Africa's present poverty, such claims are often made either without any references at all to African agricultural history or with only anecdotal evidence. But crops, agricultural technology, agrarian landscapes, farming systems and the social organization of farming changed in Africa over time, as elsewhere in the world. This chapter presents evidence for six different regional cases of agricultural intensification in the period 1500–1800.

Whatever definition of the start of the Anthropocene is accepted, it is still recognized that land use conversions has, since the global beginning of agriculture, played a decisive role for greenhouse gas emissions and hence for the late Holocene climate well before the industrial revolution. Starting from 8,000 years ago, pre-industrial forest clearance, in connection with agriculture, impacted atmospheric CO_2 levels and from 5,000 years ago expansion of rice paddies and increased numbers of domestic livestock started to impact atmospheric CH_4(methane) levels (Ruddiman et al. 2015). Therefore climate modellers are increasingly interested in reconstructions of past global agricultural history.

But the data sets on historical land cover that are available at present are all based on mechanical backcasting and only to a very minor degree on empirical evidence from history and archaeology. This is the motivation for the project Mapping Global Agricultural History, which aims at producing a series of maps covering the last millennium in which the known agricultural history of the world is made spatially explicit (Widgren 2010b). Three cross sections in time are chosen.

- 1000: a time when African and American polities and landscapes were distinctly different from those of the late fifteenth century
- 1500: or more precisely 1491, on the eve of European oceanic expansion and before the Columbian exchange
- 1800: before the nineteenth-century wave of globalization that drew large parts of the global south into commercial agriculture

The project was inspired by the work done by historical geographers in the United States on the pre-Columbian agriculture in North and South America. The three syntheses on the cultivated landscapes of different regions of the Americas (Doolittle 2000; Denevan 2001; Whitmore and Turner 2001) formed a model for our work. In the dissemination of these syntheses to a broader audience Charles Mann also later showed that it was possible to summarize the knowledge in map form (Mann 2005).

My part in that global project is to produce a series of maps of African agricultural systems. This has proven more difficult than foreseen. For the Eurasian continent there is much more research into agrarian history for the last 1,000 years and at the same time a stronger degree of continuity of agrarian landscapes. The sources for the Americas on the other hand are very much the effect of the discontinuity and the demographic collapse following the Columbian encounter. This resulted in many regions with remarkably well-preserved archaeological material, which has in recent decades been researched by archaeologists, palaeo-ecologists and historical geographers and provides a detailed insight into agricultural systems (Doolittle 2000; Denevan 2001).

Africa differs fundamentally from the Americas when it comes to evidence of precolonial farming. While in Africa there exists a certain number of abandoned field systems, they were usually not abandoned (unlike in the Americas) as a direct result of European colonialism. The evidence of precolonial agriculture can therefore only to a minor degree be found in abandoned field systems, but more in the sparse documentary and oral history as well as in the material from archaeological sites, especially in the archaeobotanical remains.

The historical literature on Africa, however, opens only a few avenues to a better understanding of precolonial agricultural systems. Much writing about precolonial agriculture in Africa still suffers from the 'ethnographic present tense'. While reading works by historians, and also archaeologists, it is often difficult, when it comes to agrarian systems, to discern between on the one hand *assumptions* based on ethnographic material, and on the other *conclusions* based on oral or written history or on archaeological results. This confusion of twentieth-century, ethnographically documented African farming practices with what was there before, and, along the same line, the attribution of certain farming practices to certain tribes was of course common in the older literature (see, for example, Beck 1943). But we can now also see that this ethnographic present tense genre did, as Paul Richards has pointed out, spill over to a certain degree into Marxist analyses of African agriculture. Richards argued in 1983 that 'the demographic and ecological processes subsumed under the category "natural economy" (or alternatively, "precapitalist subsistence production") are more plausibly viewed as the *products* of capitalism and colonialism' (Richards 1983: 1).

Another strand of research towards an ecological history of African agricultural systems was initiated by Helge Kjekshus for Tanzania, and it opened up for a more varied understanding of precolonial African agrarian systems, following in the footsteps of researchers such as William Allan (1965) and Marvin Miracle (1967). Kjekshus thought it likely that, in Tanzania, a series of intensive and advanced agricultural systems were abandoned during the nineteenth century as an effect of the caravan trade and European colonialism (Kjekshus 1977: 29–48). Juhani Koponen (1988) balanced this view of an almost total dominance of intensive systems in the precolonial period and showed that in Tanzania in the nineteenth century there was a mosaic of intensive and extensive farming systems. Today we have a partly new research situation, mainly based on the new research on the localized occurrences of precolonial intensive agriculture in Kenya, Tanzania, Zimbabwe and South Africa (see below) and on the series of works on African rice cultivation. This overview is based on this new research as well as on the existing historical and ethnographic literature and some interdisciplinary environmental history projects. To a smaller extent palaeo-ecological works have been consulted. I have not yet worked directly with the accounts of early travellers, but only used their evidence from the secondary literature.

For most parts of Sub-Saharan Africa there exists very little evidence that can be used to classify farming systems in the period 1000–1800. Large parts of the interior were most probably characterized by extensive cultivation, though we do not actually know much about the variations in shifting cultivation (as later documented by Miracle 1967; Morgan 1969) and how common the different, more intensive, practices of mounding and ridging in the rainforest agriculture were before the American crops that these practices were usually associated with later (Allan 1965; Miracle 1967).

In my mapping of agrarian systems through time the preliminary cross-sections for 1500 and 1800, respectively, show a distinct difference. For 1800 it has been possible to map a series of occurrences of terraced landscapes, paddy rice cultivation, areas with intensive maize and cassava cultivation, and infield-outfield systems based on manure as well as other forms of mixed farming. All these different agricultural landscapes witness to a labour-intensive form of agriculture, where the degree of landscape modification has been high. The cases presented here were most often in operation in the late eighteenth century. In some cases we have a clear dating of their origins based on archaeology or oral history to around 1500. In other cases we have no clear data on the origin but, as I will argue in the following, they were most likely the result of an increased geographical division of labour during that period.

This chapter thus argues that for Sub-Saharan Africa the period 1500–1800 implied an intensification of agriculture in many different parts of the continent. We note the emergence and spread of terracing, irrigation, increased investments in anthropogenic soils and the adoption of new crops. Among the factors behind this intensification were the establishment of Portuguese trading posts along the coast, the Atlantic slave trade, the introduction of American crops and the caravan trade in eastern and southern Africa. The evidence for agricultural intensification is often indirect and based on the degree of investment in terracing and irrigation.

It is in the nature of the evidence that measures of labour intensity in agriculture during this period, and especially the documentation of the *process* of intensification, cannot be very precise. When I talk about intensification in the following, I often refer to documented instances of agrarian systems based on investments in landesque capital in the form of terracing and irrigation (see the discussion on landesque capital by Widgren and Håkansson 2014). John Sutton has cautioned against a too-direct understanding of all terracing as clear evidence of intensive agriculture and prefers the term 'specialized' for the many occurrences of terracing and irrigation in Africa. He argues that, on the one hand, the amount of labour that did go into terraced agriculture is often overestimated by outside observers since much of stone clearing and terrace building was part and parcel of ongoing cultivation (Sutton 1984). On the other hand, the branding of some African agricultural systems as intensive can, according to such an argument, serve to set them too far apart from the rest of precolonial agriculture, which was equally advanced but did not lead to enduring landscape modifications. Farming on terraced land, as Sutton argues, is in principle not necessarily more intensive than farming on flat land, and could indeed include both short-term fallowing and shifting cultivation. On the other hand, there is much evidence for the claim that these landesque-capital-intensive farming landscapes were also connected to a high labour input, and possibly a more even input of labour over the seasons. We have strong reason to argue that in most of the African systems the building and repair of terraces was in itself labour intensive, even if the building was incremental (see, for instance, Stump and Tagseth [2009] on the Chagga irrigation system). At the same time, the ethnographic evidence of terraced farming gives a clear picture that such systems were also most often connected to other labour-intensive farming practices such as mulching, manuring, composting, ridging and mounding and they were also often associated with a diversified crop repertoire (Widgren 2010a). The little quantitative ethnographic evidence of labour input that we have also points to a distinctly higher labour input on the terraced fields than on fields with shifting cultivation (Netting 1973: 133ff). There is thus a good argument to interpret the archaeological evidence of landscape modification as a proxy for labour intensity, not only based on the terracing and irrigation, but also on the other labour-intensive farming practices that are usually associated with such landscapes.

Rice expansion and intensification along the Upper Guinea Coast

The development of indigenous rice cultivation in West Africa has been the subject of a series of works by Judith Carney (2001), Walter Hawthorne (2003) and Edda Fields-Black (2008). The wetland rice farming in the Senegal and Middle Niger rivers played an important role for the food supply of the Ghana Empire in the eleventh century. The Arab sources, and later evidence, indicate that this rice cultivation was mainly based on flood retreat (*decrue*), hence with few investments and landscape modifications (Carney 2001: 35). From that area rice cultivation spread and successively developed into two varieties, one rain-fed type, which had its centre in Guinea, while an irrigated type of rice cultivation, distinct from the inland Niger flood-retreat type of cultivation, developed on the Senegambian coast. This involved the clearing of mangroves, the building of dykes, the desalination of large areas of land and the creation of canals, sluices and dykes. That type of rice farming, which in Senegambia developed before 1500, was closely connected to the long-handed flat-bladed spade shovel. With its iron share it made it possible to clear the mangrove forest and expand the cultivation. This rice cultivation was documented by European travellers in the late fifteenth century. The trade in rice was considerable in the seventeenth century and from that period the details of the paddy rice system is well documented (Carney 2001: 17ff).

Hawthorne has argued that during the sixteenth century this type of cultivation was restricted to Mande-speaking people in the Senegambia. Through their control of the iron trade they also controlled the technologically advanced rice cultivation. With the arrival of the Portuguese traders other groups along the coast were able to acquire iron, and paddy rice cultivation spread southwards during the seventeenth and eighteenth centuries, and formed an integral part of the slave trading network. The Balanta, along the Guinea (Bissau) coast, were a decentralized society, which at the early period of contact with the Portuguese practised extensive cultivation of maize and yams. In response to the growing demand for foodstuffs to provision the slave ships, they turned to paddy rice cultivation and transformed their landscapes with a series of dykes to a fully fledged paddy rice landscape (Hawthorne 2003). However, Edda Fields-Black has shown, on the basis of linguistic evidence, that in the Rio Nunez region further south (in present Guinea Conakry) there was an extensive knowledge of rice production well before the Portuguese and that in some of the mangrove environments the need for heavy iron implements was not as crucial for

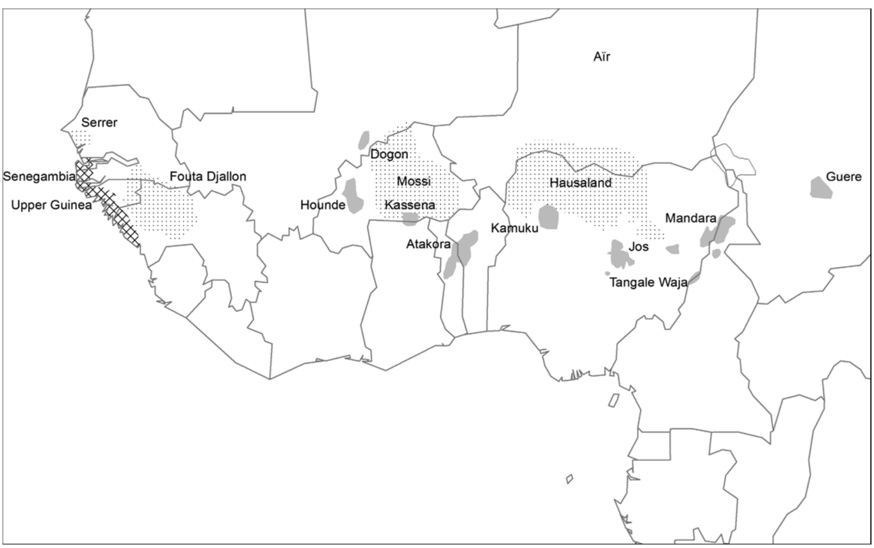

Figure 3.1 Areas of intensification in West Africa. Crosshatched: expansion of labour-intensive rice paddy cultivation; stippled: infield-outfield systems; shaded: intensive terraced farming mainly in highlands.

rice production. Nevertheless, she conveys the same image as Hawthorne and Carney of the Guinea Coast as developing into a veritable rice granary in the eighteenth century (Fields-Black 2008; see Figure 3.1).

Terraced agriculture in West Africa and the Sudan

In the semi-arid Sahel zone in West Africa and Sudan, and in the northern regions of the tropical savanna, a series of terraced hill complexes are known to have existed at the time of the Atlantic slave trade (for an overview see Widgren 2010a). Previous research has emphasized the political and ethnic contexts of these decentralized societies. From the later ethnographic record we know that not only terracing but also many other intensive farming were practised, such as indoor stalling of cattle, manuring, mulching and ridging. These intensive agrarian systems, from the Dogon and the Kassena in the west to the Nuba hills (Kordofan) in the east, have often been described as the outcome of the slave raiding from the fifteenth century onwards, when decentralized societies retreated to inaccessible hill areas to escape predatory states – hence the French term *refoulés montagnards*. In the old German and French literature they have also been described as the remnants of a *paleonegritic culture*.

While this interpretation is still often quoted, there is surprisingly little historical and archaeological evidence for the timing of the settlement of these mountains as well as for the age of the terracing and other intensive farming practices. There are however strong indications that in 1500, and well before, many of these hills were indeed settled and farmed. Also, all evidence points in the direction that they offered some environmental advantages compared to the surrounding savanna lowlands. Higher precipitation and, often, good volcanic soils offered possibilities for those who were ready to embark on labour-intensive agriculture. Terracing, mulching, manuring and other intensive farming practices might therefore in these areas have their origin in times well before the slave raiding, although the extent of terracing at that time cannot be established. In two cases archaeological work has moved us closer to a more precise dating. In the Jebbel Mara area in the Republic of Sudan the settlement type associated with the terracing predates the Islamic period and might thus have been there since at least 400 years back (Häser 2000: 245). In the Mandara Mountains in Cameroon, Scott MacEachern has, based on new archaeological evidence, shown that parts of these mountains were indeed heavily settled and probably terraced at least 800 years ago. The last 500 years would nevertheless, according to MacEachern (and in line with his previous dating), be the main period when the northern Mandara mountains were occupied by high population densities practising intensive agriculture (MacEachern 2012). In a very hypothetical but instructive analysis of two phases of human landscapes and their crop repertoires in the Mandara mountains, Christian Seignobos has recently illustrated a possible sequence of intensification. He tentatively dates the intensification and the massive building of the terracing to the sixteenth century, but the basis for this dating is unclear (Seignobos 2014).

For the discussion of the role of slave raiding for establishing or strengthening this intensive farming, the results from similar cases of intensive farming in eastern Africa (see below) may be enlightening. As has been argued by Wilhelm Östberg, the tendencies for, on the one hand, conflict with neighbouring pastoral groups and, on the other, peaceful cooperation and exchange between agriculturalists and pastoralists must not be seen as diametrically opposed, but rather as indicative of a dialectic relation between cooperation and conflict (Östberg 2004). MacEachern has argued for a similar dialectical relationship between the Wandala state and the Mandara hill farmers (MacEachern 1993). It seems very likely that the relation between these hill farmers and the predatory slave raiding states created an impetus for intensification of agriculture both in the hills and on the surrounding plains and that political and economic development during the sixteenth to nineteenth centuries thus strengthened an already existing labour division between societies in different natural environments.

Infield-outfield system in the West African plains

In a zone stretching from Senegal to Nigeria we find a type of farming system which is similar to what in Europe has been defined as an infield-outfield system, but which in Africa often has been known as a 'ring-cultivation system'. The characteristic features are an infield, immediately surrounding the town or village, where the fertility is maintained through input of manure and/or nightsoil and in an outer periphery of extensively cultivated outfields (Fussel 1992; Prudencio 1993).

Paul Pélissier has described the Serer farming system in Senegal, before the great groundnut expansion in the early twentieth century. On the small, permanently cultivated infield, millet was grown. The high productivity of this infield was based on a long history of managing the soils and an intimate integration of cultivation and cattle keeping. Through elaborate methods of stubble grazing and folding on the infields during the night, the fields were manured (Pélissier 1966: 236, 258–9). It is possible that this farming system has its roots in the thirteenth century, when the Serer first settled in the area (Reinwald 1997).

In Hausaland the examples of intensive farming practices mainly emanate from the nineteenth-century sources and observations, but Ken Swindell has argued that these practices were of a considerable age and reflected the control of labour of a centralized hierarchical political system (Swindell 1986). From nineteenth-century observations from the Hausa towns we know that agricultural slaves played an important role by carrying night soil and manure to the infields (Hill 1976: 417f; Hamza 2004). This labour is the explanation for how the acid, sandy Sahel soils could be transformed to anthropogenic soils on productive infields.

It is striking that many of these field systems existed in many of the same zones as the slave-raiding and slave-using states (cf. Lovejoy 1979, 2012). A more precise dating of the process of intensification resulting in the infield-outfield systems of West Africa is difficult. It is only through indirect inferences that we can argue that this intensification was associated with the period of the Atlantic slave trade and the system of inland trade routes, a period when a series of predatory states emerged that built their wealth on slave-raiding, agricultural slaves and trade (see more in Widgren 2012: 100–2).

Islands of intensive agriculture in eastern Africa

The 'islands' of intensive agriculture in eastern Africa have so far been much more in the research focus than many of the other instances of intensification treated in this chapter. In 2004 John Sutton and I summarized the evidence so far in an edited book (Widgren and Sutton 2004). In that work we tried to single out some of the factors leading to intensification and emphasized the geographical labour division, through institutionalized exchange. As we can understand this intensification now, it was in all documented cases connected to a geographical division of labour: in some cases as a direct consequence of the caravan trade in the nineteenth century (Baringo, Kenya; see Anderson 1988, 1989) and in other cases through institutionalized exchange within or between ethnic groups (Östberg 2004; Loiske 2004; Davies 2015). This approach to explaining localized cases of intensive agriculture was to a certain extent developed as a contrast to the approach by Gourou, who emphasized how such localized occurrences of intensive farming should be understood as the outcome of a siege-like situation, where slave raiding or threats from pastoral groups have acted as a pressure towards intensification (Gourou 1991). The scrutiny of one of Gourou's cases, the Iraqw of the Mbulu highlands, formed the basis for Lowe Börjeson's critique of the 'siege hypothesis', where he developed a model of how intensification through a self-reinforcing process could become 'its own driving force' (Börjeson 2004, 2007). The relations between, on the one hand, trade and exchange and, on the other, investments in landesque capital have been further elaborated for four contrasting cases in the mid-nineteenth-century Tanganyika (Håkansson and Widgren 2007) and in a series of papers by Håkansson (2004, 2008).

Further archaeological investigations have profoundly advanced our knowledge of both the function and dating of two of the major areas of locally developed irrigation in eastern Africa. Daryl Stump has analysed the chronology and function of the abandoned irrigation system at Engaruka (Stump 2006a,b). These results have been further analysed in a wider context of changes in climate and of the wider economy by Westerberg et al. (2010). The irrigation system was established in the fifteenth century in the context of a drier climate and during a period of growth of caravan trade between the east African coast and the interior, which increased the demand for grain along the trade routes. The ensuing history of the irrigation community, however, cannot be explained by either climate or trade alone. The irrigation system survived and intensified during a period of much drier climate between 1550 and 1670 and during the decline in caravan trade between 1550 and 1750. By then, it must have had its own internal growth dynamic based on successful farming and on interaction with local pastoralists. The final abandonment was probably caused by a combination of climate deterioration, pastoralist Maasai expansion and a resulting change in livelihood strategies. This abandonment would not have occurred under duress but can be described as the result of the 'successful accumulation of wealth in the form of cattle, by which Engaruka farmers secured a shift, or possibly a return, to pastoralism' (Westerberg et al. 2010: 10).

Matthew Davies investigated the history of irrigation canals in the Pokot in Kenya, north of the more well-known system of canal irrigation in Marakwet. The radio carbon dates for canal construction in that area are surprisingly late and many of the canals were constructed in the late nineteenth century (Davies 2008, 2012). This, together with oral histories, has led Davies and co-authors to conclude that also Marakwet irrigation 'is unlikely to predate AD 1700, with the oldest channels likely constructed between 200 and 300 years ago and subsequent channels added through time' (Davies, Kipruto and Moore 2014: 514). The new archaeological results indicating a late development of the irrigation in Marakwet and Pokot are important to note in contrast to Ehret's dating on linguistic grounds (2002: 393) of the Marakwet irrigation as being more than 500 years old.

Intensification in the Congo basin 1500–1800

In most maps of African agricultural systems, a large zone of central and equatorial Africa is usually characterized as based on shifting agriculture. From the overviews by Allan (1965) and Miracle (1967), however, we know that, throughout that region, extensive forms of shifting cultivation often coexisted with more intensive forms of cultivation close to the settlements. For some of the crops, there were also variations in the form of the forest-based cultivation so that in places a more labour-intensive

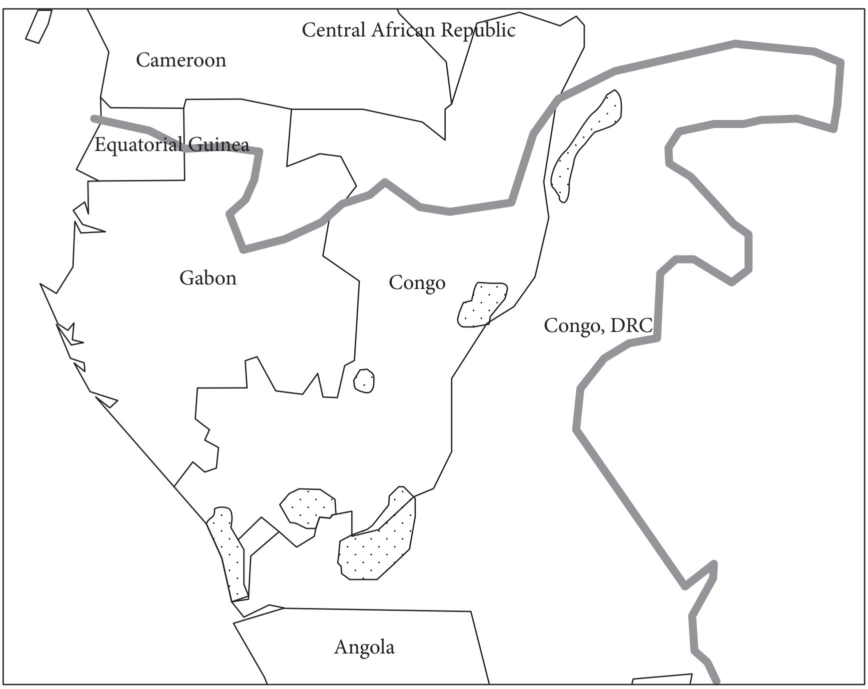

Figure 3.2 Areas of agricultural intensification (cassava and maize) along the trade routes in the Congo basin during the Atlantic slave trade. Extent of Portuguese trade area by 1830 marked with shaded line (based on Vansina 1990, map on 212–3).

kind of shifting agriculture, with mounding and composting, was practised. With the arrival of the American crops, especially cassava, but also maize, these labour-intensive practices seem to have increased in importance.

For the central parts of the Congo basin Jan Vansina has shown how the arrival of American crops combined with the expansion of the Portuguese trade led to localized areas of more labour-intensive agriculture (Vansina 1990: 211ff; see Figure 3.2). According to Vansina the demand for foodstuffs to feed the Atlantic slave trade led to this intensification, first by slave villages and farms and later on by the introduction of the new high-yielding American crops. Cassava was of special importance because of its storing capacity. Forms of intensive and labour-demanding cultivation of cassava then developed among the main trade routes and their immediate hinterland. Other labour-intensive methods also appeared during the period of the Atlantic slave trade: mounding, ridging, extra weeding, all practices which according to Vansina 'boosted yields, preserved nutrients and permitted efficient rotation of crops' (Vansina 1990: 215). Probably from the later eighteenth century onwards some even more intensive farming techniques emerged, such as the very special building of fields within retaining logs and the yearly filling of these coffers with new silt (Vansina 1990: 216).

Achim von Oppen has shown that the cassava found its way to the interior of central Africa before it was widely accepted at the coast. It was present in the Lunda Empire in the sixteenth century and reached the upper Zambesi in the seventeenth century. He shows how it enabled an increased permanency of fields, and hence a reduction in the labour for clearing new land. This had effects on the gender division of labour, with increased workloads for women in the planting, mounding and composting and reduced male labour in clearing new lands. Von Oppen categorizes the adoption of cassava in these areas as an indigenous agricultural revolution and refutes the idea that such processes of intensification should only be seen as short-sighted reactions to stress (von Oppen 1992).

Intensification in the temperate zones of Southern Africa

In the temperate zones in southern Africa two larger areas of abandoned terracing are known: Nyanga in Mozambique and Bokoni in South Africa. In these two areas the terracing remains today only as archaeological features and by the time of European colonization in the nineteenth century they were both abandoned (Figure 3.3).

Robert Soper has extensively documented and dated many of the different forms of settlement, as well as the terracing and ridging in Nyanga (in the eastern highlands of Zimbabwe bordering Mozambique). A dating of the settlement to the span between the fourteenth and eighteenth centuries has been established, with the earlier dates mainly associated with hilltop settlements and the later dates with the pit structures that appear to have been well integrated in the systems of agricultural terracing (Soper 2002: 131 ff). There are strong indications that cattle were stalled and manure used on the fields. The historical context of this vast complex of terracing and of cultivation ridges in the surrounding lowlands is not clear. In spite of a comparatively late archaeological date, the oral history does not shed any light on which later communities might have been associated with the terracing in Nyanga (Beach 2002).

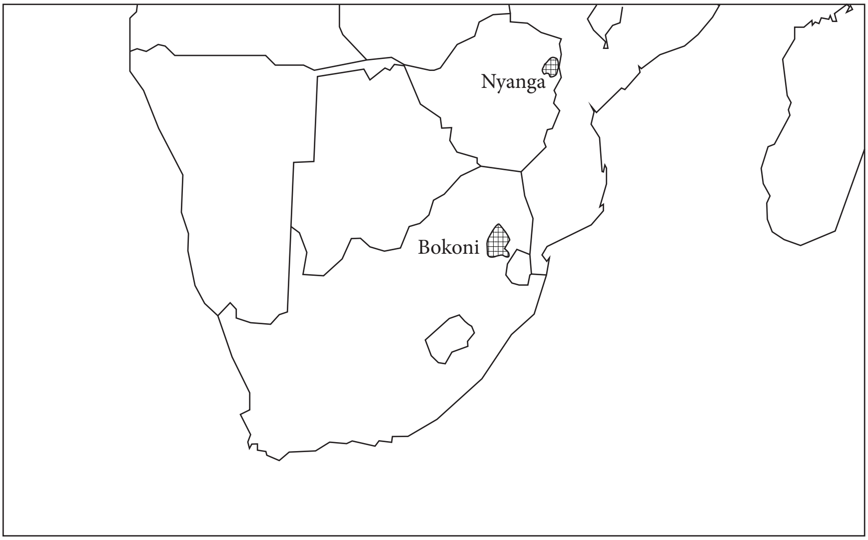

Figure 3.3 Nyanga (Zimbabwe) and Bokoni (South Africa): the southernmost examples of 'islands' of intensive and terraced agriculture in Africa.

For the Bokoni area in South Africa the historical context is much better known and is clearly connected to the archaeological remains. Oral traditions document that groups of people associated with the Bokoni were living in the region by the seventeenth century and that the occupation of the terraced and stone-walled sites continued into the early nineteenth century (Delius and Schoeman 2008; Delius, Maggs and Schoeman 2014). Bokoni formed part of a regional trade network which included the exchange of grain for metals (Delius and Schirmer 2014). The agricultural landscape was characterized by its extensive agricultural terracing, but also by the long, walled cattle roads that were constructed to lead livestock from the outlying grazing lands, through the infields and into the settlements. These are spatial arrangements that are usually connected to the daily movement and thus night-time stalling of cattle at the home enclosure. It has not yet been proven, but is highly probable, that manure was used on the fields (Maggs 2008: 180). It is also possible that maize was cultivated in Bokoni. The cultivation of maize, which demands both more nutrients and more moisture than sorghum and millet, may have been a rationale both for the possible manuring and for the successive building of water-retaining terraces (Widgren et al. 2016).

Conclusions

The different cases of agricultural intensification that are discussed here took different forms in different climatic zones and in terms of crops involved, farming practices, degree and character of investment in the land, and degree of integration between livestock and arable farming. In some cases (paddy rice on the Upper Guinea coast and the intensification in the Congo basin) a direct connection to the Atlantic slave trade has been argued. In other cases it has been shown that the areas of intensive agriculture formed part of regional exchange networks. The geographical labour division between, on the one hand, intensive cultivators and, on the other hand, pastoralists and/or less-intensive cultivation may also have played a role in the development of intensified and specialized agriculture. The American crops clearly played a role in the Congo basin but may also have been part of the developments of terracing in southern Africa, although that proposition still remains hypothetical.

In all cases discussed here the intensification was also dependent on investment in landesque capital in the form of terracing, irrigation structures and anthropogenic soils so that these improved farmlands must have been seen as capital assets (cf. Austin 2008: 595). The role of such investments in fixed capital has not been much discussed in African economic history. In all the cases discussed here, off-season labour must have been used in investing in the farmland. Lovejoy is partly contradictory on this issue when he discusses the slave economy related to the infield-outfield systems discussed above. On the one hand he shows that only manured land was saleable, and thus constituted a capital asset (Lovejoy 1979: 1282). On the other he claims that there was 'relatively little investment in capital or the improvement of land' under slavery (Lovejoy 2012: 268).

How should we interpret these different steps taken towards intensification? Are they examples which show that an 'Asian' path was possible for Africa? In one way the answer must be yes. The African environment offered ways for a development towards a more labour-intensive agriculture. The different cases bear witness to the possibilities for the development of a more productive agriculture in Africa, regardless of climatic zones and regardless of the environmental constraints that in some analyses have been used to explain Africa's lack of development.

The second question is if these cases contradict the general understanding of Sub-Saharan African agriculture as argued by Austin (2008 and in this book) as characterized by a land-extensive path of land abundance and labour scarcity. In his argument in 2008 Austin emphasized the temporary nature of the intensive systems of irrigation at Engaruka and in Baringo (see above). Ewout Frankema has even gone so far as to claim (against all evidence) that none of the pockets of intensive agriculture in East Africa has withstood the test of time (Frankema 2014: 19). On the other hand, von Oppen has argued that precolonial indigenous agrarian revolutions and innovations were either stopped by the colonial development or taken over by external development forces, before they could show their long-term effects (von Oppen 1992: 293–4). That may well be valid at a general level, but in none of the cases where we know that intensive agriculture involving terracing or irrigation were totally abandoned has it been possible to explain this by direct colonial involvement (Engaruka, Baringo, Nyanga, Bokoni). This is not to dispute that von Oppen's argument may be valid in many cases, the most obvious perhaps being the failed plan to make the Usambara mountains into a German settler colony. These plans never came through but the steps towards it shattered and disrupted the locally developed intensive agriculture (Huijzendveld 2008).

Baringo is an extreme case of an intensive system that can be seen as episodic, lasting only during parts of the nineteenth century. Engaruka, Nyanga and Bokoni have a history of some 200 years or more. The other cases discussed here have probably a longer history and several of them exist as living farming communities today. But seen in a long-term perspective the argument about the temporary nature cannot be dismissed. The dynamism of some of these cases of intensive agriculture goes hand in hand with the dynamic nature of African population densities. James McCann expressed it like this:

> The issue for human impact on an African historical landscape is the number of people at a place at a certain time – population conjuncture – and not a simple growth rate. After all, people move. They migrate to or leave an urban area and congregate on productive land, or are coerced to do so, at a rate much higher and more significant than an overall population growth rate. (McCann 1999: 20)

Much earlier, the German geographer Ernst Nowack emphasized this strongly dynamic character of population patterns in Africa (Nowack 1942). Even if the cases discussed here were not all short-lived, they do in that respect reflect the general tendency of land abundance and the political and ethnic dynamics that this situation has entailed. Delius and Schirmer, in their discussion of the Bokoni successful intensification, quote Simon Hall, who emphasized for African political culture the 'ability to move, resettle, shift allegiance, and create new identities in the pursuit of political and economic advantage' (Hall 2010, quoted in Delius and Schirmer 2014). Taken together with Börjeson's argument about intensification becoming its own driving force, with high population densities and immigration as the outcome of the intensive agriculture, rather than its cause (Börjeson 2007), we are perhaps beginning to solve the issue of why temporary or more long-term intensification occurred within the broader context of land abundance and labour scarcity. Seen in such way the different instances of agricultural intensification that have been discussed here do indeed witness to the possibilities and constraints that are offered by relative land abundance.

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4

Containers, Energy and the Anthropocene in West Africa

Emily Lynn Osborn

The effort to trace the origins of the Anthropocene propels us, as humans, to recognize some of our commonalities and to consider how we, as producers and consumers, have acted collectively as geopolitical agents and changed climate patterns across the globe and through time. At the same time, tracking the roots of the Anthropocene challenges us to show how humans produced greenhouse gases differently over time and place. Indeed, there is a notable dearth in the historical literature on Anthropogenic climate change when it comes to Africa. Debates about pathways and processes to industrialization and development, and their consequences for atmospheric conditions, have focused largely on Europe, Asia and the Americas; insufficient attention has been paid to Africa's role in these processes and the environmental foundations and climatic consequences of its economic activities.

In this chapter, I take up the topic of energy use and its history in West Africa with a particular focus on containers, that is, the receptacles that people use to hold, carry and store things. As will be demonstrated, containers tell a great deal about the culture and society in which they are created and used. Political, geographic and environmental conditions, as well as the availability of materials, technologies and modes of transportation profoundly influence the kind of containers people can make and the purposes to which they put them. People tend, in short, to create, acquire, use and move containers that serve a purpose, that function well, and that resonate – aesthetically, spiritually, materially and practically – with the world around them. Furthermore, historically, containers are typically the products of the environment (broadly construed) in which they are made, and they often stand at the core of a whole host of commercial, ritual and familial transactions and exchanges. As a result, containers and their history help cast light on what is one of the central goals of this book, to explore the intersection of environmental and economic histories.

Studying the history of containerization in Africa is additionally beneficial because it offers a framework that is both capacious and precise to consider what are, in effect, the transformations that have taken place over time in materiality, mobility and value. As such, this study considers everything from hand-crafted artisanal containers, such as baskets, pots and wooden bowls, to industrially manufactured carriers, such as plastic buckets and the large metal boxes carried by cargo ships, trucks and trains. Large infrastructural projects also fall into this analytic rubric, for railways and roads are essentially conduits designed to transport mobile containers – from ox-drawn carts to cars, trucks and trains – that can move people and goods.

Exploring the history of containers also opens up a significant new body of sources, for this approach relies heavily upon, and treats as evidence, the handiwork of men and women who may not otherwise enter into the historical record. Considering how people in the past packaged, kept and carried things directs our view on baskets, pottery, cloth, gourds, leather bags and pots – items that have long preoccupied archaeologists and art historians, but to which historians have paid less attention. At the same time, casting broadly the containerization net pulls together craft traditions that are often studied discretely and separately, often according to region and ethnic group. We may not know the names of the people who made the containers that figure in this study, or even where they come from – but their handiwork has lived on and can be tracked through archaeological findings, museum collections, engravings and photographs, as well as through the people who continue to practise handicrafts today, and transform raw materials of all kinds into useful goods.

Methodologically, this study of containerization considers West Africa writ large, an approach that is influenced in part by the wide commonalities in containerization practices manifest through the region and which owe a great deal to geography, terrain, climate, precipitation (or lack thereof) as well as to the availability or dearth of resources. But this regional approach is also a recognition of the mobility and connections of West Africans themselves, who were often more footloose and peripatetic than the historians who study them.

A preliminary examination indicates that West Africa's containerization history can be grouped into four major eras. In the first period, which dates to the dawn of the Agricultural Age or the Neolithic era, Africans used locally sourced organic materials to make containers and fuel their movements. People, animals and waterways made containers mobile in this era. The fundamental dynamics of that early period continued to undergird the second phase of containerization, which was influenced by the arrival of Europeans on West Africa's shores, starting in the late fifteenth century. The resulting trade in gold and slaves introduced new containers to West Africa's landscape at an unprecedented volume and scale. Some of these receptacles were luxury goods – fine platters and basins – but others were everyday, durable vessels that people used for cleaning, cooking, serving food, storing and transporting liquids and other goods, and for local production processes. So too did this trade bring to West Africa items that were often meant for specific uses but which could be repurposed and used to package and carry things. Textiles, for example, could be used by individuals to cover and adorn their bodies, homes and valued objects, but they could also be used to bundle together and transport other objects (Alagoa 1970; Alpern 1995). All of these imports were most intensely acquired, traded and used along the coast, and while some items, such as brass neptunes, made their way into the interior, for the most part, bulky and heavy containers, such as barrels, stayed close to the littoral, as did fragile receptacles that were vulnerable to breakage. Overall, these new containers did not fundamentally change well-established containerization practices.

In the third period, from the onset of colonial rule at the end of the nineteenth century until the end of the Second World War, the British, French and Germans threaded their colonies with new containerizing technologies. This process introduced to West Africa, which had been almost engine-free, technologies and containers that relied upon internal combustion engines and carbon fuels. But while cars, trucks and railways altered West Africa's organically driven containerization system, they did not displace them. Indeed, colonial officials faced the same geographic and logistical constraints that had long confronted other inhabitants of the region, and they responded similarly. As a result, the colonizers often relied upon carriage systems that had deep roots in the region. The fourth era of containerization, which dates from the mid-twentieth century, marks a more profound change, one coincident with what could be identified as a global revolution in the production of consumer goods.[1] This change was made possible by innovative manufacturing processes developing during the Second World War which decreased the cost and increased the output of various kinds of materials, such as plastics and aluminium. But even the expansion of the kinds of containers and the ways in which they could be transported did not altogether do away with the patterns of yesteryear – to the present day, in the twenty-first century, humans, livestock and waterways still commonly make containers mobile in West Africa (Philpott and Mullin 1995; Howe 2001).

As this temporal sketch reveals, there are many obvious and significant changes that have taken place over the past two millennia in the kinds of containers that people use and make in West Africa. But there are also some notable and persistent continuities. In all these periods, scarcity has played a powerful role in shaping containerization practices – while materials used to make containers may be abundant in many areas of West Africa (gourds, grasses, clay), the fuels that move containers are often costly or difficult to obtain (Hopkins 1973). That scarcity has, importantly, helped to foster economies and cultures throughout West Africa that emphasize efficiency, reuse and recycling, often on a highly localized scale. There is, of course, much to celebrate in – and much to learn from – those creative efforts to continually squeeze value and application out of limited resources. But those practices can also be hazardous and their toll can be measured in terms both human and environmental.

Finally, the pressures and practices that have shaped containerization practices in this part of the world offer another vantage point to consider West Africa's role in the making of the Anthropocene. Intensive agricultural practices in Africa may have contributed to global warming as early as the sixteenth century (Widgren's chapter, this book), but West Africa's containerization history demonstrates that, until

[1] Jan de Vries cautions against overusing the concept of 'consumer revolution', noting that in the European context five distinct periods have been identified as such (de Vries 2008). Africa has been notably left out of debates about consumer revolutions, but more research may establish that the post-1945 era marked a substantial shift in consumption patterns, cultures and materials in West Africa.

the mid-twentieth century, the region's transportation and manufacturing systems remained organically driven and its peoples have contributed only minimally to the greenhouse gases that helped bring about climate change.

Climate, environment and mobility

West Africa's environmental and climatic conditions have profoundly influenced the kinds of containerization practices that have taken root in the region. West Africa is made up of three distinct zones: the hot and arid Sahel, which borders the southern edge of the Sahara; the savanna, characterized by grasslands and outcroppings of hardy trees and bushes; and the rainforest belt of the southern Atlantic coast. The Sahel and the savanna stretch to West Africa's western coast, tracing through what is now Senegal, while the southern forest belt, which runs from Guinea to Nigeria, is today only partly covered by rainforest, although it is home to the heaviest seasonal rainfalls. Within each of these three broad zones there are, of course, variations – microclimates and geographic anomalies – while their landscapes have also been significantly shaped by the activities of humans and the towns, cities, fields and farms that they have built and maintained over time.

West Africa is a warm region and temperatures do not fluctuate a great deal, running generally between 20 and 30 °C. But there is a good deal of variance when it comes to rainfall. Because West Africa is not home to any towering mountain ranges that can wrest moisture from the atmosphere and bring precipitation to the earth, rainfall consequently depends upon the interactions of air currents, specifically to the meeting and collision of northeast and southeast trade winds, a process known as the inter-tropical convergence zone. The area where that convergence takes place typically moves steadily north from around the equator in the spring and summer months, bringing with them seasonal rains – which may last for many months in places like southern Nigeria, but which may yield only one or two short rainfalls per annum in the northern reaches of Senegal and Mali ('The ITCZ in Africa' 2015).

The distribution of West Africa's rains is important not simply for plant and human life, but also because they feed the tsetse fly, which is the carrier of human sleeping sickness and animal trypanosomiasis, a disease that causes fever, lethargy, weight loss and death – and which prevents most large beasts of burden from surviving in West Africa's wetter regions. The tsetse fly meant that humans living in the rainy coastal zones, as well as in the moister ends of the savannas, could not share with large animals the labour of clearing fields, building houses, processing crops and engaging in trade. The demands of making and moving containers in regions where the tsetse fly reigned thus fell largely to humans.

By contrast, in the drier Sahel, which lies beyond the reach of the tsetse fly, various kinds of livestock could and did survive. Cattle were the first large animal to be domesticated in Africa, around 6500 BC, when the Sahara desert was wet and green and home to a mosaic of fisherfolk, pastoralists and gatherers (R. J. McIntosh 1998). People likely reared cattle at first for meat and then later also for milking. Cattle, however, require significant amounts of water and do not thrive in drier climes, as when the Sahara desert started to dry out, around 1000 BCE. While pastoralists took herds of cattle to find greener pastures, donkeys, which were domesticated in other parts of Africa around 4000 BCE, helped Africans adapt to the desiccation of the Sahara and to conditions on the desert edge (Kimura et al. 2013: 885). Donkeys are hardy and sure-footed and they can carry considerable weight relative to their size and survive on little water. They were thus less vulnerable to the increasing heat and organic austerity of the Sahelian landscape.[2] Around 300 CE, the camel presented another important source of mobility in West Africa (Bulliet 1975). The hardy constitutions of camels – they can function for days and weeks without fresh water, while their lengthy eyelashes protect them from sandstorms and their thickly padded toes help them move through hot desert sands without sinking or burning – helped make possible a trans-Saharan commerce in salt, gold, slaves and luxury goods.

The different ecological niches that domesticated livestock came to inhabit – or not – reveal that the peculiarities of West Africa's environment generated both opportunities and constraints for the peoples who lived in this region. Indeed, not only is the tsetse zone hostile territory for livestock but also the torrential rainfall of the rainy season, which can endure for months, produce thick mud that hampers the practicality of carts or wagons and pose challenges – in the past as well as in the present – to the making and maintenance of roads. In the Sahel and the savannas, people have long availed themselves to cattle and donkeys for the transportation of people and goods, but dense, sandy soils likewise make difficult the use of wheeled vehicles. West Africans, as a result, did not make use of the wheel for most of their history, but instead developed other ways of moving and carrying things.

One mode that proved to be a particularly efficient response to West Africa's topography, weather and disease environment is headloading. People skilled in headloading can balance on their heads a variety of goods and containers – pots, baskets, calabashes, bundles, bags and tubs. With their load on their head, they can walk and use their arms (and sometimes a staff) for balance and forward momentum, and their bipedal agility helps them manoeuvre through different terrains. Some experts contend that headloaders can carry up to 20 per cent of their weight with little metabolic expenditure, a theory known as the 'free ride' hypothesis.[3] There is considerable question about the conditions under which this energy saving is achieved, or even if it occurs at all. But that such a theory can even be debated testifies to the apparent effortlessness with which practised headloaders transport their loads.

Regardless of whether or not there are physiological efficiencies to headloading, those who are skilled in this mode of carriage can carry large loads and climb up and down hills, traverse dense rainforests and arid grasslands, manoeuvre through muddy, sandy and rocky landscapes, and cross shallow creeks, streams and ravines.

[2] Horses also were used in the Sahel, although to a much lesser degree than cattle and donkeys; they became more important, as Robin Law has shown, in the thirteenth century as cavalry in the militaries of Sudanic states (Fisher 1972; Law 1980).

[3] The 'free ride' hypothesis is controversial and has not been conclusively proven (Scott 2009; Lloyd et al. 2010).

Indeed, the dexterity of headloaders has long impressed foreign visitors to West Africa, including Rene Caillié, the French adventurer who travelled from the Guinea coast to Timbuktu and across the Sahara in 1827–8. When in the Futa Jallon, in present-day Guinea-Conakry, he remarked upon the 'enormous burdens' carried by the porters and merchants in the caravans with which he travelled. Their loads were often stowed in large baskets, three feet long and one foot wide and deep, which could be covered and tied closed. Caillié explained that he was 'very much surprised to see these poor Foulahs and Mandingoes, who were carrying nearly a hundred weight on their heads, walk with the greatest rapidity and climb the … mountains with the utmost agility. They carry a staff in their hands to assist them in supporting their burden' (Caillié 1830: 171). Not knowing himself how to headload, Caillié relied upon the slave of one of his fellow travellers to carry his 'small bundle' (Caillié 1830: 169).

Although it is unclear when, exactly, headloading came into widespread use in West Africa – it could well have emerged with the earliest human agricultural settlements – the portering skills of West Africans, as Caillié's observations suggest, figured centrally in the long-distance trading networks that have spanned the region and connected its peoples since early in the first millennium. Headloading played a particularly important role in allowing humans to accommodate to and establish settlements in the tsetse zone, where large beasts of burden could not survive. In those regions, people used headloading in their daily lives – to collect and transport water, for example – while it also helped people to use trade to overcome the uneven geographic distribution of vital resources, such as iron ore, salt and timber.

Despite its advantages, there are some obvious restrictions that operate on headloading as a mode of mobility. Packages, bundles and baskets must be scaled to the human body and, no matter how strong and capable a headloader might be, there is an upward threshold on the weight and size of what any single person can carry. Indeed, when it comes to the tsetse zone, there is a notable parallel between portering practices and agricultural ones. As Gareth Austin observes, West Africans typically responded to the demand for cash crops such as cocoa in the nineteenth and twentieth centuries by increasing the area under cultivation – enlarging, in other words, the size of fields and number of plantings, rather than taking measures to boost the yield of each hectare (Austin's chapter, this book). Likewise, headloaders carrying maximum loads could only amplify their output by increasing the number of people doing the carrying – or by executing multiple voyages. For headloaders, carriage expansion can only take place extensively, not intensively. So while headloading was in many ways an ingenious adaptation to areas of heavy rains, sandy soils, rough terrain and tsetse-bearing mosquitoes, it also placed a very real limit on the kinds of goods that could be moved over both short and long distances.

There is, however, one kind of container and mode of transportation that has long offered economies of scale to inhabitants of the tsetse zone: the canoe. The canoe has a deep history in Africa, as exemplified by the Dufuna canoe, which dates to 6000 BC, or the Late Stone Age, and was found in present-day Nigeria. It is the oldest-known canoe on the continent, and one of the oldest in the world

(Garba 1996). Like its successors, Dufuna's makers carved it from one tree, from which they stripped branches and bark and excavated an interior shell, which was probably seasoned with fire, to protect it from insects and ensure its longevity. The construction of canoes depends upon the availability of trees, while it also requires tools for felling, carving and treating (although the earliest canoes were probably made from logs that had fallen down on their own). The trees that lend themselves to canoe making, particularly large ones, concentrate in particular regions. Consequently, some areas of West Africa emerged as regional hubs of canoe production.

Canoes were probably used by some of the earliest fisher communities on the continent, and they fostered some of West Africa's earliest long-distance trading networks. Canoes were likely used to transport iron ore to Jenne-Jeno from its earliest years, around 200 BCE, while Arabic sources suggest that an active commerce in a range of goods took place along the Niger River from the cities of Gao and Jenne since at least the thirteenth century (Hopkins 1973: 73). European maritime visitors to coastal West Africa in the sixteenth and seventeenth centuries likewise remarked upon the canoes, large and small, that they encountered and that helped to facilitate trade. In the Ogoni region of southern Nigeria, Pacheco Pereira asserted that local people made canoes that could carry 'up to eighty men' and were used to transport yams, livestock and people, including slaves.[4] The importance of canoes to the Niger Delta region can be seen in the name of one of the Ijaw ethnic groups, the Arogbo, which means 'canoe forest'. As that term suggests, the region's combination of waterways and tree cover helped it become an important canoe-building centre (Smith 1970; Alagoa 1970).

The advantages of the canoe are shown in Figure 4.1, which is a 1971 photograph from Burkina Faso. In the photograph, a large canoe sits beached on the bank, near what look like clay bricks, drying in the sun, and a large pile of earthenware jugs. Once the bricks are dry and ready to be sold at market, they, along with the pots, will likely be carefully loaded into the waiting canoe, whose carrying capacity far exceeds what any single person could headload. Although this picture was taken in the twentieth century, it depicts a set of activities and relationships – of water, wood and clay, as well as of potters, canoers and commerce – that could have taken place 5,000 years earlier.

It is thus evident that different environments fostered different systems of containerization and mobility and gave rise to a network of people and transport that spanned West Africa. The particular starting points, crossroads and endpoints of these networks shifted and changed over time – as when, for example, miners opened up the Akan gold fields in the fourteenth century – but their basic constitution endured without enormous modification for at least one millennium. The trading centres that emerged at the junctures of different geographic and productive zones not only allowed for the exchange of goods – as has been well established in the scholarly literature – but also for transitions in transportation and carriage. To put it

4 As quoted by Kpone-Tonwe (1997: 140).

Figure 4.1 Canoes with drying bricks and fired pots, Burkina Faso, 1971. Eliot Elisofon Photographic Archives, National Museum of African Art, Smithsonian Institution. Reproduced with permission.

another way, a bundle of merchandise taken from the Akan gold fields in what is today Ghana to the commercial centre of Timbuktu in the year 1850 would be transported by similar methods to those used in the year 1400. That bundle would start its journey as a headload and be carried by a human being through the rainforest and wetter savannas. Arriving in the commercial centre of Jenne, the package of goods could be traded and reconfigured and then hoisted, depending upon season and availability, onto a donkey's back or into the belly of a canoe. Once in Timbuktu's marketplace, the load could be once again divided, traded and reconstituted before being tied onto a camel for the trek across the Sahara.

Notably, the modes of transportation that make up this trajectory – from headload to pack animal, canoe to camel – have proved remarkably resilient, and so too have the modes of containerization that have accompanied them. Starting in the late nineteenth century, new infrastructure and forms of transportation started to pick away at parts of this interlocking chain of mobility; today, the trail through the rainforest is more likely to be made by gas-powered trucks and cars than by caravans of porters while semi-trucks and 4×4s join camels on the tracks of the Sahara. But headloading has nonetheless persisted as an important localized mode of moving things, and the continued practicality of canoes, donkeys and camels for propelling people and goods in the wider region indicate that West Africa's transportation economies are diverse in form as well as in fuel. Put differently, some of the environmental and geographic forces that helped give rise to and ensure the persistence of these organic modes of mobility have also, in effect, acted to hamper and slow West Africa's twentieth-century transition to fossil fuels.

Containers and the agricultural revolution in Jenne-Jeno

The emergence of sedentary agricultural societies brought with it a fluorescence of containerization practices in West Africa. It is not that other kinds of human communities, such as pastoralists and hunter-gatherers, did not employ containers. Hunters made quivers, sheaths and pouches to carry their hunting gear and supplies; gatherers used calabashes, baskets, bags and hollow horns to collect plants, seeds and berries; and nomads and herders relied upon sacks, pouches and egg shells to carry and consume food, milk and water. But the mobility intrinsic to the lifeways of hunters, gatherers and pastoralists acted as a preventative to accumulation and storage. The persistent movement of these peoples furthermore required that containers be durable and lightweight. There was thus not an excess of things or resources – be they luxury goods, provisions or liquids – for people to keep, package and carry, nor was there much imperative to do so.

When people settled down to lead more sedentary lives, by contrast, the needs and horizons for containerization practices changed considerably. As communities came to rely upon systematic cultivation for sustenance, they required baskets for collecting and storing crops; grinders for crushing cereal grains; bins for stowing seeds; cookware for preparing meals; containers for collecting and keeping water; and bags, sacks, baskets and cloth to bundle together valuables and other goods for keeping, trading and safekeeping. Potters, basket-weavers, leatherworkers and woodcarvers helped to meet those needs – although the archaeological record most reliably keeps records of the handicraft of potters. Some of the earliest remnants of ceramics have been found in the western Sahara from around 4000 BCE, an era when the that region was wet, green and home to a variety of aquatic and terrestrial plants and animals (R. J. McIntosh 1998: 48, 52). The desiccation of the Sahara, from around 1000 BCE, drove people north and south out of the growing desert, but they did not abandon their use of pottery.

The earliest inhabitants of Jenne-Jeno, a settlement in the Middle Niger that dates to around 300 BCE, made use of small, delicate pottery made in the Sahelian style. By around 500 CE, as Jenne-Jeno's population expanded, so did the shape and style of its pottery. As pottery became more robust, it also served to anchor processes of biological and social reproduction: newborn babies would be washed in ceramic basins at birth, and they would grow into adulthood eating food cooked in wood-fired pots and drinking water and beer cooled in earthenware jugs. At death, they were laid to rest and buried at the edge of town in large funerary urns. Even the round houses built of mud brick, starting around 800 CE, share similarities in their shape and constitution with the handcrafted clay vessels that animated daily life (S. K. McIntosh and McIntosh 1990).

Wood-fired pots were not, however, the only kind of container that fostered Jenne-Jeno's growth and success. Baskets, leather sacks and canoes facilitated the transportation of iron blooms to Jenne-Jeno's blacksmiths, who worked them into weapons for hunting and war and tools for farming and fishing. Jenne-Jeno's fisherfolk also likely traded bundles of smoked fish and sacks of fish oil for livestock and meat from pastoralists who visited during the dry season and encamped nearby.

As Susan McIntosh and Roderick McIntosh have established, Jenne-Jeno's emergence as a dense urbanized centre reaching 33 hectares by 850 CE owed much to the various occupational specializations its inhabitants developed, as well as to the connections its residents made with peoples of other geoproductive regions. Situated as it was on a floodplain, Jenne-Jeno was not home to iron ore or to the stones that people used to make grindstones; those items were procured through the community's neighbours and trading partners (R. J. McIntosh and McIntosh 1981; S. K. McIntosh and McIntosh 1990). But it is also important to recognize that Jenne-Jeno's productive systems and containerization practices were undergirded by a deep strain of localism. Because earthenware vessels are heavy and fragile, makers and consumers often lived in the same community, or in a neighbouring area accessible by a waterway. While some artisans may have made their pots for sale at market, many were likely produced as the result of a personal negotiation between artisan and client. Their decorative details – stamps, imprints, coils and channels – may well have also been made to order, and specifically designed for either quotidian or ceremonial use. That many of Jenne-Jeno's baked pots feature round bottoms likewise reflects the earthy particulars of the region; these jugs and pots were made to be nestled into the sandy ground for stability which would also, in the case of liquids, help to insulate and cool their contents (Sargent and Friedel 1986: 189).

Personalized transactions between producers and consumers also probably resulted in the stitching of leather bags and sacks, the weaving of baskets, nets and mats (which could be used to make bundles), and the carving of wooden bowls and mortars. Those items of leather, straw and timber have left little material vestige in Jenne-Jeno because of the ease with which they disintegrate, but they certainly played an important role in the productive, commercial and cosmological relations that helped the settlement to grow and prosper. While blacksmiths did not make containers per se, there is little doubt that their iron goods were also subject to similar circuits of recycling.

Indeed, the biases in Jenne-Jeno's archaeological record towards vessels that its inhabitants deliberately preserved, such as burial urns, is at least in part the result of the organic material of which their containers were made, as well as of the premium that people seem to have placed on reuse.[5] Ethnographic studies in the much more recent past show, for example, that a broken pot is almost never discarded, but rather finds new life in different form. A cracked but relatively intact broken pot can provide a chicken or a guinea fowl with a coop, while large shards of pottery can hold roof thatching in place, protect the tender roots of young trees and plants, serve as lids, scoops and scrapers, and function as a water dish for animals. Nor are smaller pot shards discarded: they are often ground into temper or grog and incorporated into mud for plastering walls, or into fresh clay to be kneaded and molded again (Sargent and Friedel 1986: 193; Bedaux 2000: 114–15). Other containers can be similarly repurposed – a tattered leather bag can be cut into patches to repair

[5] The Middle Niger is particularly well known for the sacred objects, in the form of terra cotta figures, that were produced in its period of decline, from 1200 to 1400 (Grunne 2014; see also 'Jenne-Jeno, an Ancient African City: Rice University Department of Anthropology' 2015).

another; a torn basket can be repaired with fresh grasses or, alternatively, it can become a cover for cooked food or a fan for wafting a cooking fire, or be tossed into the dung heap to deteriorate and eventually be used as fertilizer. So too can a damaged wooden mortar be carved into small tools or decorative objects and adornments.

In effect, the containerization practices that helped Jenne-Jeno thrive at its height from 450 to 1400 (when the site was abandoned) reveal some fundamental principles that hold true for West Africa more generally, with some variations, from at least the first millennium CE and well into the twentieth century. That is, first, West Africans generally made containers out of raw materials that they could either collect, cultivate or acquire locally (although in some instances, as with Jenne-Jeno's stone grinders, materials for containers could be imported from elsewhere). Second, unless canoes or livestock could be used for carrying, people typically made and used containers that could be transported by a human being. It was consequently people and their caloric intake that made containers mobile. Third, this organic era of containerization fostered creative and resourceful approaches to storing, carrying and recycling. These strategies took advantage of the abundance of West Africa's landscape and its capacity to produce the organic stuff from which containers could be made, such as clay, trees, grasses, gourds and animals. These tactics also depended upon the capacity of the earth to generate energy – in the form of food for humans, fodder for livestock and the gravitational pull of waterways – that could be drawn upon to transport those containers. But these containerization strategies also paid heed, in their emphasis on carriage efficiencies and recycling, to the toll – in energy, effort and skill – that it took to transform raw materials into containers and make them mobile through different regions.

The photograph shown in Figure 4.2 was taken in Ghana just over a hundred years ago, but it nonetheless illustrates some of the enduring tenets of containerization in West Africa. The receptacles that the women are carrying are locally produced – the potter who made the clay jars in the photo almost certainly does not live too far away. Each of the vessels that these women carry are made out of materials (clay, grasses) that are no doubt plentiful in this part of West Africa, but that are also particular in their locale. That is, some specialized knowledge would be necessary for finding deposits of workable clay and good fibres for basket weaving. At the same time, materials alone do not a container make and move: creating these utilitarian vessels required a good deal of expertise on the part of a potter and a basket weaver, and carrying them as headloads, as these women are pictured doing, is also a talent that demands practice. Nonetheless, the barriers to acquiring and using these containers were defined more by skill and knowledge – skills and knowledge that could, with some effort, be acquired – and not by a particular level of wealth, material resources, a specialized form of fuel or technical know-how. Finally, it is safe to assume that when the basket and jars pictured here reached the end of their useful life, they were incorporated into an organic ecosystem of reuse. Presumably as a result, the use of these receptacles in the early twentieth century has left behind virtually no residual trace in the twenty-first century.

Figure 4.2 Photograph from Ghana taken between 1885 and 1910, from Eliot Elisofon Photographic Archives, National Museum of African Art, Smithsonian Institution. Reproduced with permission.

Containerization in the era of the slave trade

In the late fifteenth century, transformations in the fabrication of sea-faring vessels in Europe – as well as political ambitions and competitions – changed Africa's relationship to the Atlantic Ocean. The development in Europe of new kinds of three-masted ships, called caravels, enabled the Portuguese to tackle the currents of the Atlantic Ocean and make their way down the coast of West Africa over the second half of the fifteenth century. The Europeans were drawn to the continent for its gold, which had previously entered European markets from the Sahara across the Mediterranean, but by the mid-sixteenth century it was the trade in slaves that sustained the contact between Europeans and Africans. Those European ships that plied the coast functioned as floating warehouses and then as prisons. Bound for Africa, they carried merchandise of all kinds, including textiles, iron, firearms and brass pans. Merchants traded those goods for captives, who were then locked down and transported to the Americas. Whereas the coast had previously been a remote and sparsely populated region – distant from the epicentres of trade on the edges of the Sahara – the arrival of Europeans helped to significantly change the status and roles of coastal peoples. No longer peripheral, coastal states and chiefs emerged as powerful players in the European commerce for slaves and other goods.

This process provoked some changes to West Africa's containerization practices, for it introduced to the region various vessels of foreign manufacture that could be used to carry and contain things. At the same time, however, while the European trade significantly reconfigured commercial patterns and routes in West Africa – and radically altered the lives of 13 million enslaved humans and their descendants – they did not and could not fundamentally change the various constraints that operated on the carriage of people and things in Africa. To put it another way: historians have long debated the effects of the slave trade on African political, economic and social systems, with some scholars contending that the slave trade radically altered Africa's institutions and practices, while others (not necessarily incompatibly with the former) arguing that Africa's elites exercised control over the commerce in slaves and managed the terms of trade with their European trading partners. What these debates overlook, however, is how the containerization landscape also profoundly shaped the interactions of Europeans and Africans.

It is notable, to start, that containers of various sorts became important items of trade. Europeans learned, in their dealings along the coast, that their African trading partners were quite discerning – items that sold well at one trading post or factory could draw little interest at a neighbouring one. But some goods, such as textiles, became staples of the trade. While Africans typically used imported textiles for clothing and adornment, and they also sometimes unravelled imported fabric and used the threads to make new pieces. They also used cloth as a container. A length of it could be used to gather goods – such as vegetable and fruit produce or even other lengths of cloth – into a tight bundle that could then be transported by people, canoe or animal. Imported cloth was particularly useful in this regard, because of its size and quality. Domestically produced cotton cloth was woven into long, narrow strips and was relatively costly to produce and acquire. Imported cloth, by contrast, could be obtained more cheaply, and its generous proportions meant that it could be easily used to make bundles.

Another mainstay of the trade became popular specifically because of its containerizing capacity. Brass and copper basins, often referred to as neptunes, sold well in West Africa from the earliest years of contact. William Towerson, an English merchant, travelled to the Guinea coast in 1555 where he exchanged European manillas, basins and beads for grain and ivory. He noted that what their African trading partners 'desired most' were the basins (Towerson 2010: 367). Further down the coast, he sold '39 basons [*sic*] and two small white sawcers [*sic*]' to a Portuguese-speaking 'young fellow', a deal that was 'the best reckoning that we did make of any basons' (Towerson 2010: 381). And at yet another trading post, the African traders 'desired most to have basons [*sic*] and cloth'(Towerson 2010: 382). The demand for these receptacles did not decline in subsequent decades and centuries. In 1645, Dutch vessels imported over 10,000 large brass neptunes to the Gold Coast and 1,500 small ones (Herbert 2003: 137). Records from the Royal Africa Company from 1673 to 1704 likewise indicate exports of 'Iron ware of many Sorts', and 'brass neptunes, kettles, and pots' as well as 'Pewter basons [*sic*], dishes, tankards, pots, plates, [and] spoons' (Royal African Company 1730). Africans put these vessels to various purposes: to serve food, to store provisions and other goods, to pan for gold, to produce salt and to wash infants and clothes, while they also employed them in rituals, ceremonies and burials (Alagoa 1970: 325; Herbert 2003). But as with imported textiles, Africans also sometimes repurposed these imported vessels by treating them as a raw material, cutting them into strips and making bracelets or other decorative items, or melting them down and moulding them into utensils, accessories and figurines.

While neptunes entered frequently in the transactions along the coast, they were not the only containers that slave traders introduced to West Africa's shores. The slave trade also brought drinking glasses, earthenware pottery as well as a variety of cases, crates, barrels and kegs that carried other commodities. Some kinds of containers arrived in the region as carriers of other goods. Alcohol, for example, arrived in wooden drums, ceramic jugs, glass jars and bottles which, after their original contents were consumed, could be put to all sorts of other uses. Sometimes, as with brass neptunes, it was the materiality of these containers that gave them new form. At Ife in Nigeria, for example, archaeological digs suggest that local artisans may have recycled imported glassware to make beads and other small objects (Connah 2001: 170). But they more likely kept their initial form, and were repurposed and used for carrying, storing and serving various goods and liquids, such as water, oil, palm wine or foodstuffs. It is notable, however, that the difficulties of transport still limited the extent to which these imported containers travelled. A pattern that characterized the consumption of alcohol in coastal Nigeria in the nineteenth century is probably broadly applicable to the era of the slave trade. In that region, locally produced palm wine tended to be consumed in the precise locality in which it was made. Even imported alcohol, which enjoyed a robust market, did not travel far from the coast because, according to Simon Heap, 'the fragile, bulky, heavy bottles and demijohns imposed transport restrictions' (Heap 2000: 29). In effect, headloading alcohol of either local or foreign provenance proved too costly and risky an undertaking, even for short distances. In the era of the slave trade, this dynamic helps to explain both the popularity of brass neptunes – whose hardy material meant that they could be carried over longer, more treacherous trade routes without damage – while it also indicates that the vast majority of more fragile European containers likely spent their use-life near their coastal points of embarkation.

Those same pressures also probably apply to the destinations of other, larger containers that arrived in Africa during the slave trade. Carpenters and coopers often travelled aboard slave ships, in order to build interior decks for the captives, as the balance of cargo shifted from commodities to humans. Some of their handiwork, or that of their European compatriots, stayed on Africa's shores. Barrels, which could be flipped on their side and rolled, found their way into West Africa's coastal towns, although their size and heft seems to have meant that they generally stayed close to the coast.

While the slave trade generated myriad changes in West Africa, it was also fundamentally shaped by the ecological and environmental context in which it took place. European traders had no means to subvert the carriage cap created by the tsetse fly, while their ventures onto land were hindered by Africa's political leaders as well as by its malarial mosquitoes and a coastline that offered almost no natural harbours. European slave traders thus depended upon the same means of conveyance that had long shaped commerce and mobility in the region. Captives, taken in war or through judicial proceedings, found themselves on West Africa's pathways or waterways, travelling by foot or canoe. These trips could be fatal, and many captives fell ill and died, from disease, malnourishment, dehydration and abuse, before they reached the shores of the Atlantic. But many of them survived, and this flow of captives to the coast did inspire some new practices and efficiencies in the realm of transport and carriage.

Sometimes captives themselves facilitated the movement of goods to the coast, for some slave traders coerced them to carry headloads of produce and other trade goods. That process entailed a sort of doubling up of value and containerization. That is, captives – who were themselves considered to be commodities with a particular worth – become carriers of other kinds of containers and bundles of trade goods. Other efficiencies took place in the realm of canoe transport. Canoe-men were critical in linking ships to shore, since European boats typically had to anchor their boats a distance from the coast. As early as the sixteenth century, Europeans observed that Africans started to build larger canoes to manoeuvre captives and goods through West Africa's rivers and ocean. At one trade post, for example, Towerson noted in 1555 that 'The boates [*sic*] of these places are somewhat large and bigge[*sic*], for one of them will carie [*sic*] twelve men, but their forme [*sic*] is alike with the former boates of the coast' (Towerson 2010: 386). Pieter De Marees' 1602 book on the Gold Coast includes an engraving that depicts a variety of canoes conveying people, goods and animals to and from ships and the coastline (Figure 4.3). Two of the canoes pictured are notable

Figure 4.3 The slave trade inspired canoe builders in West Africa to make their vessels larger and to experiment with the use of sails. Reproduced from Pieter de Marees and S. P. L'Honoré Naber (1912: 121).

for their size, for one (A) easily holds ten people, while another (B) carries two oxen and a row of gourds. A more distant canoe is distinctive because its single oarsman is supplemented by a sail, which De Marees describes as being made from bark cloth. The use of sails did not become commonplace on Africa's shores, but it was also not exceptionally rare: there are instances of chiefs requesting sailcloth from European merchants for use on their boats (Alpern 1995). Indeed, efforts to raise the carrying capacity of water-borne vessels meant that, by the eighteenth century, canoe builders in the Niger Delta were able to make canoes that carried upwards of 100 captives and that could withstand military attacks (Alagoa 1970).

While the slave trade generated new methods of bulking and bundling in some realms, it certainly did not inspire innovation in all sectors. Archaeologists have noted that in the Senegambia, for example, European contact corresponds to a decline in the quality and creativity of pottery produced in the region. This deterioration may have been the result of competition from imported cookware and vessels, but it probably also reflected the precariousness of the era. Because of increased regional conflicts and the persistent threat of captivity, potters may well have heated their kilns and fired their pots in haste, to avoid lingering in vulnerable, open-spaced areas where the risk of kidnapping may have been high (S. McIntosh and Thiaw 2001: 26–9).

The intertwined histories of captivity, containers and carriage are neatly illustrated by a visit that a British official made to the Kingdom of Samori Touré, a late-nineteenth-century empire builder who conquered vast territories and whose armies enslaved tens of thousands of people. In the midst of a celebratory day of festivities in 1892, some soldiers interrupted the fanfare to deliver to Samori a group of seventy men, women and children whom they had just captured. Each one of them, according to a British visitor and observer, carried a headload of booty – perhaps taken from their own homes – consisting of salt, palm oil, kola nuts and 'large brass pans of American make'.[6] Forcing captives to headload goods carried hazards, from the perspective of the captor, for slave owners or traders who used slaves to porter goods ran the risk of losing both their merchandise and their slaves, should their chattel engineer a successful escape (Austin's chapter, this book).[7] But the scene nonetheless reveals that little had changed by the end of the nineteenth century when it came to overland transport in the interior of West Africa. The enduring equation of power in African politics, which turned on the control of people, not land, continued to be tested by challenges posed by the tsetse fly, the terrain and the weather. In this context humans remained the most efficient and effective carriers of goods and containers in much of the region.

6 Sir J.S. Hay to Lord Knutsford 'Account of Mr. Garrett's visit to Samory's country', 12 July 1890, CO879-32, United Kingdom National Archives. See, further, Osborn 2011: 105–8, 221.

7 Caillié encountered one slave master who feared just that from a recently acquired slave. The next day he witnessed 'the poor slave bearing on his head a burthen [*sic*] which he could scarcely carry, fastened to a rope the other end of which was tied round his leg, so that it was out of his power to run away; for his prudent and suspicious master took care the he should not have a knife to cut the rope' (Caillié 1830: 251–2).

Colonization and motorized containers

Colonization helped usher in a new era of containerization in West Africa, in part because it brought new, automated means of moving around containers. Steamships started to ply the coast in the nineteenth century, but those motorized technologies remained bound to the sea until the early twentieth century. At that point, steam started to be used to power railways, and fossil fuelled motors made cars and lorries mobile on West Africa's vast expanse of land.

Throughout West Africa, French, German and British colonizers placed a great emphasis on building new transportation systems, which they viewed as critical to both promoting commerce and ensuring political stability. An editorial in Lagos, Nigeria, published in 1891 identified some of the 'immense beneficial results' of building a railway in the colony, which included 'the cessation of inter-tribal wars … the extinction of the slave trade, and the increased development of legitimate commerce'. It went on to counsel that all inhabitants of the region should 'look forward with hopeful expectation' to the moment when a railway would become a 'happy reality' (*Lagos Weekly Record* 15 August 1891: 2).

But as historians have noted, implementing this vision proved much more challenging than anticipated. Railway lines, which typically originated in coastal port cities and moved to the interior, frequently had to pass through dense rainforests that required clearing, while they also had to manoeuvre through regions that were fragmented by rivers, streams, ravines and precipices. Such conditions demanded expensive engineering remedies, as in the Freetown-Songotown line in Sierra Leone, which required eleven viaducts in its first twenty miles (Sunderland 2002). So too could the building and operations of railways be threatened by poorly designed routes and heavy seasonal rains, which could and did sweep away tracks. In 1904 in the Gold Coast, for example, sixty-three derailments took place on one badly built stretch of track, while in 1917 heavy rains washed out several stretches of the railtrack, including a twenty-foot bridge (*Gold Coast Annual Report* 1917: 45; Dumett 2006). Particularly in British West Africa, railway builders grossly underestimated the costs associated with building the lines and then managing them. Once they became operational, with certain exceptions, railways in both British and French West Africa did not stimulate the economic boons that their promoters and planners had promised. These failures were due in part to the physical landscape and environment, but mismanagement, corruption, a dearth of skilled labour as well as difficulties recruiting unskilled labour also contributed to the dismal performance of many lines (Sunderland 2002). There was, however, another threat to railways, which came from roads and the cars and large trucks, or lorries, which were imported to travel them.

While trains captured the imagination of colonial officials, road building also emerged as an important component of the colonial project, although it often took second place to railways. In British colonies, cars and trucks were treated as a complement to locomotives in the first decades of the twentieth century, and colonial public works designed railways to function as trunk lines which were then fed, at regional stations, by networks of roads. But, as it turns out, roads and the lorries that travelled them usually proved better suited to serving West Africa's markets for mobility. In the Gold Coast, for example, lorries played a key role in fostering the growing cocoa boom – although only fourteen cars and two lorries operated in the whole colony in 1914, those vehicles were credited with expanding cocoa production along the Kumasi-Ejura road, while the opening of the Kumasi-Sunyani road in 1925–6 increased profits for local farmers by 100–300 per cent in one season alone. The importance of roads to the cocoa trade inspired some villages to relocate altogether, so that their inhabitants could be closer to thoroughfares on which travelled motorized vehicles. Colonial officials also found that local chiefs could be called upon to build and maintain roads that ran through their jurisdiction, and that they often did so willingly (Heap 1990: 22, 30).

The imperative that colonial states placed on constructing transportation infrastructures in their West African colonies meant that motors and engines started systematically to make their way onto land in the first decades of the twentieth century. In effect, railways and lorries came to function as the 'ships' of the interior. Their holds could carry far more than that which could be borne by people, livestock or canoes and they could do so far more cheaply. As a consequence, these mobile containers – and the roads and rails that carried them – greatly augmented the volume of goods that circulated from the coast and through a given colony.

It is also worth noting who helped to direct the movement of people and goods in these new motorized containers. Colonial governments and governmental-sanctioned bodies owned the railways and strictly controlled access to them. The amount of capital required to build, operate and maintain a railway put it far beyond the reach of even the most enterprising and successful of African entrepreneurs. The acquisition of cars and lorries, by contrast, proved to be much more feasible. While European merchants resident in West Africa were typically the very first adapters of cars and trucks – a French trader in the Gold Coast bought that colony's first car in 1902 – Africans were never far behind. The initial trickle of imported vehicles became a stream by the 1920s and by 1926, 2,401 motorized vehicles circulated in the Gold Coast, many of which were owned by Africans (Heap 1990). These small-scale operators, who might own just one or two lorries, established themselves as a serious force in the road transport sector, succeeding where larger, European-owned firms often struggled. That achievement came about largely because of the adaptive approach that African transporters took to the market for mobility. Not only did they enjoy better local knowledge and connections than did foreign firms but they could also respond more easily to changing commercial conditions because they were not locked into particular routes or schedules. They also, moreover, designed their vehicles for carriage flexibility, for these African operators typically built the beds of their lorries in ways that allowed them to transport produce or people, or both at once. There was a corollary to that nimbleness, however, when it came to loading, for these drivers typically would not travel until their vehicles were fully charged. Waiting to achieve 'high load factors' may not have been the most efficient use of time, but it put to maximum use storage space and fuel. The quest for these optimal loads has left a documentary trail, in that one of the most common traffic ordinance violations in the Gold Coast was 'carrying persons in excess of the number allowed by license' (Drummond-Thompson 1993: 48).

Trains and roads certainly reconfigured patterns of movement in West Africa, and intensified the flow of goods into and out of the region – increasing the trade in other kinds of containers. One container whose circulation seems to have increased as the result of transportation systems were wide-mouthed enamelware basins. These industrially produced receptacles, which could be used for serving, washing and storing, were durable in material and uniform in shape, so they could be efficiently stacked for transport. Likewise, barrels, bottles and casks started to circulate more widely in the interior, as local and foreign merchants fed demand for spirits, wine and other liquids. Large cast iron pots, which are valued in food preparation for their sturdiness and capacities to retain heat, likewise started to make their way from the coast to the interior, although they were still costly and cumbersome enough to have remained luxury items that would have been beyond the reach of most people.

But even though trains and lorries increased the movement of people and things through land-locked parts of West Africa, a number of serious downward pressures continued to operate upon the mobility of containers in the region, even those that were motorized. Some of those constraints were environmental and seasonal. Roads and railways were costly to build and often, particularly in West Africa's wetter regions, difficult to maintain: they could become virtually impassable during parts of the year. Trains, cars and trucks also required specialized skills to operate and repair, and specialized parts that either had to be imported or that required creative fixes from local artisans and mechanics. Other factors also limited access and use – passengers typically had to pay a fare to ride aboard one of these vehicles, while the cost of vehicles put them far beyond the reach of most of the population. But it is also clear that the use of trains and vehicles in West Africa started to create a new regime of energy consumption, because the motors of cars, trucks and trains require particular kinds of fuel. While some efforts were made to use locally sourced organic materials – charcoal and wood – to produce steam for West Africa's trains, the American-made vehicles that became popular in places like the Gold Coast by the 1920s consumed petrol, which was initially imported almost exclusively from the United States. In this region where energy sources for overland transport had been exclusively organic in origin, the adoption of fossil fuels to power the movement of people and things, even if not commonplace and widespread, nonetheless marks a significant turning point in West Africa's containerization practices.

While this shift to fossil fuel use is important, it would nonetheless be an overstatement to assert that motorized vehicles fundamentally changed the way that most West Africans moved and carried things in their daily lives. Indeed, headloading continued to be the main mode of transport in different parts of West Africa through much of the first half of the twentieth century, such as in the northern reaches of the Gold Coast, for example, or the southern, forest region of French Guinea, or through much of the French Soudan (present-day Mali and Burkina Faso). The postcard, in Figure 4.4, of Upper Guinée (Conakry) in the early colonial period, exposes quite starkly that neither colonial infrastructure projects nor African transport entrepreneurs rendered obsolete the practice of headloading.

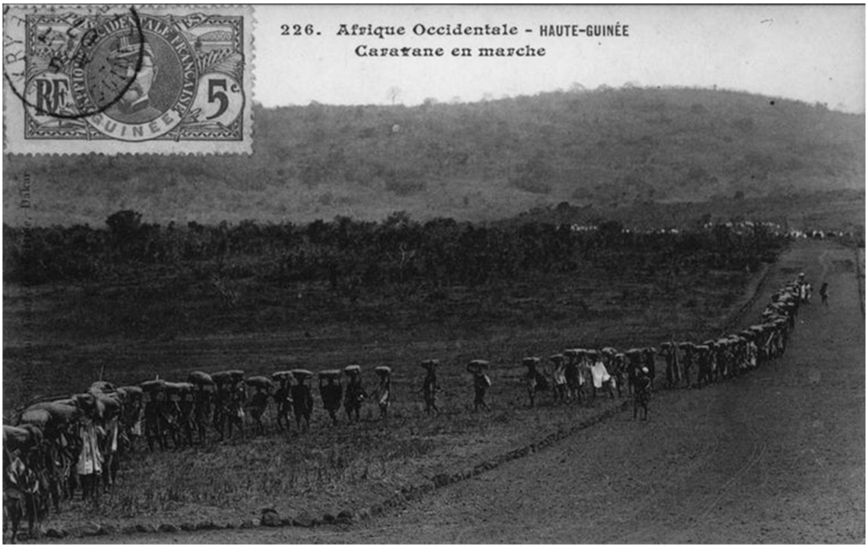

Figure 4.4 This image, from a 1905 postcard, depicts a caravan of porters, perhaps carrying bundles of rubber and headed to Kankan's train station in Upper Guinea. Note what may be another group of porters, up on the hill on the right, in the distance.
Note: All reasonable efforts have been made to trace copyright owner.

Close inspection reveals that only one pair of wheeled tracks can be seen, on the lower right quadrant of the image, tracing through the freshly grated road; for the first decades of its existence, this road undoubtedly recorded far more frequently the footprints of pedestrians than it did the tyre tracks of motorized vehicles. Head-carriage continued to be used to carry bundles and containers on local and even regional circuits, or from those more remote areas to places where motorized transport could be accessed. It was not unusual, in other words, that roadsides and railway stations served as a transit points from which headloads were transformed into train- and lorry-loads, and vice versa.

Although the image on this postcard dates from the first decade of the twentieth century, it conveys a dynamic that persisted for at least three more decades in much of the larger region. Motorized vehicles were neither ubiquitous nor abundant in West Africa in the first half of the twentieth century. Trains, cars and lorries, which are themselves containers, did provoke changes in how people and things moved around West Africa's vast terrain, and they helped to make imported containers and other manufactured goods more accessible in the interior. They also introduced the use of fossil fuels to the region. At the same time, however, as the image above indicates, the thin new colonial infrastructures that laced their way through parts of West Africa did not displace human, organic modes of transportation, nor did the region become a major producer of greenhouse gases.

The Second World War, containers and the Anthropocene

The Second World War generated massive changes in the production of materials and goods. Wartime demands for munitions, vehicles, parts, gear, medicines and medical supplies, packaged foodstuffs and uniforms spawned a drive, on the part of both the Axis and Allies powers, to ramp up existing production facilities and to develop new manufacturing processes and technologies. The fabrication of various kinds of materials, including metals, which were used for making weapons as well as to build trucks, cars, airplanes, ships and submarines, increased dramatically as a result. To take but one example, that of aluminium: in 1939, Nazi Germany led the world in aluminium production but was outpaced, during the war, by the United States and Canada. Alcan, an aluminium production company based in Canada, went from producing 75.2 thousand metric tons of aluminium in 1939 to 1,545.4 tonnes in 1945, a more than twenty-fold increase (Evenden 2011). The circulation of plastics witnessed a similarly massive uptick. In the United States, annual production trebled every year during the war; in 1945, American manufacturers produced 818 million pounds of plastic for the military alone. The end of the war changed the client, but not the trend – in 1960, 6 billion pounds of the substance came out of US plants in the form of consumer goods (Meikle 1995: 2–3). The innovations and materials made for war often found new applications in peacetime; the plastic coverings of airplane cockpits gave way to Barbie dolls, dishes and other household products.

While these trends affected first and foremost the industrialized countries that they directly involved, they also mattered for West Africa, and for the circulation and use of containers in that region. The Second World War assumed an African front as well, and some of that wartime materiel made its way onto the continent in the form of weapons, trucks and planes. But it was, arguably, the aftermath of the war that mattered most for changing the ways that people in West Africa moved, carried and stored things. The production of canned and freeze-dried food as rations during the war gave way to 'convenience food' in its aftermath. Packaged foods and liquids consequently became cheaper to produce and consume the world over. Nigerian newspapers from the 1950s and 1960s suggest that this boon did not restrict itself to the United States, Europe or Japan. Advertisements abounded for canned and bagged foods and liquids, from Ovaltine to Star Beer and various kinds of cereal, powdered milk, coffee and flavourings, as shown in Figure 4.5, for packaged goods being sold in Lagos (*Nigerian Morning Post* 3 January 1964: 11).

Likewise, promotions for cars of all kinds – Peugeot, Renault, Mercedes-Benz, Citroen as well as a used 'car mart' that sold Chevrolets and Jeeps – suggest that the post-war era also witnessed a rise in vehicle ownership (*Nigerian Morning Post* 2 January 1964: 9–11, *passim*). Indeed, anecdotal evidence reveals that car purchasing was within the realm of possibility for at least some well-employed adults – in an oral interview, Suzanne Tanoh, an elderly (now deceased) resident of Abidjan, Côte d'Ivoire, explained that in the early 1950s she saved earnings from her first year of employment at a grocery store to buy herself a car (Suzanne Tanoh, June 2006). While foreign imports played a large role in changing containerization practices, and rooting West Africa more firmly in an economy that turned on fossil fuels, external

Figure 4.5 Bags, cans and bottles of products that benefited from manufacturing innovations developed during the Second World War. Reproduced from *Nigerian Morning Post,* 3 January 1964, 11.

Note: All reasonable efforts have been made to trace copyright owner.

forces were not the only source of change. African manufacturing also witnessed a modest expansion in the 1960s, particularly in the transition to independence, as African leaders sought to industrialize their countries. Local manufacturing plants used petroleum energy to make various kinds of plastic and metal containers. It is thus in the post-war era, when automobile use in West Africa became more common, when shared modes of automobile transportation (buses, vans, etc.) became a feature of urban and rural life and when containers whose manufacture, importation and use relied upon fossil fuels became widely used, that West Africa started to contribute more seriously to the production of greenhouse gases.

But the proliferation of new consumer goods and modes of containerization, many of them dependent upon forms of energy that come from deep within the earth's crust, did not mean that all West Africans gained easy access to them, or that long-standing practices of re-purposing evaporated. Indeed, if there was a 'consumer revolution' in post-war West Africa, it continued to be contoured by the imperative of reuse. Aluminium, which is derived from bauxite ore in an incredibly energy-intensive process, is a case in point, for a whole sector of the so-called 'informal' economy emerged after the Second World War around transforming scrap aluminium into household objects.

In the photograph shown in Figure 4.6, which was taken in the late 1960s in Côte d'Ivoire, the material that was used to make those locally made shiny aluminium pots at the front probably entered the country as beverage cans; once their contents were consumed, artisans melted down the scrap and used sand moulds to make

Figure 4.6 Photograph of marketplace in Bouaké, Côte d'Ivoire, in 1968. Courtesy of Anne Marie and John Rabke. Reproduced with permission.

cooking pots. The other containers in the photo likewise testify to the shift away from organic containerization practices which took place in the decades after the war – plastic containers, probably produced in-country, are perched behind the cast aluminium pots, while enamelware, to the left, is likely of Asian origin. The metal containers painted in different colours were probably locally made, stamped out of old oil drums, while the shiny pails on the right look to be industrially manufactured, perhaps of steel, and could be either imported or of domestic manufacture. But each of these containers is, in one way or another, woven into a global economy that is fossil fuelled – the plastic is a petroleum-based product; the aluminium in the locally made pots cannot be made without massive inputs of energy at highly industrialized bauxite-processing plants; the pails and the enamelware would have required fossil fuels for their fabrication as well as for their transport to this market.

It is also notable that the containers in this image do not emerge from, nor will they return to, a highly localized, organic substrate. The fibre baskets and clay pots of yesteryear could disintegrate and dissolve, leaving behind virtually no remnant, but the plastic buckets of the late 1960s pictured here – and the thin plastic bags that are today resplendent in cities, towns and villages across the continent – do not give way to the environment around them. That is, for all its assets and applications, plastic is a virtually indestructible material. What this means is that the record of plastics use in West Africa, as with everywhere else in the world, will in no way vanish or be absorbed into an organic cycle of reuse, but will rather persist for generations and centuries to come.

Conclusion

The particularities of containerization practices in West Africa reveal that the region came relatively late to fossil fuelled energy. This analysis indicates that West Africans have only much more recently started to produce the greenhouse gases that have contributed to anthropogenic climate change; and even if they have contributed, it has been at a far lesser rate than other parts of the world that have benefited from greater prosperity, higher per capita income and better transportation infrastructures. Nonetheless, it is evident from changing containerization modes that West Africans did become, in the post-Second World War era, embedded in a world of mobility and storage that had become fossil fuelled. At the same time, the premium that has and continues to be placed on reuse and repurposing useful materials, as with the case of aluminium, offers lessons that are worth considering as we explore how to manage the consequences of human actions on the climate and environment of the planet on which we live.

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5

Africa and the Anthropocene

Gareth Austin

This chapter examines the interactions between economic activities and physical environments in Sub-Saharan Africa[1] in the context of the general intensification of human impacts on the physical environment that began with the start of global industrialization towards the end of the eighteenth century (the 'Anthropocene'), and stepped up a gear with the 'Great Acceleration' since 1945.[2] The focus is human responses to resource scarcity. The argument has four parts. First, so far there has been too little overlap between research on the economic and environmental dimensions of African history. Second, human interaction with the environments of most of Africa, over the long term and well into the twentieth century, is best framed within the concept of an overarching 'land-extensive' path of economic development within which there were, however, elements of intensification. Third, the last several decades have seen major steps in a continuing transition towards labour and capital intensity as the main path of further economic development. This transition, however, is made much more difficult by the context of climate change and other aspects of the Anthropocene, making it imperative to seek ways of mitigating environmental impacts while pursuing both higher-productivity agriculture and industrialization. The final part of the discussion, starting from the observation that resource scarcities not only constrain production possibilities but also create economic rents, over which there is likely to be contestation, examines the political economy of resource scarcities and agricultural intensification. In accord with standard usage, 'agricultural intensification' is defined here as an increase in the quantity of labour and/or capital inputs per unit of land. For the present context, 'economic development' means the sustained growth of productive capacity.

In addition to the Geneva conference, where this book was born, this chapter has developed through presentations at the October 2014 and 2015 editions of the annual African Economic History Workshop, held respectively at the London School of Economics and Wageningen University, and at the University of the Witwatersrand in November 2015. I am grateful for the valuable feedback received on all four occasions.

1 'Africa', in the rest of this chapter.

2 The notions of the Anthropocene and the Great Acceleration are introduced in Chapter 1.

Thinking African history in the Anthropocene

Mats Widgren's chapter in this book emphasizes the long history of Africans as re-shapers of their landscapes, vegetation and soils. As the original home of humanity, Africa has been under human influence for longer than anywhere else. At global level, Africans were active agents in the prehistory of the Anthropocene, especially by their participation in the domestication of animals, an early source of anthrogenetic greenhouse gas (Ruddiman 2005). Yet modern manufacturing in Africa, though dating back to the end of the nineteenth century, has made only a relatively tiny contribution to industrial output of greenhouse gases. Rather, the main connection between Africa and the spread of industrialization remains the role of Euro-American exploitation of African slaves in the Americas in the origins of the British industrial revolution. The causal mechanisms turn out to be different from those proposed by Eric Williams (1944), but much of the argument is revived, in different forms, in recent analyses (such as Inikori 2002). These accounts include arguments that emphasize the importance of the availability or non-availability of key resources in certain regions, including the critical fact that cotton could not be grown in Britain, and would have been much more costly for British mills to obtain had it not been available from the Americas on land tilled by slaves of African origin (Pomeranz 2000; O'Rourke, Escosura and Daudin 2010). Clearly, no one blames Africa – still less Africans – for global climate change: which may help explain why Sub-Saharan Africa appears in a peripheral manner in such major late-modern environmental histories as McNeill (2000) and Grataloup (2009). Sub-Saharan Africa is, however, a major participant in the Great Acceleration. This is partly through its emergence, from the 1960s to the present, as a significant supplier of crude oil (about 8 per cent of the world total in 2010). Above all, it is because its population has multiplied even faster than the world average during the last seven decades.

Meanwhile, the core process of the Anthropocene greatly affected economic and political change in Africa. It was the spread of industrialization outside the continent which made Africa the supposedly 'resource-rich' region that it is often claimed to be today (despite being the driest continent, short of coal, with few navigable rivers and a predominance of soils that are relatively infertile and/or easily degradable). It was the first and second industrial revolutions that created or magnified the overseas markets for African silvicultural and agricultural exports, most strikingly in the cases of rubber and cocoa beans, following the invention of the bicycle, the internal combustion engine and milk chocolate. More important still, it was external technological innovations that converted the oil and gas, beneath Africa's soils and seas, from geological curiosities into sources of wealth – and climate change.

Various literatures have linked African environments and economic development, with equally varied degrees of persuasiveness and insight. In recent decades there has been a general scepticism about environmental determinism. In African studies, mention of the latter still tends to evoke memories of a semi-racist literature from the colonial era. Most historians of Africa, including economic historians, are reluctant to take the broad environmental arguments of Alfred Crosby and Jarrod Diamond as more than stimulating hypotheses. Crosby's 'biological expansion of Europe' (1986) is much more applicable to the 'neo-Europes' of Australasia and the Americas than to Africa, especially tropical Africa, where the importation of exotic species over the centuries turned out overwhelmingly positive for productivity and food security, and came mostly from Asia and the Americas – and mainly from roughly parallel latitudes – rather than from Europe.[3] Diamond's (1997) proposition that useful crops and crop varieties spread more easily along the same latitudes, to the benefit of continents that are aligned north-south rather than east-west, is stimulating in the context of Africa being the continent with the smallest number of truly indigenous cultivable plants, and therefore being in particular need of (selective) imports: a need which, however, was met over the centuries.[4]

Over the last century, the most fundamental debates about economic development in relation to the physical environment in Africa have been about the quality of African lands and the efficiency of African farmers, specifically, the techniques used characteristically (but not exclusively) by small-scale farmers. The issues are not identical, but they are related: the view that soils in Africa were and are basically as promising as those in regions with higher agricultural productivity has the corollary that the techniques used in Africa must have been economically inefficient and/or ecologically wasteful. European planters in early-twentieth-century Ghana were confident that their neat, relatively capital- and labour-intensive forms of production were superior to the land-extensive methods of their African rivals (Austin 1996b). European settlers in 1930s Kenya, anxious to persuade the colonial administration not to restore land reserved for Europeans to African use, asserted that African methods caused cumulative soil erosion (Anderson 1984). Champions of mechanized agriculture, both foreign and indigenous – from the late-colonial Tanganyika Groundnut Scheme to the present 'land rush' – have repeatedly defined their methods as progressive, destined to release the potential of the African environment. The results have generally been disappointing, in some cases humiliating (Hogendorn and Scott 1981; Mutsaers and Kleene 2012b: 29).

Alarms about soil erosion, deforestation and desertification arose early in the twentieth century among officials in colonial agricultural and forestry departments. In a book published in 1922, the senior forestry officer for the Gold Coast, the appropriately named Mr. Chipp, diagnosed a process of deforestation that was steadily shrinking the forests of what is now Ghana, leading to the southward spread of the savanna. The solution, he argued, lay in the creation of forest reserves to be administered by his department (Chipp 1922). Fears about soil erosion across colonial Africa were exacerbated in the 1930s by the example of the American Dust Bowl. In the settler economies of southern Africa officials had earlier criticized settlers for reckless use of the soil. Now, in the 1930s and 1940s, there was widespread official concern about erosion also on African peasant farms, coupled with fears of overstocking by African pastoralists (Beinart 1984).[5] This prompted coercive

[3] For more general discussion of Crosby's thesis, see Polónia and Pacheco (this book).

[4] Diamond, though, underestimated the difficulties which the natural environment of Africa posed for economic activity, compared to the Americas (Frankema 2015).

[5] For a longer view, specifically focussed on South Africa, see Beinart (2003).

countermeasures, such as compulsory terracing in East Africa, which provoked serious protests (Bates 1983: 94–5).

As more agricultural and agronomic research was carried out, in the colonial and early post-colonial decades, the notion of African soils as rich was undermined, indeed discarded as a generalization. This recognition was accompanied by increasing 'expert' respect for African agricultural methods (Richards 1985; Tilley 2011: 115–68, 390–401).[6] For example, the widespread practice of intercropping (planting more than one crop in the same field), which was and still is standard practice over much of Africa, turned out to conserve fertility (Richards 1985), as does another 'traditional' practice, of clearing around the biggest trees rather than clear felling (Wilson 1989). Again, James Fairhead and Melissa Leach drew on archival sources, especially for colonial Guinea, as well as on oral fieldwork, in concluding that, for the area they studied, the notion of continuous deforestation as a result of shifting cultivation and 'slash and burn' was false: the existence of a savanna-forest mosaic was basically a stable condition, rather than a step towards the destruction of the forest, and farmers themselves planted some of the trees (Fairhead and Leach 1996).

These trends, towards an emphasis on environmental constraints and farmers' wisdom, did not imply that farming methods and agricultural productivity could not be sustainably improved. That would be an unnecessarily fatalistic conclusion. Not all African soils were poor, far from it: though it seems that even the fertile soils tend to be vulnerable to leeching because of highly concentrated rainfall (Areola 1996). Then again, the trend of increasing soil degradation and desertification has often been exaggerated; the detailed story is concerning but complex (Stocking 1996). Crucially, even the most pessimistic of the authoritative views on the general level of soil fertility insist that African soils can be improved, though to do this in an economically efficient manner requires not only chemical fertilizers but also 'locally-available soil amendments, such as animal manures and crop residues' (Breman and Debrah 2003, quotation at p. 153; further, Breman 2012). Meanwhile the leading advocate of the efficacy of farmers' solutions, Paul Richards, has consistently argued for scientific research to recognize the rationality of farmers' working within the template of their hard-won experiences, and to make use of farmers' discoveries, made through trial and error – as he put it, a combination of natural and 'cultural selection' – for example, of new varieties of seed (such as hybrids of Asian and African rice varieties) (Richards 1985, 2010).

The environmental historiography of Sub-Saharan Africa is voluminous and rich.[7] It is perhaps particularly strong on the cultural and political dimensions of state interventions in African agriculture and African living in general. A notable recent example is Allen Isaacman and Barbara Isaacman's history of the Cahora Bassa dam in Mozambique. They document a lack of accountability by colonial and post-colonial governments for the violence inflicted upon the displaced peasants,

[6] This respect seems to be much less common among 'social enterprises' and NGOs in the current 'Green Revolution for Africa' drive (Moseley 2017).

[7] Even by the end of the last century the literature was impressive. See the discussion and the density of the references in Beinart (2000); for a recent survey, see Carruthers (2012).

or for the adverse environmental consequences of the hydroelectric 'development' (Isaacman and Isaacman 2013). But there is a surprising lack of attempts by environmental historians to relate such issues to the economic historiography, except in particular, contingent ways.[8] If economic change has been the biggest driver of environmental shifts, one would expect a larger overlap between the two literatures.

Conversely, much of the economic historiography does not engage very directly with environmental issues. Considering that neoclassical economics defined itself as the study of optimization under scarcity, it is ironic that many economists and economic historians sharing or influenced by the neoclassical tradition have not always taken very seriously the particular constraints that specific kinds of land or labour or capital may pose for economic activity. There is a tendency to think that, if the price is 'right', the constraint naturally will be overcome, whether by technical or institutional means. Not all economists in the mainstream tradition take this view, but it helps to explain the tendency to assume that the relatively low level of foreign investment in Africa must have been essentially the result of unsupportive institutions, including in the colonial era. It is true that institutional obstacles existed, hindering the connection of suppliers and users of capital (e.g. see Cowen and Shenton 1991). However, when most of Africa was ruled by Britain and France, two of the biggest exporters of capital in the world, there would surely have been a way around institutional constraints had the demand to invest been sufficient. Frankel (1938) remains the only study of foreign investment across Sub-Saharan Africa in the colonial period. This puts the grand total for 1870–1936 as £1,221.7 million in nominal terms; 42.8 per cent of it in South Africa. Per capita (while underestimating the population), Frankel made this less than £12.7 overall: £55.8 in South Africa, £3.3 in the French colonies and only £4.8 in British West Africa, which contained the more prosperous 'peasant' colonies, Nigeria and the Gold Coast (Frankel 1938: 158–60, 169–70). That foreign investment was so low under colonial rule suggests that the biggest constraint was a lack of investment opportunities. Given that the region was extremely capital-scarce, this implies difficulties in literally 'embodying' capital in effective means of raising productivity in agriculture and other sectors. This suggests a need to take environmental constraints more strongly into account (Austin 2008a).

On the other hand, when economists have taken environmental constraints seriously, this has tended to be in a present-tense, static form of little use to historians (for instance, Bloom and Sachs 1998). In any case, among economic historians generally, in recent years the dominant approach has been rational-choice institutionalism, formerly known as 'new institutionalism'. While this line of inquiry has achieved a lot in the study of Africa,[9] such has been its dominance that environmental issues have been neglected, except for recent attempts to

[8] For example, references to studies that unite environmental and economic history are almost entirely absent from Carruthers' interesting survey (2012), which cites over 100 works on African environmental history. Neither Kjekshus nor Webb (see below) are included.

[9] For an introduction to the current state of the African economic historiography, see Austin and Broadberry (2014).

examine econometrically the impact of climate shocks on slave exports or, in the colonial period, on conflicts of various kinds (Papaioannou 2014; Fenske and Kala 2015). Mono-causal institutionalism (Acemoglu, Johnson and Robinson 2005) is not conducive to exploring the economic implications of specific resource constraints.

Yet there is also a current in the economic history of Africa that emphasizes human responses to environmental constraints, striving to avoid minimizing the agency of the first or underestimating the second. This is epitomized by A.G. Hopkins's *An Economic History of West Africa* (1973), including in its emphasis on the implications of the physical properties of successive staple exports from West Africa – human and agricultural – for the distribution of income among the exporting communities, and for economic growth. More generally, while Hopkins' book was organized around the history of markets, he approached them with an appreciation of the environmental constraints faced by producers and buyers. John Iliffe's concise history of Africa adopts a strongly demographic perspective, presenting precolonial history as above all a struggle to control a hostile environment (Iliffe 1995 and later editions). Austin (2008a) reviewed, modified and reapplied the factor endowments approach to African economic history.

There are a very few works which go further in examining the implications for economic development of human interactions with specific environmental constraints in African history. A pioneer was Helge Kjekshus (1977/96)'s book on nineteenth- and early-twentieth-century Tanganyika (mainland Tanzania), followed by James Webb's study (1995) of the precolonial Western Sahel. Webb went as far as to argue that increasing aridity was more important than external relations as a determinant of economic change on the southwestern edge of the Sahara from the seventeenth to the mid-nineteenth century. Kjekshus emphasized the competition between humans and wildlife for land and water, and (building on a classic study by the historical ecologist John Ford)[10] in particular the struggle against sleeping sickness. After a generally upbeat account of the precolonial nineteenth century, he saw the 1890s as a catastrophe, with the arrival of rinderpest, and ultimately depopulation enabling the tsetse fly (and the sleeping sickness parasite it carried) to regain much of the kingdom which humans had prised away from it in the preceding decades. Kjekshus's work stimulated more research and debate, with subsequent studies accepting the notion of an early colonial debacle but tending to criticize the optimism of Kjekshus's view that the precolonial societies had achieved a kind of equilibrium in their relations with nature (for instance, Koponen 1988).[11] We need more such local studies and debates, and we need to link them more closely to the broader economic historiography of Africa.

[10] Ford (1971). On the origins and context of Ford's book, which was critical of colonial 'doctrine' yet, in Helen Tilley's words, was also 'in many respects an outgrowth of what he had been hired to do' by the Colonial Office in the late 1940s, see Tilley (2011: 118–20, quote at p. 119).

[11] For a survey of the evidence on the changing incidence of trypanosomiasis in Africa, see Beinart and Hughes (2007: 184–99).

A land-extensive path of development

Sub-Saharan Africa is not only vast but also vastly varied, including in rainfall, soils, agricultural techniques and mineral resources. Yet for analysis – especially comparative – it is necessary to risk proposing a general interpretation, without claiming that it works for every part of the subcontinent (unlike statements of universal truths, a generalization admits exceptions; though the explanatory power of the generalization is greater if the exceptions 'prove the rule'). The generalization suggested here is that most of Sub-Saharan Africa followed a broadly land-extensive path of economic development until well into the last century.[12] This necessarily included elements of intensification, but in most of the subcontinent the displacement of the land-extensive path by a general intensification began only in the twentieth century, often decades into it. It started in the colonies of European settlement, as a result of land grabs, and is still in progress in many countries. Before defining 'land-extensive', and clarifying its relationship with intensification, it is necessary to outline the general form of resource scarcity that prevailed in most of the subcontinent through most of its recorded history.

Until well after the European partition of 1879 to around 1903, and in some areas until today, most of Sub-Saharan Africa had an abundance of land for cultivation and pasture in relation to the labour available to exploit it. In space, the biggest exception was highland Ethiopia (e.g. Crummey 1980); in time, a notable exception was early-nineteenth-century Natal (Gump 1989). The general pattern was partly a function of a relatively low average population density compared to Europe and much of Asia: several times less than non-European Russia in around 1750, according to any one of the range of 'guesstimates'.[13] The economic situation was encapsulated by the Scottish explorer Mungo Park, commenting on the Manding Kingdom in what is now Mali, where he stayed in 1796–7: 'Few people work harder, when occasion requires, than the Mandingoes; but not having many opportunities of turning to advantage the superfluous produce of their labour, they are content with cultivating as much ground only as is necessary for their own support' (Park 1954 [1799], 215). Thus the quantity of output was constrained by the level of inputs of labour, rather than the availability of land. Capital was scarce too, but – except for livestock accumulation – the major forms of feasible capital formation, whether in arable agriculture or artisanal manufacture, were embodiments of labour equipped with simple tools (Austin 2008a; for land extensiveness in a more arid environment, the southern edge of the Kalahari, see Jacobs 2003: 49–52).

Land abundance sounds helpful, and it reduced the risks of pauperization and famine (Iliffe 1987). But in this case – much more than in eighteenth- to nineteenth century-North America, for example – it was accompanied by major constraints

[12] The argument here elaborates on the proposition, first put forward in Austin (2008a).

[13] For a brief discussion of the older population estimates, see Austin (2008a: 590–1). More recently, Manning (2010) has revised his estimates of precolonial population upwards, though not by enough to alter the argument here. Frankema and Jerven (2014), in turn, challenge Manning's revision.

on the productivity of agricultural labour, and on the productive exploitation of land. The frequency of thin soils, vulnerable to erosion, limited returns to labour and made it harder to pursue intensive cultivation, especially where animal manure was absent. Sleeping sickness prevented the use of large animals – for ploughing, transport and, indeed, as a source of manure – in the forest zones and much of the savannas (Ethiopia being again a major exception). Again, in much of tropical Africa the rains were and are concentrated to a few months. This entailed an often sharp trade-off between planting food crops and planting such inedible cash crops as cotton (Tosh 1980). The often sharply limited agricultural year freed labour for dry-season occupations, including handicrafts and (in some places) gold mining; the low opportunity cost of such seasonal labour made even low-productivity production worthwhile (Austin 2008a). All this helps explain why the productivity of African labour was seemingly higher outside the subcontinent, over several centuries: the basic economic logic of the external slave trades, which in turn aggravated the scarcity of labour within Sub-Saharan Africa itself (Manning 1990: 33–4; Austin 2008b).

How to characterize the pattern of economic development in relation to the resources available? In practice, very long-term growth in productive capacity usually entails greater intensity in land use. Moving from hunting and gathering to crop-growing and/or stock-keeping necessarily raises the ratio of inputs of labour and (at least with pastoralism) capital per unit of land. Given those prior steps, in the context of land abundance, reinforced by the constraints on agricultural intensification, the operations of cultivators and herders showed a widespread pattern of land extensiveness, which may be seen as a development path, defined as a general, long-term revealed preference for methods which used additional land where that would raise returns on labour or capital, or conserve the latter. In pastoralism the preservation of the cattle stock (the herd) was paramount. In arid areas cattle needed to be moved periodically in search of water. Transhumance might also be propelled by the threat of disease, as with Dinka cattle-keepers in southern Sudan moving to higher ground for the rainy season to avoid the tsetse fly. In arable farming, land extensiveness was embodied in the widespread use of the hoe rather than the plough, the predominance of systems of extended fallowing (the overlapping categories of shifting cultivation and bush fallowing), the avoidance of clear felling and the preference for intercropping over monoculture.

Even with a tree crop such as cocoa, whose adoption in parts of the West African forest zone in the late nineteenth and early twentieth centuries constituted an intensification of land use, as the trees would occupy the plot for thirty years or more, and as their planting was itself a form of capital formation, African farmers chose extensive over intensive techniques where there was a choice. They preferred to invest labour and money in planting more land rather than in maximizing yields per hectare. Thus they rejected the capital and labour-intensive methods that European planters and the colonial government agriculture departments favoured for dealing with capsid infestation. The logic of the farmers' 'weeds overgrown' method was explained in a letter to a committee of inquiry by one Kojo Dunkwoh of Kumasi, Ghana.

> When a cocoa-farm is partly attacked by 'Akate' [capsid], the farmer leaves that portion infected uncleared; left to wild plants, weeds, and climbing stems to overgrow that portion for three years good. The farmer will inspect period by period, and in due course, he will find that … the infected area had entirely changed, and had become fresh and flourishing trees with fine dark and long leaves appear [*sic*]. The farmer would then engage labourers … to clear out the wild weeds and plants; he will find that, that method had proved successful: the trees turned out to be new and healthy.[14]

By 1948 European cocoa plantations had disappeared from Ghana, defeated by competition from African farmers who kept their labour costs lower, as with the technique set out by Dunkwoh (Austin 1996b).

The planting of tree-crops for export agriculture was a striking example of the formation of fixed capital, but the latter was already an essential part of land-extensive production. It happened through the input of human labour, aided by simple tools. When land was cleared for food farming it was usually incorporated in a rotation cycle. In the Ghanaian forest zone, for instance, the moist weight of vegetation in 40–50-year-old forest is estimated as averaging 300 tonnes per acre. But, when the land has been cleared, cultivated and allowed to fallow, even for twenty years (normal in the nineteenth century), the task of re-clearing the land for a new round of cultivation was much reduced by the earlier investment of labour: the average moist weight of vegetation would be 'only' 100 tonnes (Phillips 1959: 160–1). Thus, in Ashanti, a *dadaso*, a farm cleared and cultivated already, was a capital asset, increasing the returns on the labour put into replanting and weeding it in future (Austin 2005: 74). It is an example of Widgren's 'landesque capital' (Widgren's chapter, this book).

In the context of a preference for land-extensive methods the major source of higher productivity and improved food security was the selective importation of exotic crops and crop varieties, improving on a repertoire of indigenous cultigens that was comparatively meagre except in Ethiopia. Whether adoption of a new crop constituted intensification depended, by definition, on whether it was grown in a way that increased the ratio of labour and/or capital per unit of land. The first wave of importation of exotic crops was from Asia, notably in the form of the plantain-banana complex. This was followed, during the Atlantic slave trade, by a range of crops from the Americas, including maize, cassava (manioc) and groundnuts (peanuts). One of the advantages of new crops was that, in some cases, they permitted more efficient use of labour over the year. This could happen when they allowed double cropping, as in Burundi from the late eighteenth century, with the adoption of maize and an American variety of haricot bean. It also happened where the new crop allowed harvesting to be extended months further into the otherwise agriculturally underutilized harvest season, as happened on a major scale with cocoa (Cochet 1998; Austin 2008a,

[14] UK National Archives CO964/17, Kojo Dukwoh to Secretary of [Watson] Commission, Kumasi, 19 April 1948.

2014). Lengthening the agricultural year involved more hours devoted to farming; as we will see, at the likely expense of what were now less-profitable off-farm activities. Thus it entailed a degree of agricultural intensification, without necessarily raising total labour inputs in the economy as a whole.

The adoption of cocoa by farmers in southern Ghana and southern Nigeria – mostly at their own initiative, and free of the pressure of direct taxation – was part of a longer process: the creation and deepening of Africa's comparative advantage in land-extensive production. This can be seen in the emergence of agricultural exports along the West African coast (initially palm oil and groundnuts) during the period of 'legitimate commerce', between the beginning of the end of the Atlantic slave trade (around 1807) and the European colonization. The colonial governments and European merchants invested in further deepening this comparative advantage, notably by constructing steamer ports and railways, but the trend had already been established. Specialization in agricultural exports was a logical next step in land-extensive production, raising the returns on the scarce factor, labour, over the year as a whole. With the adoption of cocoa, and of coffee growing in certain areas, farmers in the forest zones concerned finally had a product with a market sufficient able to enable them to extract maximum economic advantage from their (so far) relatively abundant land.

But it came at the cost of squeezing out much of the large part of craft production and artisanal gold mining, which depended on the availability of a seasonal surplus of labour during the now-reduced agricultural off season (for instance, Austin 2005, 2014). However, some weavers and dyers survived and even thrived, often by specializing at the top end of the local market, selling high-quality handmade cloths to prosperous cash-crop producers (Kriger 2006). The development of a comparative advantage in land-extensive exports helps to account for the lack of continuity between artisanal manufacturing and factory production that was introduced, on however modest a scale, by foreign investment during the colonial period (Austin 2013; Austin, Frankema and Jerven 2017).

Intensive agriculture, old and relatively new

Despite and within the predominance of the land-extensive approach, pursuit of the ultimate aims of stronger food security and higher incomes entailed moments and spaces of intensification in African agriculture. But it was only in the twentieth century that labour and capital intensification displaced land extensiveness as the predominant development path in Africa, though still by no means everywhere.

Over the centuries, where a form of intensification – usually irrigation or terracing – became necessary for survival, as with groups taking refuge in hills or swamps from the risk of slave raiding, farmers made the necessary adaptations (see, for example, Hawthorne 2003). Less dramatically, as the archaeologist John Sutton noted, growing crops on stony slopes might require the construction of stone terraces, thereby reducing an excess of stones in the fields and protecting the soils from erosion. Intensification might also be limited to one dimension, as when cultivation was rotated between different plots within a system of terraces (Sutton 1984). In other cases, Widgren emphasizes (this book), intensification was a response, not to necessity but to opportunity, as when a particular water supply offered the chance to increase returns to labour by the adoption of small-scale irrigation (Sutton 2004).

It used to be argued that these 'islands of intensive agriculture' came and went during the precolonial era, but that intensive agriculture as a whole tended not to spread: neither by emulation nor internal growth, partly because intensification might end in accelerated soil erosion or in polluting the water supply (Sutton 1984; Widgren and Sutton 2004; see also Hopkins 1973: 31–7; Austin 2008a). However, Widgren (this book) shows that agricultural intensification appears to have become more common during the sixteenth to eighteenth centuries. While part of this may have been a response to the growth of slave raiding, especially in West and West-Central Africa, there were also cases where intensification was a positive strategy to raise returns. An example is Bokoni in South Africa, a district some 150 by 50 kilometres in area, characterized by 'densely-walled [hillside] settlements with roughly circular homesteads linked by walled cattle paths situated among spreads of agricultural terraces' (Delius and Schirmer 2014: 39). However, intensive agriculture in this area declined from about the 1820s; we will return to its demise below. A further aspect of intensification was that African farmers adopted ploughs where they could do so without causing self-defeating soil erosion, which was the case of parts of southern Africa, especially when the market made the investment profitable for them, as it did at the Cape from the mid-nineteenth century onwards. Elsewhere, the hoe remained supreme.

When intensification became a widespread process, the causes and timing varied across the continent. It was given an abrupt push by the appropriation of land for European settlers, creating scarcities on the remaining African 'reserves'. The appropriations were motivated at least as much by greed for African labour as greed for African land: it was the former that was initially scarce, after all (Feinstein 2005). In the settler economies, whether colonial or self-governing, the problem of labour shortage was tackled by coercion, especially via the indirect approach (now that slavery was illegal) of appropriating most of the land for European use, while banning Africans from working on European-owned lands as tenants, rather than as wage labourers (Arrighi 1970; Palmer and Parsons 1977; Mosley 1983). Thus were wages ratcheted downwards, permitting the expansion not only of settler agriculture but also especially of the mining industries (Feinstein 2005). The result, by the mid-twentieth century, was intense pressure on land in the 'native reserves', and many reports of soil erosion, encouraging (illegal) migration of families to the cities. This was part of the context for the above-mentioned official concerns about overstocking and soil erosion on African farms in settler colonies.

The more prosperous of the 'peasant' colonies were generally those in which export agriculture took off during and since colonial rule, notably with tree crops. We have noted that the adoption of cocoa cultivation was part of a long history of agricultural innovation in Africa, in the characteristic form of the selective adoption of an exotic crop, combining elements of intensification with a preference for extensive methods where possible. The example of cocoa illustrates how export demand contributed to the gradual and uneven decline of the land surplus in the twentieth century, as more land went into permanent cultivation (Weiskel 1988; Austin 2005). It also exemplifies the inter-generational implications of the use of resources under scarcity.

Cocoa trees often bear for 30–40 years, and by the end, the soil they stand on has lost much of its fertility. The economist François Ruf has coined the term 'forest rent', defined as the difference between the cost of producing a unit of beans on a farm that has been replanted with cocoa, compared to one freshly cleared from forest (Ruf 1995a,b). Thus, in the absence of effective and affordable chemical fertilizers, the first generation or two of cocoa cultivators could prosper, but at the expense of their successors, who would face reduced fertility or higher costs for restoring it. Meanwhile, in any case, the area available for food crop cultivation was progressively reduced, for although West African farmers planted food crops to shade the young cocoa plants, there was no light to nurture the former once the latter had matured enough to form a shade canopy. By the 1940s there was evidence of land becoming scarce in some of the older cocoa-growing districts in Ghana, leading farmers to plant cassava rather than plantain, because of its greater tolerance to relatively infertile soil (Austin 2005: 66, 474).

Across most of Sub-Saharan Africa, incipient or actual land shortage, combined with moves towards agricultural intensification, became much more widespread and stronger after the Second World War, and especially after the recovery of political independence. On the pastoral side, a combination of tendencies encouraged and propelled herders from transhumance towards sedentary stock-raising. The positive trend was the increasing use of boreholes and water pumps, which made sedentary stock-raising possible. The negative tendency was an element of coercion. Not that coercion was new: in precolonial Africa pastoralists had often held a military edge over stationary, sedentary populations. This enabled, for example, Tuaregs to extract rents from peasants in what is now Niger (Baier 1977). But in contrast, with the notable exception of Botswana, post-colonial governments tended to be dominated by urban elites (Bates 1981), and to some extent by arable farmers. Pastoralists in Kenya found themselves fighting – sometimes literally – to defend territory against increasing incursions from sedentary farmers.

On the arable side, in addition to the growth of export agriculture, much more land went under food crops, responding principally to population growth and urbanization. The proliferation of mechanized transport, especially lorries from the 1910s and especially after 1945 (Osborn's chapter, this book), facilitated this expansion of the internal food trade. The population of the subcontinent as a whole increased roughly five times between 1945 and 2010 (see Frankema and Jerven 2014). Combined with the disproportionately rapid growth of the towns, population growth reinforced the need to raise agricultural productivity, feed the towns and contribute to broader economic development by releasing labour, earning import-purchasing power and providing raw materials and markets for domestic manufacturing. But the Green Revolution, successful at least in current economic terms in some of the more densely populated regions of Asia (though with questions about its environmental sustainability), is generally considered to have been a non-event in Africa.

According to Henk Breman, former Africa director of the International Center for Soil Fertility and Agricultural Development, 'the main reason why the green revolution bypassed (most of) Africa' is that 'Africa, with soils built mostly on extremely old mother rock, is dominated by (extremely) poor soils' and suffers 'extreme climates' (Breman 2012: 181; see, further, Breman and Debrah 2003; Norman 2012: 141–2; and Vanlauwe et al. 2002, especially Mokwunye and Bationo 2002: 209–11). At a sub-regional level, this view is supported by the geographer Yanni Gunnell's comparison of savanna-Sahelian West Africa with Tamil Nadu, the latter having often been held up as a model from which Africa could learn. He concluded that what works in southern India simply does not work as well in West African drylands, because the soils in the latter are less fertile (Gunnell 1997). Mokwunye and Bationo's quantitative survey of the characteristics of West African soils found that 'Across all agroecological zones, the soils are poor in organic matter content, base exchange capacity and available phosphorus' (Uzo Mokwunge and Andre Bationo 2002: 209). As Breman recognizes, there were exceptions to his generalization, and we noted earlier that not all African soils are infertile. Again, the record of cocoa farming is quite encouraging in this context, because higher-yielding, quicker-maturing varieties developed in West Africa, combined with insecticides and later also fertilizers, have now enabled Côte d'Ivoire and Ghana to expand their output of cocoa beans well beyond what was possible from the use of only lands newly claimed from forest (see Teal 2013). Thus there has been something of a 'green revolution' with this export crop. Again, optimists have challenged the neo-Malthusian assumption that more people means lower agricultural output per head. Mary Tiffen, Michael Mortimore and Francis Gichuki (1994)'s celebrated case study of Machakos district in Kenya, 1930–90, found a positive relationship between population density and average rural incomes, and argued that this was achieved primarily by investment in the land, notably through terracing. On the other hand, their critic, John Murton, comparing his own survey in 1996 with a 1965 study, reported not only the expected fall in average farm size but also increased inequality in land holding. He concluded that 'Boserupian intensification on richer farms, and a form of Geertzian involution on poorer farms are seen to be proceeding side by side in the same village' (Murton 1999).

The soil fertility problem is especially worrying, because not only was the average level too low to facilitate a green revolution, the tendency is for that level to decline, though not as fast as some had predicted. In many areas, by 2000 and more so by now, it is reported that average fallow periods have been shortened below that sufficient for full restoration of prior fertility, in the absence of other methods of achieving this (see, for example, Mutsaers and Kleene 2012a). Chemical fertilizers have been increasingly used, but the rate of use in Sub-Saharan Africa has remained below that in any other major world region. Moreover, the initial effects of their use were often disappointing: lessons needed to be learned before they could be used efficiently. They also need to be combined with inputs of both organic nutrients and minerals such as phosphorus rocks (Vanlauwe et al. 2002). And, transport costs in much of Africa remain much higher than they were in the parts of Asia that participated successfully in the Green Revolution, entailing high prices for external inputs and low prices for farmers' produce (Breman 2012: 181).

Meanwhile, Richards has cautioned against the assumption which continues to guide agricultural research on Africa: that higher and quicker-yielding varieties are the key to an African 'Green Revolution'. He notes that these varieties require more water and more energy, posing serious cost problems (Richards 2010). If not, it might be wiser to focus crop research on more efficient varieties, that is ones that use fewer inputs to achieve a given yield. Either way, the path of land-extensive growth, where it is still open at all, seems to be reaching its end.

In the last decade, across Africa, there have been many reports of scrambles for land, partly by foreign investors, partly by African farmers, many of them large scale, and apparently risking making the same kind of mistakes, especially in overexploitation of soil fertility, perpetuated by many of the earlier generations of large-scale, 'progressive' farmers in Africa (Mutsaers and Kleene 2012b: 29). A new feature of the present rush for land (Cotula 2013; Oya 2013) is the presence of foreign companies wanting large areas to grow fuel crops, often for export: thus increasing the growing land scarcity, while transferring even more biomass energy overseas (cf. Pomeranz's chapter, this book). African agriculture will need more inputs per unit of land merely to maintain the current levels of total factor productivity. Whether they can be raised sustainably to the much higher level required if Africans are to catch up current Chinese, let alone Western, living standards remains to be seen (according to the World Bank, in 2015 income per head in purchasing power parity terms averaged $3,562 in Sub-Saharan Africa, $6,020 in India and $21,740 in China [World Bank 2016, table 1.1]). In part, it is a matter of political economy.

The political economy of resource rents

Resource scarcities constrain possibilities, by making preferred actions more costly, or even impossible. The other side of the coin is that the 'rent' created when the supply of a resource is inelastic is itself valuable, providing an incentive for the use of power – administrative, legal or directly violent – to capture it, and/or also providing opportunities for productive investment. Much of the literature on resource rents, especially in Africa, is highly pessimistic, focusing on 'predatory' behaviour by states (whether precolonial, colonial, or post-colonial) or other armed groups, or on the ways in which natural resource export booms can distort national economic development, stimulating corruption and boosting the value of the currency so much that the country's manufacturing sector loses such international competitiveness as it had. There is much in each of these ideas but, especially viewed over the long term, both the mechanisms and the outcomes are more complicated and in some cases more positive than is often realized. As in the preceding two sections, the discussion turns on the still incomplete transition from relative land abundance and labour scarcity to the opposite.

It has long been argued, I think correctly, that land abundance and low population density hindered political centralization, because subjects could more easily evade supervision, taxation and conscription (Goody 1971; Herbst 2000). In this setting, acquisition of gold-mining areas (and thus resource rents), or control of trade routes (offering locational rents), was a major asset for political entrepreneurs seeking to create or enlarge states (see, for instance, Arhin 1967). Meanwhile, the abundance of land in relation to labour also made it profitable to use coercion to reduce the cost of obtaining labour (given also the context of capital scarcity and an absence of technologies offering big advantages of scale) (Hopkins 1973; Austin 2005: 155–70, 495–8; Austin 2017). In my view, it was not usually predation and extraction as such that characterized the larger and more prosperous states of nineteenth-century Africa; trade and comparative advantage (e.g. in the handloom cotton trade within West Africa) played a key part also. In West and East Africa, at least, it was rather a combination of favourable physical resources, often including possession of at least some areas of relatively fertile land; a state and institutions which encouraged private producers and traders; *and* a state apparatus which supported the use of (externally acquired) slaves within the economy, partly by obtaining them through capture and tribute, and partly by facilitating private importations of slaves. For example, this crude summary applies, in varying proportions, to the kingdoms of Asante and Buganda (Austin 1996a, 2005; Reid 2002; also Law 1978), and to the largest state of the era, the Sokoto Caliphate, which encompassed the greatest centre of cotton textile production, the city of Kano (Lovejoy 1978; Lovejoy and Hogendorn 1993; Shea 2006).

The political economy of agricultural intensification in the nineteenth century was also not simple. While slave-raiding states might provoke intensification by those who sheltered from them, Peter Delius and Stefan Shirmer (2014) suggest that the end of intensive farming in Bokoni, around the 1820s, can be attributed to the rise of a predatory state in the region, which extracted too much from the Bokoni farmers to encourage them to continue. On the other hand, in the 1890s, the Lozi king, Lewanika, used slaves and corvée labour in draining lands in the Zambezi valley (Prins 1980: 56, 60, 70).

Colonial rulers, too, found that predation and extraction as such were not the most effective ways to establish economically viable entities at low administrative and military cost, the latter being a priority outside the settler states (Austin 2008b). King Leopold's extreme depredations in the Congo caused such embarrassment in imperial Europe that the Belgian parliament made the territory into a Belgian colony; one in which a degree of more regulated coercion was combined with productive investment to the considerable profit of Belgian companies (Buelens and Marysse 2009). Again, there is an instructive contrast between two neighbouring colonies, Côte d'Ivoire and Ghana, with very similarly physical endowments, equally favourable to cocoa farming. In both, the history of cocoa production was ultimately a triumph of African farmers. But Côte d'Ivoire lagged far behind Ghana until the abolition of forced labour in the French Empire, in 1946, enabled Ivoirien farmers to bid for labour on the same terms as their Ghanaian counterparts, after which Côte d'Ivoire cocoa production began to soar (Hopkins 1973: 219).

It has often been noted that resource rents have been central to the political economy of post-colonial Africa. While the negative aspects of this are well known, it is important to avoid simplifying the causation. The example of Botswana, the one country in Sub-Saharan Africa whose economy grew consistently faster than its population from independence to the international recession of 2008, illustrates that a mineral windfall can be used for socially and economically productive purposes.

The emergence of land scarcity in various parts of Sub-Saharan Africa has changed the nature of competition for resources, making land as such much more commonly the target than before.[15] Whereas strangers had often been welcomed by rulers as providing additional sources of revenue and labour, assimilation has become much more difficult if not impossible, a change neatly described by the anthropologist Stefano Boni (1999), in the context of southwestern Ghana, as 'the emergence of the permanent stranger'. There have even been instances of expulsion of 'foreign' communities, even after long periods of residence, as followed in the case of Mobutu Sese Seko's withdrawal of Zairian citizenship from inhabitants of Rwandan descent in 1995. Pressure on land has undoubtedly aggravated rivalries, even when it is by no means the only issue. An extreme case is the Rwandan genocide of 1994. While its causes were multiple, the acute scarcity of land was at least a facilitating condition. A local study showed that the genocide was used as an opportunity to kill a number of people who were neither Tutsis nor opposition politicians, but included old men seen as holding on to land that they should have shared with their sons (André and Platteau 1998).

It is important to avoid any assumption of simple determinism. The point can be illustrated by returning to the two largest producers of cocoa. In the aftermath of Côte d'Ivoire's independence, President Felix Houphoet-Boigny made a verbal promise to people from the savanna of Côte d'Ivoire and across the border in what is now Burkina Faso, promising 'land to the tiller' to those who would work on Côte d'Ivoire's cocoa and coffee farms. In Ghana, continuing colonial policy, no such promise was made. In short, the Ivoirien authorities offered to share the forest rent with savanna people who came to help harvest it; their Ghanaian counterparts did not. The difference in the offer to northerners helped to divert labour from Ghanaian to Ivoirien cocoa farms, and therefore was one of the reasons why Côte d'Ivoire eventually overtook Ghana as the world's biggest exporter of cocoa, in the late 1970s. After Houphoet's death, however, his successors took advantage of the fact that the promise had never been put into law to renege upon it. This was one of the major causes of the subsequent civil wars (beginning with that of 2002–4). In contrast, in Ghana the lack of rights of northern workers over southern lands, whether under colonial rule or since, has not been a major political issue (Woods 2003; Austin 2006). This illustrates the importance of political contingency: there is no inevitability about resource conflicts leading to violent conflict. Or at least, it is not inevitable in any particular case; but the potential for conflicts of this kind to occur in Africa has increased substantially as land has become physically scarcer.

[15] Boone (2014) provides an excellent analysis of the political and institutional patterning of land conflicts.

Pressure on land could be reduced by greatly increasing yields per hectare, which requires overcoming the problems, such as the vicious cycle of reduced fallow times and falling long-term soil fertility, discussed in the previous section. This is, in part, a political issue. The share of agriculture in government spending remains low in many African countries. Again, agricultural research in Africa continues to be funded, conceived and directed overwhelmingly from above, with little or no accountability to the mass of small-scale farmers (Breman 2012; Norman 2012: 143). Only a small fraction of the scientific research seems directly to investigate what farmers have found, such as new crop varieties that have emerged on their farms (Richards 2010). It seems easy for governments to be seduced by big offers from prospective large-scale investors, whereas economic growth, and especially development, requires investment also in small-scale agriculture (Norman 2012: 145). The lack of an African Green Revolution to date may be partly attributable to the political weakness of agricultural interests, especially the small-scale farmers, in most African countries.

The other side of rising population pressure on land is the decline of labour scarcity. By comparison with around 1960, when most African countries became independent, their labour forces are larger, relatively cheaper in international terms and better educated. This reflects arguably the biggest success of independent governments: in health and education (Sender 1999), despite Africa's continued lag behind other regions in relative terms. In turn, these changes improve the prospects for labour-intensive manufacturing (Austin, Frankema and Jerven 2017), the growth of which could also alleviate pressure on agricultural land, as well as representing the best hope of fundamental improvements in average living standards. In the context of climate change, Africa's share in greenhouse gas emissions remains so low that it has an overwhelmingly strong case for being allowed to increase it within any system of agreed international quotas. Meanwhile, the falling cost of solar panels offers the prospect of Africa being able to obtain much of its electricity from a source that is both renewable and locally abundant.

As with an African agricultural revolution, an African industrial revolution would require an active role for the state, in pursuit of public interests. For example, a competitive manufacturing sector in the early twenty-first century presupposes a reliable and cheap supply of electricity. This is not simply a matter of having oil, as Nigeria demonstrates. There, the notoriously long-running failure of the public electricity company to provide a reliable service, even in the major cities, has spawned a major trade in supplying generators to companies and households. It is widely alleged that this industry is now itself a powerful lobby, dissuading the state from finally providing the public service it is supposed to deliver.[16]

Thandika Mkandawire (2001) has argued that the 'developmental state' has a deeper history in Africa than is often supposed, and much more of a future than is often feared. In contemporary Africa the systematic pursuit of economic development requires state action to prevent one sector of production damaging another, and also

[16] Hanaan Marwah, currently an affiliate of the London School of Economics, is researching the history of electricity supply in Africa.

directly damaging public welfare itself. In Western Ghana, for instance, there are reports of small-scale gold production polluting both rivers (through irresponsible dredging) and fertile agricultural land (by opencast mining, without re-landscaping and using poisons such as mercury), thus hurting other economic activities and the health of the local population. If the predictions of the Intergovernmental Panel on Climate Change are correct, global warming will make tropical Africa, in particular, drier and hotter: creating problems for agriculture (IPCC 2014) and presumably raising demand for air conditioning and therefore electricity. Areas on the southern edge of the Sahara, which already have had episodes of economic decline resulting from droughts (Baier 1980; Webb 1995), are particularly in the firing line.

At international level, in Africa as in Asia, states need to cooperate to resolve conflicts of interest over the use of rivers that cross borders. But international cooperation on resource scarcities is at risk from the conflicts of interest involved, as we see from current territorial disputes over land containing oil reserves, for instance in the case of an island in Lake Victoria whose status as Ugandan territory has been challenged by Kenya. In Africa as elsewhere, resource scarcities are increasingly such that the task of providing effective regulation of water, energy and cultivable land is becoming a critical test of the credentials of would-be developmental states, collectively as well as individually.

Conclusions

Africa was entangled in the origins of global industrialization and thus of Crutzen's 'Anthropocene' and has been part of the Great Acceleration in progress since 1945 (see also Osborn's chapter, this book). It seems unavoidable that future economic development in Africa will be constrained by the environmental consequences of global warming. If the latter are mitigated by internationally agreed action, that is likely to entail the serious cost of leaving some of Africa's fossil fuel reserves unexploited commercially. Climate change epitomizes but far from exhausts the concept of the Anthropocene for Africa, for it highlights the growing human pressure on natural resources – the closing of previously open frontiers, often as a by-product of increased production supporting larger and (often) eventually healthier populations – that has characterized the modern, and especially the contemporary, history of Africa. From the importation of American crops during the Atlantic trade to the proliferation of internal combustion engines and plastic bags that were part of African experience in the Great Acceleration, the continent fits Timothy Weiskel's remark that in what used to be called 'the Third World':

> Future archaeologists will have to account for a thin, almost indistinguishable stratum in the soil profile [which] … Upon laboratory analysis … will no doubt show evidence of substantial shifts in the floral and faunal populations, an efflorescence of new cultigens, a remarkable invasion of exogenous material culture, and a considerable upsurge in rates of soil erosion and sedimentation. (Weiskel 1988: 141)

In an age when the traditional subject of economic history – economic development – is putting at risk the environmental conditions that have made it possible, the existing overlap between the environmental and economic historiographies of Africa is insufficient. Economic historians of Africa need to give more direct attention to problems of resource scarcity, engaging more closely with the notions of 'land' (or 'natural capital') as a factor of production, especially by disaggregating it in recognition that its components are often not substitutes for each other (see also Austin 2008a). Environmental historians of Africa could surely also pay more direct attention to what has become the primary motor of environmental change: human economic activity.

It has been argued here that much of the economic behaviour of African individuals, households and polities, until well into the twentieth century, is usefully considered as the pursuit of a 'land-extensive' path to greater food security and higher incomes; albeit, even 'land-extensive' development necessarily included moments of intensification. But the material conditions that made land-extensiveness optimal shifted, especially during the last century, as a result of settler intrusion, the export-crop revolution and above all, population growth. As a result, agricultural intensification became increasingly the main story in Sub-Saharan land use, while labour-intensive industrialization has become a plausible medium-term aim in a subcontinent which for most of its history was labour-scarce. In this context, it is suggested here that a more nuanced interpretation is needed of the political economy of resource scarcities in modern African history, so often represented as an unmitigated story of predation and extraction. Such behaviour has been necessarily integrated with, or in some cases subordinated to, peaceful market exchange. It can only be hoped that this somewhat more optimistic historical perspective applies to the contemporary tensions over scarce resources, including the political requirements of the green revolution – from below as well as from above – that Africa badly needs, despite – or even more so because of – the looming likelihood of greater aridity as global warming proceeds.

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6

Monsoon Asia, Intra-Regional Trade and Fossil-Fuel-Driven Industrialization

Kaoru Sugihara

This chapter discusses the evolution of Asia's population-holding capacity for the last few centuries, and its relationships with the environment and resources. While Western Europe and its offshoots (especially the United States) led global industrialization from the nineteenth century onwards, with a remarkable rise in real wages, Asia's living standard lagged behind, together with that of the rest of the non-Western world. Starting in the second half of the twentieth century, there was an economic 'resurgence' of Asia, and some parts of the region have largely 'caught up' with the West in living standards, while the rest remain in the 'middle' or 'lower' income categories. Throughout these changes, monsoon Asia as a region sustained more than a half of world population (Maddison 2009).

In what ways were resources secured to sustain the livelihood of an unprecedented and rapidly rising number of people? Some resources can be obtained through exchange of goods and services, but others, such as land and water, usually need to be secured locally. Where electricity is not always available, which is the case for a vast area of the world even today and for the whole world for most of human existence, securing local biomass energy for cooking and heating purposes could be a matter of life and death. Hence, securing all essential resources for production and livelihood has been a twin target for the welfare of the local society for most of human history. If large parts of Asia, especially China and India (present South Asia), held an unusually large population in 1820, and exhibited a rapid expansion in absolute numbers during the last half century, it implies that these societies found answers to meet this target, especially in the early modern and the most recent periods.

Historians of the colonial period have discussed the more stagnant trends dividing these two periods, by referring to rebellions and environmental problems in nineteenth-century China, and for India to famines in the 1870s and 1890s, and to

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the influenza pandemic of 1919–20, for example (Ho 1959: 273–7; Wakimura 2002; Dyson 2004: 22; Pomeranz 2011: 5–7). Economic and social historians have discussed the prevalence of poverty, social inequality and instability in the last two centuries, often by linking them to the resource shortage, especially that of land. Low agricultural productivity and a low land-labour ratio were among the most important indicators of a resource-poor country (for a brief description of the thinking of classical economy and its limits, see Hayami and Godo 2005: 80–9). Malthusian and neo-Malthusian thinkers have considered these issues in connection with population control. However, they have left unanswered the critical question of why population grew so much in the long run only in Asia.

The best-known approach to this question is to discuss the environmental characteristics of monsoon Asia. The idea is to link a massive water and air circulation regime centring on the Himalayas to long-term regional economic growth. Thus, in describing post-war economic development up to c. 1980, Harry Oshima stressed the common socio-environmental characteristics of monsoon Asia, stretching from East and Southeast Asia to South Asia, in terms of seasonal rainfall patterns induced by monsoon winds, and the centrality of the large delta for the growth of rice farming and dense population. His formulation focuses on the sequence of intensive rice farming, population growth, availability of cheap labour and labour-intensive industrialization leading to economic growth (Oshima 1987; Sugihara 2015a: 114–15). This sequence implicitly assumed several topics, which have been more explicitly taken up by other scholars, mainly with reference to East Asia. The development of intensive farming under land scarcity implied successful labour absorption (Ishikawa 1978). It also implied the intensive use of water and manure required for commercial crop production (Elvin and Liu 1998). Population growth required the maintenance of social order (Wong 1997). Proto-industrialization and commercialization of agriculture meant the growth of intra-regional trade through merchant networks (Sugihara 1996: 84–8). Finally, labour-intensive industrialization implied the capacity to engage in intercontinental trade, to exchange primary products at an initial stage, and increasingly to export labour-intensive manufactured goods in return for fossil fuels and other resources as well as for capital-intensive goods (Sugihara 2013: 30–8, 43–55). In other words, monsoon Asia's feeding capacity came as much from the development of economic and social capacity to acquire resources as from the basic water and air circulation regime. Each country or sub-region (East Asia, Southeast Asia and South Asia) responded to this challenge, with varying difficulties and policy support, and eventually incorporated fossil fuel-driven industrialization into its development path.

What economic and environmental factors enabled Oshima's sequence to post-war growth to take place on a regional scale, and what were their limits? This chapter shows that the growth of intercontinental and intra-regional trade played a critical role in the transformation of resource base from the biosphere to fossil fuels. It also suggests that, while this brought about unusually rapid economic growth, fossil fuel-driven industrialization has fundamental limits in responding to locally specific resource constraints, and argues that monsoon Asia's environmental characteristics remain relevant in sustaining the region's population and livelihood in the present century.

The next section describes resource and livelihood regimes in Asia and their evolution up to c. 1800. In most parts of the region the regime was local or sub-regional. Food shortages or disasters had to be dealt with mainly within the regime. The second section discusses the evolution of a modern regional regime under Western impact and colonialism. While external influences had disruptive effects, the growth of intra-Asian trade and Japan's (and East Asia's) labour-intensive industrialization provided the basis of regional response to resource needs, especially local land scarcity. They helped sustain population growth.

The third section discusses the transformation of Asia's resource base into a global, fossil fuel-based one in the second half of the twentieth century. A succession of rapid industrializations, starting from Japan and spreading to other Asian countries (collectively called 'growth Asia' here), would not have been possible without imports of coal, oil and natural gas, involving the growth of both intra-Asian trade and imports from outside the region, especially the Middle East. At the same time, the rapid economic growth put pressure on local non-tradable resources such as land, water and biomass energy. The fourth section discusses Asia's responses to such constraints, and suggests a new factor endowment framework, which determines monsoon Asia's and sub-regional development paths. The last section places the perspective of this chapter in global history.

The evolution of resource and livelihood regimes

In the early modern period the economic base of Asia's state formation can be classified into three types: maritime, agrarian and nomadic. In both Mughal India and Qing China a nomadic empire came to rule a vast agrarian society, and transformed itself into an agrarian empire to a large extent. Judging by population size, these two agrarian empires were much larger than nomadic empires (the Ottoman Empire was both nomadic and agrarian, but its population was smaller than the other two) and other earlier ones spanning vast regions of Eurasia. Within the environmental framework of monsoon Asia, agrarian empires and their offshoots, including Japan, played a central role in the growth of population and the idea of welfare provision to sustain it. It was the agrarian empire that developed the basic regime of resource and livelihood for ordinary people.

Various types of empires, states and other regional and international bodies tried to secure resources for their own survival and expansion. Among the most important means deployed were fiscal policy (typically tax extraction) and trade and territorial expansion. While in early modern Europe the execution of war was closely related to the issue of bonds and shares in the capital market, this was not the case in Asia. Land tax, together with sales monopolies, tariffs, tolls and so on served the needs of war, law and order and the consumption of the ruling class. The Mughal Empire and the Tokugawa shogunate were perhaps the two states that extracted the highest proportion of agricultural output in the seventeenth century (Smith 1988: 50–70; Richards 1993: 79–93; see also Yun-Casalilla and O'Brien 2012).

What made it possible for them to extract such a heavy tax for a long time? The main source was agricultural surplus. In East Asia the surplus came from the high land productivity of rice agriculture where plenty of water and rich land were available, and labour-intensive technology and labour-absorbing institutions were developed. The 'industrious revolution' occurred both in Western Europe and East Asia (de Vries 2008), but it was in the latter that labour absorption led to population growth (Sugihara and Wong 2015).

Perhaps more important, a population-holding capacity was supported by the local community, as well as by an agrarian empire or state. In many peasant societies in Asia, including relatively land-scarce ones, village autonomy was guaranteed to a certain extent, as long as the village paid land tax and fulfilled other obligations. Within the local community welfare was provided by the family, the village community, market mechanisms and local hierarchies (Nakamura 1980: esp. 277–9). The changing land-to-labour ratio for each household as a result of the family life cycle appears to have been 'equalized', through the reallocation of land from land-abundant to land-scarce households, largely because the village-based taxation system prompted them to do so (Arimoto and Kurosu 2015). Meanwhile, the shape of centralized power differed sub-region by sub-region (and differed again within it, between China and Japan, for example), in terms of the size of revenue, the extent of currency manipulation (by debasement and issuance of paper money), external policy and the degree of freedom of migration. There was also diversity in the relationships between central and local governments. In the history of commons and common pool resources, institutions to govern communal land emerged relatively early in land-scarce regions such as Japan and South India, while response to deforestation or decline of fish stocks came much later in resource-rich regions of Southeast Asia (Yanagisawa 2015).

Concerns for livelihood and resource security in this period included not just the acquisition of food, shelter and clothing, but the more specific capacity to secure food during famine or food shortages and respond to infectious diseases, natural disasters and war. While strong states were capable of destroying the livelihood of their people by conducting war or supressing resistance, early modern states were also interested in the welfare of the people who were the foundation of their power. In seventeenth- to eighteenth-century China, granaries stored food in preparation for local food shortages (Will and Wong 1991), while the reduction of land tax in Tokugawa Japan was partly a response to local natural disasters such as flood (Kamatani, Sano and Nakatsuka 2015). The main social mechanism of resource allocation and livelihood security in India was the caste system, which combined occupational division with status hierarchy. In certain castes work/income rights (shares or entitlements) were recognized and exchanged, while water, as well as land, was used to signal and reinforce status hierarchy. The system served for both stability and discrimination (Kotani 1996; Mizushima 1996; Tanabe 2005; for the rules over water use, see Mosse 2003).

Meanwhile, maritime states based on port cities and surrounding rural areas grew along the coasts of the Indian Ocean, including maritime Southeast Asia. Here the key organizing agents were port cities (or port city states) and networks of merchants

(Reid 1993: 62–131). Agrarian population was not necessarily the mainstay. Products derived from the sea, land and the forest were all involved in the exchange economy, and the economic base of the state could shift from one commodity to another, and from one producer to another relatively easily. This was one way of securing their resources and livelihood. The first serious economic contacts with Europe often began via these states.

In mainland Southeast Asia there was a tendency for territorial consolidation from c.1350 to 1830–40, echoing similar trends in territorial integration in Europe (Lieberman 2003: esp. 1–6, 28–31). Meanwhile, in the mountainous areas spanning South and Southeast Asia and China, people formed small political entities and retained their linguistic and cultural identities (Scott 2009). Furthermore, the impact of Islam (and Arab merchants) on state formation in the Indian Ocean trade regions cannot be ignored. All these features coexisted with agrarian empires and maritime states in South, Southeast and East Asia, often competing, complementing or overlapping with them.

It is possible to see a tendency for the two types of political units, agrarian and maritime, to initiate or encourage the growth of the market to reinforce their respective strength. For example, the Chinese Empire discouraged maritime expansion to a certain extent, but left the development of local and regional markets without heavy intervention. In eighteenth-century Jiangnan, where labour-intensive rice farming had developed, a large amount of silk and cotton cloth was exported to foreign and domestic markets, and grain and fertilizers were imported (Li 1998: 99–115). The Tokugawa government was much more regulatory. It promoted the growth of the central market in rice through the collection of land tax, managed foreign trade under strict control, partly discouraged other types of trade and regulated the growth of factor markets (in land, labour and capital). It was nevertheless 'market-enhancing', in that the system allowed relative sociopolitical autonomy, and even encouraged the peasant household to engage in commercial agriculture and proto-industry, especially from the latter half of the eighteenth century. Finally, the East Asian maritime networks were governed by the tendency to discourage intercontinental trade, which denied the European style of expansion backed by military and technological capabilities. But by the end of the seventeenth century, piracy was curtailed, and East Asian seas became peaceful. In addition to, and partly in place of, the tributary trade relations, China developed a more equal regime of managed trade (the Hushi system), and both Japanese and Chinese governments recognized the utility of bilateral trade relationships. They communicated through 'silent diplomacy' (Iwai 2010, 2012; Hao 2015).

By contrast, Indian Ocean trade was fostered by multi-layered networks of merchants, characterized by openness, spanning ecologically diverse areas and with relatively large intercontinental trade components. Territorial boundaries were observed, but the rules of exchange were not as imposing as in Europe, especially in sea-borne trade. Europeans, Arab traders and local merchants overlapped in their operations, and they were not necessarily structured in a hierarchical way. The Mughal Empire was a strong fiscal military state, at least at its peak, but was relatively flexible towards trade, including maritime trade. In the Indian Ocean commodities from all over the world were exchanged as a result. The range of commodities traded in Atlantic or East Asian waters was not as comprehensive as that in the Indian Ocean (Chaudhuri 1985: 182–202; Riello and Roy 2009).

Southeast Asia was not only directly exposed to intercontinental trade but was also at ease with local and regional trade at the same time, and possessed an 'inland sea' quality of a Mediterranean kind. Helped by the presence of Indian and Chinese merchants, the region emerged as a hub of the trading world in which intercontinental, regional and local trades vigorously interacted. Nevertheless, states did not develop a capacity to hold a large population. Resources were freely transferred through trade. The states thrived when they consolidated power or were in touch with other regions, including Asian agrarian and European overseas empires. But their livelihood security was often threatened by external shocks through the introduction of infectious diseases, loss of comparative advantage as a result of the emergence of new production methods and trade regimes, and violence and war, in addition to natural disturbances, especially famines.

In 1820 estimated populations were 381 million in China, 209 million in India and 31 million in Japan, while the total population of nine Southeast Asian states/regions was about 38 million (Maddison 2009).[1]

Western impact, intra-regional trade and labour-intensive industrialization

In the late eighteenth and early nineteenth centuries an overwhelming proportion of world non-agricultural production remained unmechanized, and the bulk of this was located in Asia, especially in China and India. Even in industrializing Europe in 1840 a half of textile production remained unmechanized. By 1910, however, the world market of textiles was dominated by the modern English cotton textile industry (Jeremy and Farnie 2004; Riello 2013; Beckert 2014). The decline of traditional industries, especially cotton textile industry in India (and to a lesser extent China), was a serious global event that involved a loss of employment on an unprecedented scale (Bagchi 1976: for a more recent assessment see Roy 2005). Asia's share of world GDP declined from 60 per cent in 1820 to 25 per cent in 1913, while that of Western Europe rose from 20 per cent to 31 per cent, and of North America from 2 per cent to 20 per cent (Sugihara 2015c: 20).[2] This mainly reflected the widening gap in labour productivity between Asia and the West, although the growth of GDP in North America reflected the rapid growth in the immigrant population as well. Asia became an importer of English textiles and an exporter of tea, rice, sugar, tin, rubber, raw cotton, raw silk, raw jute and wheat. In this way an international division of labour emerged between industrialized Western countries

[1] Twelve countries of Western Europe had 115 million (Maddison 2009).

[2] The data are from Maddison (2009). I have attempted to compare them with industrial production estimates in Bairoch (1982) and various trade data.

as exporters of manufactured goods, and Asian countries (though, for the most part, not East Asian ones) as exporters of primary products.

The environmental implication of this division of labour was the transfer of (mainly land-derived) natural resources from the latter to the former, in exchange for the improvement of transport, urbanization and the use of mass-produced consumer goods. Industrialization in this context has typically been portrayed as an agent of both resource exploitation and the diffusion of modern science and technology. Together, they restructured the local resource and livelihood regimes in a major way.

In these respects the Western impact in the nineteenth century was much stronger than that of the early modern European expansion. Those port cities that developed through the earlier contacts with Portugal, the Netherlands and Britain were now more deeply incorporated into the colonial projects of Western powers. The latter exhibited a definitive superiority in military and navigation technology across Asian waters by the middle of the nineteenth century. A regime of forced free trade was imposed, while sailing and steamship routes were established by the late nineteenth century. The more efficient transport networks were linked to local junk trade and traditional road transport. The timing of the initial contacts of the West differed sub-region by sub-region: generally they started in South Asia and moved to Southeast Asia, and eventually to East Asia. Nevertheless the pattern of contacts was similar in character, in that the Asian territorial boundaries became more clearly defined and Western-style legal frameworks (sovereignty and up to a point the regime of private property rights) were introduced. Colonized or not, all states were gradually incorporated into the West-dominated international order.

However, Asia's response to Western impact also contained another feature, namely the resurgence of merchant networks and labour-intensive industrialization. To start with India, Britain had begun territorial acquisition in the late eighteenth century, expanded it from the three port cities of Calcutta, Bombay and Madras in the first half of the nineteenth century, and penetrated into the hinterlands of the subcontinent through the construction of railway networks in the second half. A vast sub-region with diverse linguistic, religious and civilizational characteristics became strongly connected by the establishment of the British rule. While intercontinental-trade-related economic development eased some of the local resource constraints, various 'hinterland' resources were converted to commercial use (tea plantations in Assam and raw cotton cultivation in Bombay Presidency and nearby princely states, for example). This put local livelihood security at risk in various ways. Deforestation as a result of demand for timber for railways (both as fuel and as sleepers) changed the availability of biomass energy for local use (Nishimura and Sugihara 2009; Parthasarathi's chapter, this book), or more generally raised the price of timber. Cultivation of water-intensive crops for commercial production also put pressure on the availability of land and water for local use.[3] Better and more frequent contacts with the outside world were also a

[3] Today the implications of exports of water-intensive crops for national water supply are discussed in the literature on virtual water and water footprints, with attention to both positive and negative roles of trade. See Chapagain and Hoekstra (2008). As with today, many agricultural products such as oil crops, cotton and rice that were internationally traded in the colonial period were water-intensive, with clear implications for water-scarce regions.

cause of the diffusion of infectious diseases and alien plants and other species. In late-nineteenth-century India there emerged signs of strain in livelihood security in terms of food shortages, famines and epidemics, and a reduced ability to secure local supplies of water and biomass energy (Wakimura 2009; Sugihara 2010: 176–9).

However, between 1890 and 1920 there was a major shift in the commodity composition of rail- and river-borne trade. Domestic commodities such as local grains, sugar, salt and spices (including opium), a commodity chain of raw cotton, cotton yarn and cotton cloth, largely driven by the modern textile industry, and heavy materials for local use such as stone and timber, increased through the modern transport network, and, after the First World War, became more important than intercontinental-related trade (Sugihara 2015b). Famines largely disappeared (for mixed effects of railways on famines and food supply, see McAlpin 1983), while a number of livelihood security concerns were voiced by nationalist movements (employment, literacy and education, for example), as well as by B.R. Ambedkar (1891–1956) who sought to end the discrimination against the outcaste people, including the restriction of their use of water.

Similar tendencies towards the growth of local and regional division of labour occurred in East and Southeast Asia. In Southeast Asia a territorial integration of an Indian kind did not occur, as European and American powers divided the region, but trade integration did take place via the establishment of entrepots such as Penang and Singapore. Beginning with the 1824 Anglo-Dutch Commercial treaty, Southeast Asia became a substantially free trade sub-region, and intra-Southeast Asian trade, as well as trade between Southeast Asia and other parts of Asia, grew (Sugihara 1996: 15–22, 69–78; Kobayashi 2013: 443–74). The sub-region traded a variety of local tropical products (largely non-timber forest products), in addition to international commodities such as rice and sugar, which were also in demand for local and regional use.[4] Hong Kong also acted as an entrepot for Southeast Asia, as well as for China, from the mid-nineteenth century. The success of the entrepots reflected not just the British lead (the imperialism of free trade) but also the region's historical experience of port city economies. Chinese merchant networks in East and Southeast Asia were reorganized and developed under Western impact. Actual patterns of networks changed as they developed more multilaterally, together with migration, remittances and shipping and accommodation networks, but the organizational principles seeking gains from trade through the use of native place- and dialect group-based networks remained intact (Sugihara 2005b).

This was a crucial moment for Southeast Asia as a sub-region. By the early twentieth century the sub-regional economy became much more deeply integrated into the Asian international economy. A massive (though mostly temporary) migration of

[4] In this respect traditional understanding of the dominance of European powers in Southeast Asian trade must be qualified. If we include intra-sub-regional and intra-regional trade of primary commodities (such as rice and sugar) as separate from intercontinental trade, in order to focus on the nature of merchant networks (thus, for example, count Chinese merchant trade of sugar from Java to Singapore as intra-sub-regional), rather than on the commodity chain (thus regard it as part of intercontinental trade from Java to Europe), then the sum of intra-sub-regional and intra-regional trade was probably just as important as intercontinental trade for most of the nineteenth century. See Sugihara (2015c: 22–34, 41–51).

Indian and Chinese workers to Southeast Asia and associated development of various regional networks meant greater factor mobility between relatively land-scarce parts of Asia and resource-rich Southeast Asia, which also accompanied sociocultural fusions in Southeast Asia. The growth of intra-Asian trade between Southeast Asian primary producers and other Asian producers of manufactured goods led to the growth of an international division of labour on a scale comparable to British India's. Chinese, Indian and Japanese merchants took advantage of the modern infrastructure brought by Western powers. Information travelled faster through telegrams, trade finance became easier and transaction costs were reduced. As a result, the centre of gravity of Asia's economic and population growth shifted from the agrarian base to the maritime and coastal regions of Asia (they are sometimes called maritime monsoon Asia), and Southeast Asia emerged as a focus of Asian regional economic development. The region's population share in Asia (East Asia, Southeast Asia and South Asia) increased from 5.6 per cent in 1820 to 11.6 per cent in 1913, and to 13.8 per cent in 1950.

Japan's labour-intensive industrialization was dependent on this growth of intra-Asian trade, as well as being a major driver of it. By the early twentieth century she imported raw cotton from India, rice and sugar from Southeast Asia, Korea and Taiwan and soybeans and their products from Manchuria, and exported labour-intensive manufactured goods to other parts of Asia. The environmental implication of this division of labour was an easing of resource shortage, which enabled Japan to expand her cotton textile industry. In this respect the basic logic was similar to England's discovery of 'ghost acreage' in North America during the period of the industrial revolution (Pomeranz 2000: 274–8).

China was an important importer of cotton yarn, first from India and later from Japan, till it went through import-substitution industrialization. Japanese merchants brought a wide range of cotton manufacture (cloth and apparel) and sundries (matches, soap, toothpaste and tooth brushes, traditional medicine, umbrellas etc.) to Asian peoples, and a vast market for cheap modern manufactures was created. With a time lag and political disturbances, labour-intensive industrialization spread to China and eventually to other parts of Asia.

Thus Asia was not just de-industrialized; it reorganized itself into a new form of industrialization. In this period there emerged two different routes of the diffusion of industrialization, the capital-intensive route originating in the West, and the labour-intensive one originating in East Asia. The latter was too small to be recognized in terms of the size of value added at this stage, but was already an important source of employment. It also tended to be less resource intensive than the capital-intensive path. Therefore, what actually emerged in the period from the nineteenth century to the 1930s was a three-tier international division of labour – capital-intensive manufactured goods, labour-intensive manufactured goods and primary products – and an increasingly uneven global resource allocation in favour of Europe and regions of recent European settlement. It also developed an international division of labour within Asia, in which Japan, China, India and Southeast Asia were hierarchically placed in the order of industrialization (see Figure 6.1). The growth of intra-Asian trade was faster than that of world trade or Asia's trade with the West between 1880 and 1938 (Sugihara 2005a: 6–7).

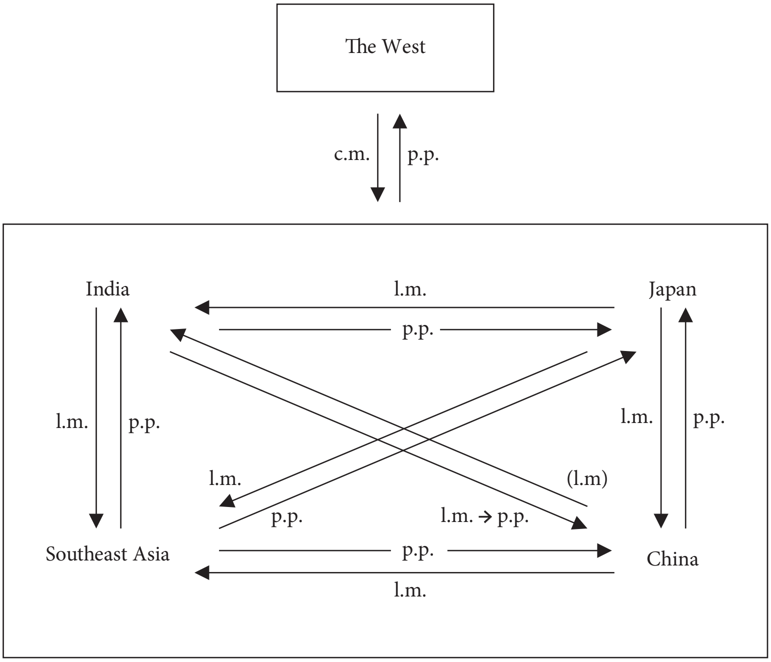

Figure 6.1 Intra-Asian trade, c.1880–1938.

Note: m.: refers to manufactured goods, p.p.: primary products. Since the late nineteenth century, India exported cotton yarn to China in large quantities, but from the end of the 1910s, it was replaced by the exports of raw cotton. China exported a small amount of silk textiles in turn. c.m.: capital-intensive manufactured goods; l.m.: labour-intensive manufactured goods; p.p.: primary products.

Source: Sugihara (1996): slightly revised.

Regional integration through local and regional merchant networks appears to have been less marked in most parts of Africa, the Middle East and Latin America where the local economies were integrated into the metropolis-led international economy as satellites. In Asia, they played a crucial role in easing local resource constraints.

However, even in Asia, the productivity of proto-industries with traditional technology, modern labour-intensive factories and commercial agriculture built on the low land-labour ratio remained low. The standard of living rose very slowly.[5]

Finally, both intra-Asian trade and labour-intensive industrialization were severely disrupted by Japanese imperialism and territorial expansion. From 1931 to 1936 Japan grew faster than most Western countries, and proceeded with heavy

[5] An estimate suggests that a PPP (purchasing-power-parity)-adjusted per capita income of Japan in the mid-1930s (at current prices) was 32 per cent of the US level, which means that the gap between the two countries was greater than the Maddison estimate suggested. Since Japan's level was far higher than other Asian countries', there was no sense of 'catching up' with the West in this respect. See Fukao, Ma and Yuan (2007).

industrialization. This partly came from the 'import-substitution industrialization', in the sense that competitive pressure from the West was eased (largely as a result of the Great Depression and the devaluation of the yen) and many domestic machinery sectors developed. The intra-yen bloc trade now included a significant proportion of machinery trade. But it was also a move towards a 'relative autonomy', anticipating post-war India and China, in that most new industries were linked to the research and development efforts relating to Japan's military industries (Sawai 2012). If the direction of industrial development was driven by political and military interests (and in Japan's case without a full understanding of global military and resource balances), there was no guarantee, or even a prospect, that the country was adopting a sensible import-substitution strategy based on factor-endowment considerations.

Regional industrialization and global resource transfer

After a heavy intervention of the emergence, development and abrupt collapse of the Yen bloc in the 1930s and the first half of the 1940s, intra-Asian trade recovered fast among a much smaller number of countries. By 1950 India, China and many Southeast Asian countries and North Korea withdrew from the regime of free trade, and a relatively small number of countries along the western Pacific coast (Japan, South Korea, Taiwan, Hong Kong and Malaya-Singapore among others) were integrated into the US-led world economy. We then saw the high-speed growth of Japan, the NIEs (Newly Industrializing Economies: South Korea, Taiwan, Hong Kong and Singapore) and the ASEAN 4 (Thailand, Malaysia, Indonesia and the Philippines), followed by the reintegration of China, India and some Southeast Asian countries (those which joined ASEAN later) in the second half of the twentieth century, which led to a full recovery of the intra-Asian trading zone that existed in 1928.

In the early post-war period the share of the US (and other Western countries) in Asia's trade was large, and its influence was dominant. However, the US share rapidly declined, and was replaced by the growth of regionally driven trade. In 2014 the share of intra-Asian trade in the exports of Asian countries was 70 per cent, a figure comparable to intra-EU trade (see Table 6.1).[6] Furthermore, Asia's high regional share was accompanied by 'open regionalism', with lower tariff barriers within the region, but, unlike the European Union, without discriminating measures against countries outside the region. While economic nationalism often qualified and delayed the process, especially in trade in agricultural products, Asian countries enjoyed the presence of Hong Kong, and to a lesser extent Singapore, as free ports. Most growth economies of East and Southeast Asia traded heavily via these ports, especially with the United States and intra-regionally. As long as the region's growth rates remained the fastest in the world, it was believed that the region would have the most to gain from trade. Open regionalism was thus adopted as the guiding principle for the formation

[6] Given the regime of free trade and globalization, there must be a saturation point in the trend growth of the share of intra-regional trade. It is not yet clear if we are currently witnessing the end of the upward trend.

Table 6.1 Growth of Intra-Asian Trade, 1950–2014 (billion dollars)

	(1) World exports total		**(2) Asia exports total**		**(3) Intra-Asian trade total**		**(3)/(2)%**
1950	58.0	(100.0)	10.7	(18.4)	2.9	(5.0)	27.1
1955	93.9	(100.0)	13.4	(14.3)	4.0	(4.3)	29.9
1960	128.9	(100.0)	18.3	(14.2)	5.9	(4.6)	32.2
1965	188.2	(100.0)	25.7	(13.7)	9.1	(4.8)	35.4
1970	320.7	(100.0)	44.4	(13.8)	15.6	(4.9)	35.1
1975	887.4	(100.0)	143.4	(16.2)	49.8	(5.6)	34.7
1980	2,018.1	(100.0)	332.6	(16.5)	135.9	(6.7)	40.9
1985	1,987.0	(100.0)	424.2	(21.3)	167.7	(8.4)	39.5
1990	3,601.2	(100.0)	805.4	(22.4)	357.3	(9.9)	44.4
1995	5,325.1	(100.0)	1,460.6	(27.4)	764.8	(14.4)	52.4
2000	6,385.6	(100.0)	1,456.8	(22.8)	738.9	(11.6)	50.7
2005	10,369.0	(100.0)	2,285.5	(22.0)	1,330.0	(12.8)	58.2
2010	14,937.3	(100.0)	4,495.3	(30.1)	3,073.9	(20.6)	68.4
2014	18,442.9	(100.0)	5,603.2	(30.4)	3,905.9	(21.2)	69.7

Note: The coverage in Takanaka 2000 is slightly wider in the scope of coverage than the IMF data, but the differences are small. Intra-Asian trade total refers to the value of exports from ten Asian countries (Japan, four NIEs, four ASEAN countries and China) and their imports from the smaller Asian countries (adjusted by FOB-CIF conversion).
Source: For 1950–99, Takanaka (2000); for 2000–14, IMF, Direction of Trade Statistics Yearbook.

of the Asia-Pacific Economic Cooperation forum in 1989. Intra-Asian trade has been by far the most dynamic section of world trade for the last half century.

Why has the growth of intra-regional trade been such a persistent tendency for the 130 years? Our hypothesis is that it was essential to transform the region's resource base, first from a local to a regional one, in order to overcome the shortage of land, and then into a global, fossil fuel-driven one, to broaden the range of industries and embrace urbanization.

First, the growth of regional trade was accompanied by a tendency to minimize the use of fossil fuels at the very time of fossil fuel-driven industrialization. Table 6.2 shows changing patterns of composition of fossil fuels and biomass energy in 1952, 1971 and 2008. The share of non-commercial (mainly biomass) energy in total energy consumption in South Korea, China, Thailand, Indonesia and India in 1952 was very high, but sharply declined by 2008. Even so, figures for South Korea and China in 1971 and those for Thailand, Indonesia and India in 2008 show that the use of biomass energy remained substantial during industrialization. In Asia the rate of urbanization at the time of industrialization was generally lower than in Europe, and biomass energy was widely used for heating and cooking purposes at home, as well as in public and commercial buildings. By contrast, domestic consumption of coal was visible in European cities for centuries. By the early twentieth century the share of coal consumption in households and commercial buildings in total coal consumption in Britain, France, Germany and the United States were between 15 per cent and 23 per cent (Clark 1990: 22). Meanwhile, the shares of solid fuel (mostly coal) in total energy consumption in Europe and North America were 78 per cent and 34 per cent respectively, while those of non-commercial (mostly biomass) energy in these regions

Table 6.2 Biomass Energy Supply in Asian Countries, 1952, 1971 and 2008 (kgoe: kg of oil equivalent; toe: tonne of oil equivalent)

	1952				**1971**				**2008**			
	Non-commercial energy supply (1 million toe)	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**	**Non-commercial energy supply (1 million toe)**	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**	**Non-commercial energy supply (1 million toe)**	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**
Japan	9.30	47.74	(19.5)	107.57	0.00	269.57	(0.0)	0.00	17.10	495.55	(3.5)	134.33
South Korea	3.20	4.12	(77.7)	152.76	4.11	16.52	(24.9)	124.99	3.37	226.95	(1.5)	69.58
China	81.67	116.67	(70.0)	143.55	154.24	391.71	(39.4)	183.38	202.60	2,117.48	(9.6)	152.93
Taiwan	1.33	3.08	(43.1)	164.99	0.08	10.08	(0.8)	5.38	1.22	105.50	(1.2)	53.23
Hong Kong	0.20	0.70	(28.1)	92.51	0.05	3.00	(1.7)	12.36	0.06	14.14	(0.4)	8.55
East Asia	95.69	172.30	(55.5)	139.39	158.48	690.88	(22.9)	158.70	224.34	2,959.62	(7.6)	146.59
Malaysia	0.77	2.39	(32.1)	113.61	1.24	5.89	(21.1)	111.00	2.98	73.02	(4.1)	117.91
Thailand	3.30	3.66	(90.2)	155.01	7.60	13.69	(55.5)	198.94	20.09	106.30	(18.9)	306.75
Indonesia	12.04	15.72	(76.6)	141.76	26.34	35.06	(75.1)	219.93	52.27	191.80	(27.3)	229.66
The Philippines	3.48	4.82	(72.1)	154.87	7.44	15.58	(47.8)	187.32	6.92	39.61	(17.5)	72.04
Vietnam	4.54	5.14	(88.3)	173.04	12.48	17.44	(71.6)	286.15	26.07	64.34	(40.5)	259.77
Myanmar	3.02	3.33	(90.7)	150.14	6.36	7.88	(80.7)	227.74	10.43	15.64	(66.7)	218.39
Southeast Asia	27.14	35.05	(77.4)	149.33	61.46	95.54	(64.3)	219.19	118.76	490.71	(24.2)	211.11
India	55.75	81.43	(68.5)	149.87	95.78	181.96	(52.6)	172.89	163.56	619.02	(26.4)	142.47
Pakistan	12.54	15.03	(83.4)	303.33	10.63	17.04	(62.4)	157.50	28.91	82.78	(34.9)	167.30
Sri Lanka (Ceylon)	1.14	1.70	(67.2)	142.92	2.74	3.80	(72.1)	212.91	4.70	8.97	(52.4)	222.44
Bangladesh	n.a.	n.a.	n.a.	n.a.	4.46	5.69	(78.4)	64.43	8.69	27.94	(31.1)	56.60

Table 6.2 Biomass Energy Supply in Asian Countries, 1952, 1971 and 2008 (*continued*)

	1952				1971				2008			
	Non-commercial energy supply (1 million toe)	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**	**Non-commercial energy supply (1 million toe)**	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**	**Non-commercial energy supply (1 million toe)**	**Total supply (1 million toe)**	**Share of non-commercial energy**	**Per capita non-commercial energy supply (kgoe)**
South Asia	69.43	98.17	(70.7)	164.79	113.61	208.49	(54.5)	161.49	205.86	738.71	(27.9)	137.61
Total Asia	192.26	305.52	(62.9)	149.09	333.55	994.91	(33.5)	168.25	548.96	4,189.04	(13.1)	152.96
Total for Non-OECD countries	178.83	298.16	(60.0)	93.18	539.98	1,995.92	(27.1)	187.28	984.34	6,453.99	(15.3)	178.72
Total for OECD countries	78.69	1,417.92	(5.5)	112.63	82.98	3,372.30	(2.5)	93.60	236.58	5,480.77	(4.3)	199.32
World Total	257.53	1,716.08	(15.0)	98.37	622.96	5,532.45	(11.3)	165.25	1,220.93	12,273.86	(9.9)	182.37

Note: Classification of countries/regions for the 1952 UN data differs slightly from the IEA classification. For Vietnam, 1952 entry refers to Indochina (Vietnam, Laos, Cambodia); 1971 to Vietnam and 2008 to Vietnam and Cambodia. For Malaysia, 1952 entry refers to Malaya and Singapore. OECD membership was adjusted based on membership in 2008 in order to allow comparison between years.

Source: 1952 data = UN (1956: 18–20); 1971 and 2008 data = IEA (2011, 2nd edn: 335–40); population and GDP data = Maddison 2009. For total supply for China 1952, see UN (1956: 17). Non-commercial energy supply for China 1952 has been estimated, on the basis of coal consumption trends (see Thomson 2003: 63). Data for non-commercial energy supply for Japan 1971 are not available, but are thought to be very low. Data for non-commercial energy supply for Korea 1971 is from IEA (1989: 112).

were 7 per cent and 4 per cent in 1952 (UN 1956: 18–20. For trends in commercial energy consumption since 1925, see Darmstadter 1971).

Monsoon Asia also had a tendency to choose relatively less energy-intensive industries and energy-saving technology. Despite rapid industrialization and urbanization, the overall energy intensity (measured by total primary energy supply divided by GDP) of the Japanese economy remained low. This reflected both the tradition of (mainly coastal) maritime transport and the post-war policy of developing industrial clusters along the Pacific coast (for the low share of transport sector in Japan, see Schipper and Meyers 1992: 63). In addition, the development of energy-saving technology was actively pursued, especially in the 1950s (Kobori 2010 and this book). The energy intensity of other Asian countries (except for socialist ones) was also low.

Second, however, growth Asia began to import a massive amount of resources and energy from outside the region. In the 1950s and the 1960s this was not so visible, as the price of oil stayed low, but since the oil crises in the 1970s Japan became a major absorber of oil at high prices, especially from the Middle East (Sugihara 2008). In the 1990s NIEs were responsible for importing a large amount of oil, and this was followed by China, Southeast Asia and South Asia from the 2000s onwards. Today Asia is collectively the largest net importer of oil (though the United States is the largest single consumer), not only because of an increased demand from industrial and commercial transport sectors but also from a rapid increase of demand from household, residential and passenger transport sectors.

Growth Asia used its export earnings to import fossil fuels and minerals. The region went through the 'energy transition' (World Bank 1983),[7] and its economy became largely fossil fuel-driven. This eased regional resource constraints on a scale unimaginable pre-war, and the rapid improvement of transport facilities across Asia accelerated intra-Asian resource transfer as well as imports from outside. The availability of fossil fuels and mineral resources at competitive prices enabled (initially East) Asia's labour-intensive and relatively less resource-intensive development path to incorporate urbanization, modern infrastructure and a large part of capital-intensive industries into its structure.

Third, the dynamic relationship between the growth of intra-Asian trade and industrialization (until relatively recently mostly labour-intensive industrialization) continued, and Asia as an economically coherent region interacted with a broader trend of globalization. Under the US hegemony the commodity composition of intra-Asian trade became increasingly industrialization-driven, first among a small number of countries under the regime of free trade, and gradually embracing others (think of the 'Asian textile complex' in the 1970s in which Japan produced rayon [yarn], Taiwan wove it and Hong Kong made it an apparel and exported it to the United States. Arpan et al. 1984: 112–17, 136–49, 159). New 'culture-neutral' intermediate goods included cheap plastics, man-made fibres, machine parts and

[7] The same word is used today to refer to the transition from the fossil-fuel regime to the renewable one.

eventually microchips, which served diverse cultural needs. Again, we do not see such a dynamic relationship in Africa, the Middle East or Latin America in this period. South Africa and Brazil proceeded with industrialization without accompanying regional integration. It is only in Asia that economic nationalism has embraced regional integration. This trend continues to this day, most recently in the shape of the ASEAN Economic Community.

This chapter is concerned with how such a distinctive feature has emerged in monsoon Asia. The key concept is intra-regional trade, as distinct from both local and intercontinental trade. It originally created a regional division of labour between a commercial agricultural region and a proto-industrial region in the nineteenth century, and contributed to a gradual shift in the character of Asian economies from agricultural to industrial, from rural to urban and from continental to maritime. The changes often meant changes in competitive locations, reflecting the changes in the relative share of GDP in various parts of Asia, for example, from China and India to Japan and Southeast Asia between 1820 and 1980, and then from the latter to the former after 1980. The structural transformation took place, not within a country or sub-region but on a regional scale. This made it easier for populous Asia to adjust to the rapid change in the comparative advantage of the region in the world economy.

The main carrier of this regional flexibility has been the merchant network, rather than the modern organization with the head office and a visible (Chandlerenian) structure, and both types of carriers of trade remain important to this day. Intra-regional trade transcended social and cultural boundaries through Asian merchant networks, and exploited different cultural and social value systems for commercial gain. Merchant networks did not involve state monopolies such as European East India Companies, a product of mercantilism, but were often responsible for the state formation in port cities and their hinterlands, which in turn provided institutional foundations for these networks. Where the power of the state was weak, merchant networks themselves organized schools, hospitals and social functions, to facilitate personal networks and information flows. Today they exist in the forms of overseas Chinese business associations in Southeast Asia, for example.

Heavy and chemical industries (producing steel, machinery, petro-chemical products) were more capital- and resource-intensive than traditional 'light' industries, and were able to raise labour productivity more rapidly. But it was usually more difficult to relocate. In Asia, an industrial complex was successively created along the Pacific coast (first in Japan and NIEs, then gradually in Southeast Asia and China), and by now along the coast of the India Ocean to a certain extent, which combined relatively cheap labour with imported oil. Since the initial high growth economies, Japan and NIEs, were resource-poor, their energy transition to a fossil fuel-driven economy was also accompanied by the diffusion of a variety of resource- and energy-saving technology and institutions. Equally important, labour-intensive industries were not abandoned, but were either relocated to other parts of Asia or were upgraded with the latest technology. Thus employment was retained, while the standard of living in the core parts of the region rose substantially.

The evolution of a new factor endowment framework

At the same time, while food and fossil fuels could be imported relatively easily, the resulting growth put less tradable factors of production under strong pressure. Water, which had been a crucial factor of production and livelihood security in monsoon Asia, became scarce, and emerged as a focal point of politics in local, national and regional contexts (Pomeranz 2009, and this book). Parts of China (e.g. the Yellow River area) were affected by water scarcity, which restricted the area's options for development, even if it had good-quality labour and a government with the will to industrialize. In hinterland China electricity provision depended on the construction of large dams, which in turn further qualified water use and the conservation of the eco-system. Transportation of imported goods to the hinterland, especially if it was far from river transport, added additional costs, and building an infrastructure was more costly and often more energy intensive than in coastal regions. If we compare those regions with the 'East Asian path' regions, which typically followed labour-intensive industrialization, including coastal China in addition to Japan and NIEs, differences in local resource constraints, and the degree of difficulties to overcome them, largely account for different outcomes.[8]

Asia's food security has been largely met by the development of new, high-input agricultural technology of rice, wheat and other commercial crops. In addition to the seed technology (the core of the green revolution in Asia), this meant the development of water-intensive agriculture. The exploitation of water resources (and electricity generation to accompany it) became a frontline of the sustainability of economic growth. At the same time, local livelihood had to be sustained through the continued use of biomass energy, until modern infrastructure and household equipment (such as the refrigerator) were fully introduced. Flexible mobilization of these resources required attention to the sustainability of the local environment, including the understanding of the local trade-off between water, food and energy. When attention to such a 'nexus' was not forthcoming, livelihood was threatened with severe environmental and social consequences.

The new salience on local resource constraints would in theory happen to any emerging economy beginning to engage successfully in international trade, but the constraints were particularly severely felt in growth Asia, as the very high speed of growth itself was unprecedented, and the size of the population unusually large.

Fossil energy moves almost as globally as capital, while water for agricultural and industrial use is almost as locally rooted as land. Labour as a factor endowment might be located between these two extremes. It moves between the core regions and the periphery more easily than water, but not as globally, culture-neutrally and cross-occupationally as fossil fuels do. Bringing in water and energy, that is, considering a

[8] Since I began to use the term 'East Asian path', Pomeranz repeatedly commented that a large part of China was historically not on that path. This chapter is a belated response to his comment, but mainly with the difference between coastal and inland areas within monsoon Asia in mind. China's large semi-arid areas, especially in the northwest, are outside monsoon Asia, but may be considered as part of inland areas in this context. See Sugihara (2000, 2003) and Pomeranz (2001).

new framework of factor endowments, illustrates the significance of coordinating the procurement of both tradable and non-tradable goods.

Although neither energy nor water has featured largely in Ricardian and later theories of factors of production, 'water-intensive crops' and 'energy-saving technology' were critical actors for determining the region's technological path. If we treat the five factor endowments of capital, land, labour, water and energy as having the same weight, the distinction between capital-intensive and labour-intensive development paths might become part of a larger set of development paths across time and space, which various regions of the world had historically followed. In fact, until the early modern period, (biomass) energy was rather less tradable and transportable than labour. The massive use of fossil energy enlarged the portfolio of factor endowments, and radically redefined the comparative advantage of each environmental region.

Oshima's formulation on monsoon Asia's path did not pay serious attention to the possibility that labour-intensive industrialization could cause environmental degradation and threat to resource and livelihood security through such changes. Indeed many growth regions in maritime monsoon Asia to c.1980 (e.g. the Pacific coast of Japan) were better endowed with water and biomass than inland monsoon Asia, although the former regions were characteristically disaster-prone.

However, the transformation of coastal and maritime regions was not a full story. In Indian agriculture, water management was closely linked to land use, and its influence was so large that water, rather than land, often determined the direction of technological and institutional development, especially in South India, home of tank irrigation and one of the frontrunners of tube well capitalism. This may be called a 'water-intensive path of agricultural development'. Today, the use of tube wells is affecting the water table, pretty much all over India. At the same time, as soon as water (for agricultural use) became a scarce commodity (and acquired a price), drip and sprinkler irrigation, semi-capital-intensive but also skill-intensive technology, began to diffuse, reflecting the long tradition of tank irrigation management. Sources of agricultural technology development were strongly correlated to the use of water. The diffusion of tube well capitalism (Dubash 2002) was a major accompanying force behind the green revolution, which promoted the diversification of agriculture into a range of more water-intensive, land-intensive and labour-intensive crops (Shar 2009: esp. 44–50). India has achieved self-sufficiency of food as a result. Lowering of the water table suggests that this path is unsustainable, but it was a decisive determinant of India's 'take off' in the 1990s.

The water-intensive path has been supported by the policy of free electricity for farmers distorting resource allocation and putting further pressure on the Electricity Supply Board, which struggles for the improvement of its poor performance (Fukami 2009).

If Japan's industrious revolution prepared her response to the Western impact in the form of labour-intensive industrialization, its post-war high growth was a result of a fusion between the Western path and the labour-intensive path. India suffered from poor agricultural productivity, especially since the late nineteenth century when land became scarce (Roy 2007). A major reason for the poor quality of land was water shortages. To take the example of South India, there was a century-long trend of successive deterioration of water availability, and a succession of efforts to create a water-intensive path, through tank irrigation, then diffusion of commercial crops and finally through abandonment of the tank and dependence upon electrically operated deep tube wells (Sato 2016).[9] The core technological and institutional competence was not so much an improvement of the quality of labour as an ability to overcome local, non-tradable, resource scarcity of an overwhelming magnitude.[10] The South Asian path sustained a large population, comparable to East Asia's, as a result.

Meanwhile, the livelihood nexus could be slowly threatened, as a result of deforestation for example. A village survey of 560 households conducted in 1981 in Karnataka state revealed that 88 per cent of energy was used for domestic purposes (others included for industry, agriculture, lighting and transport) and its supply consisted of firewood (82 per cent), human energy (7.7 per cent, of which 3.1 per cent by men, 3.8 per cent by women and 0.8 per cent by children), animal energy (3 per cent), kerosene (2 per cent) and electricity (1 per cent), among others. Most human energy was spent not so much in economically productive activity such as agriculture, but in survival tasks like fetching water and gathering firewood, most of which have been rendered unnecessary in urban areas. As far as this village is concerned, 'increasing deforestation implies walking longer distances to collect firewood for cooking fuel – distances which are walked by human beings, and usually by women and children' (Batliwala 2012: 342–3, quotation from 342).[11]

Another study confirms that this picture was not uncommon in other parts of India. High oil prices, and the environmental movements, which effectively stopped the construction of large dams and reduced the speed of deforestation, narrowed the options. Local biofuel stations using newly-planted fast-growing trees in waste land were recommended (Ravindranath and Hall 1995: 140–209).

A larger, more recent survey of 15,293 households from 148 villages in four states (Uttar Pradesh, Rajasthan, Himachal Pradesh and Tamil Nadu), published in 2005, detailed the drain on human resources due to cooking fuels. Ninety-six per cent of households used biofuels, mostly fuelwood and dungcake, 11 per cent used kerosene and 5 per cent used LPG for cooking. That is, many households used multiple fuels. They consumed about 314 million tonnes of biofuels a year for cooking. These biofuels were mostly procured through gathering. In a year about 352 hours were spent per household on gathering of biofuels.[12] Eighty-five million households are estimated to

[9] For a discussion on water-intensive agriculture in other regions, the relationship with animal power through the limits of land on pasture, and the 'carrying capacity', a concept developed especially in the 1920s, see Roy's chapter, this book.

[10] The issue of water is not necessarily centred on the amount of water needed for production or for human use. Annual and seasonal variability could make the *timing* of water availability a critical element. Also, water variously contributes to drought, floods or spread of infectious diseases. The essence of the water-intensive path lies in the persistent technological and institutional attention to water as an independent factor endowment, not just as a determinant of the quality of land.

[11] For a broad Third World perspective, see Agarwal (1986).

[12] If we divide the number of individual health records (direct and proxy) by the number of households, an average size of the household was 5.3, that of each state ranging from 4.4 to 6.

have spent 30 billion hours on gathering 314 million tonnes of biofuels per annum. In addition, the rural people had to spend a substantial number of days collecting drinking water (Parikh, Parikh and Laxmi 2005: 85, 87).

In sum, globalization mitigated some of the resource constraints through trade and technology transfer, but created new local resource scarcities and threatened livelihood security by weakening the water-food-energy nexus on which the local people had been dependent. On the one hand, globalization achieved a degree of convergence towards factor prices of capital and certain commodities such as fossil fuels. Labour also became somewhat uniformly measurable in terms of wages and quality (education) in developed and emerging countries. Meanwhile, the fate of less resource-endowed areas was determined not so much by the ability to earn foreign exchange as by the capacity to address the more pressing issues of livelihood security. In rural areas, the availability of drinking water and (biomass) energy underpinned the quality of the standard of living, while securing basic needs such as water and electricity, internationally competitive education and health institutions, and a less polluted and disaster-resilient environment would determine the liveability of the cities. In this way the competitive factor-endowment frontier has shifted from the availability of capital and the quantity and quality of labour to the quality of local resource and livelihood security regimes.

Asia's resource regimes and global environmental sustainability

Prior to the two oil crises of the 1970s, heavy and chemical industrialization, with military industry leading the energy-intensive technology, made the level of energy intensity of leading powers (the United States and the Soviet Union) very high, while the global level of energy consumption was ameliorated by many countries following the labour-intensive path. However, there was a remarkable convergence after the 1970s, through the reduction of energy intensity of the United States and Western Europe, as well as of China, and eventually of the (former) Soviet Union. The traditional distinction between capital-intensive industrialization and labour-intensive industrialization became skewed to some extent, as the focus on energy-saving technology began to dictate the direction of global technological innovation. By now resource transfers through trade have become the main vehicle of global economic development, and global prices of fossil fuels have substantially converged.

It is therefore possible to suggest that a global development path dictated by factor endowment considerations has emerged for the first time in history (see Figure 6.2). Looking back from some time in the future, the last two centuries of the energy-intensive development path might eventually be seen as a great divergence from the more balanced, environmentally sustainable path.

However, it is this energy-intensive path that caused an unchecked increase of the use of fossil fuels. The best known linkage to climate change is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by the increase of aerosols (particulate matter in the atmosphere), leading to global warming. There are

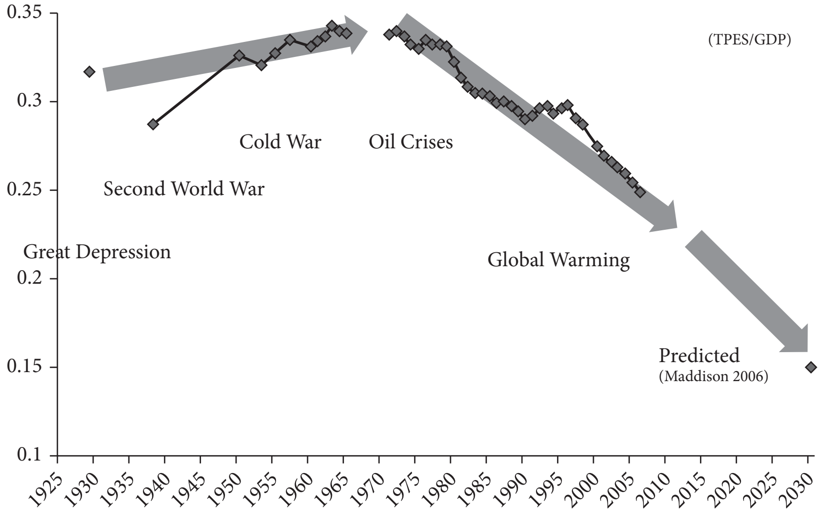

Figure 6.2 World energy intensity, 1925–2030.

Source and Notes: TPES: Darmstadter (1971), International Energy Agency, Energy Balance of OECD Countries; Do., Energy Balance of Non-OECD Countries; GDP: Maddison (2009). Energy efficiency refers to total primary energy supply in oil equivalent per GDP. Until about 1990 TPES data did not include non-commercial energy (traditional biomass).

many other linkages that suggest human-activity-induced climate changes, some of which are thought to be irreversible. Other environmental damages such as loss of biodiversity, deforestation and air and water pollution are thought to be serious. Today these issues are being raised and addressed to some extent. The development of clean energy and the lesser use of carbon are being attempted.

From our point of view, these recently accelerated processes can be seen as part of a long-term impact of, and response to, fossil fuel-driven industrialization, which started in the industrial revolution in England. In global economic history, therefore, the term Anthropocene should be associated with the two centuries of global industrialization, even though Asia's story is largely compressed into the second half of the twentieth century.[13]

This chapter explored the impact of fossil fuel-driven industrialization on the longer-term development paths in Asia. It has several implications for understanding the history of global environmental sustainability.

Globalization under the regime of free trade favoured countries and regions capable of combining tradable resources, such as fossil fuels, with local non-tradable ones, and highlighted the diversity of local resource constraints as a major determinant of comparative advantage. Globalization also threatened the livelihood security of the ordinary people, by penetrating into the hinterland where the water-food-energy

[13] For a fuller discussion on the definition of the Anthropocene, see Introduction of this book.

nexus could easily be broken by a shift to the fossil energy-based way of life, and leaving the fulfilment of essential daily needs subject to the wild price fluctuations of oil and other commercial energy.

At the same time, the study of Asia's long-term development paths offers an insight into the potentiality of creating the dynamics between geography, trade and population. In particular, it highlights the importance of the multi-layered and multilateral development of local, regional and intercontinental trade as a mechanism of easing local resource constraints and securing livelihood. But trade's contribution to factor endowment adjustments has its own limits. A more general observation is that Asia's population-holding capacity has been sustained by exploiting the possibilities that different combinations between tradable and non-tradable resources create at local, regional and global levels.

In order to establish the global condition for long-term economic development, we need to go beyond the classical framework of factors of production of land, labour and capital, to discuss all relevant factor endowments and their potential combinations that could sustain production and livelihood in environmentally diverse regions of the world.

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7

Forests and a New Energy Economy in Nineteenth-Century South India

Prasannan Parthasarathi

The study of forests in nineteenth-century South India is not a new subject. However, this chapter, which focuses on the areas that make up the modern state of Tamil Nadu, seeks to take it in two new directions. First, the chapter moves out of the hills and mountains and into the plains. The extensive tracts of hardwood forest in the Western Ghats and Nilgiris of South India are famous and have been studied by a number of historians, but the woodlands of the plains, which were cut down in the nineteenth century and then forgotten, have been neglected. Second, it will bring the perspective of energy to questions of forests in South India. The demand for wood as fuel is rarely discussed, but the rise of a new energy economy from the second quarter of the nineteenth century was critical in the denuding of these forests.

Historians of South India's forests have focused on the hills because they contained valuable stands of teak and sandalwood, which gave them enormous commercial importance. Teak, in particular, received much attention from the East India Company authorities in the eighteenth and nineteenth centuries as it was demanded for shipbuilding and then later railway ties.[1] By focusing only on the hills, however, historians have overlooked the extensive wooded areas of the plains, which from the standpoint of the British did not contain timber of commercial importance but nonetheless provided indispensable resources for both urban and rural dwellers in the region.[2] The neglect of the forests of the plains may also be due to the fact that many of these woodlands disappeared completely within the span of a few decades. As a result, they have been erased from historical memory. The trees that made up these woodlands were chopped down in the nineteenth century, perhaps in less dramatic fashion than those of the hills, and by the twentieth century there was little sign that these tracts of forest had once existed. The primary purpose of this chapter is to look at the plains and to begin to trace their transformation. Much of the evidence is drawn

[1] See, for example, Buchy (1998).

[2] For an important exception, see Murali (1995).

from three areas: Udaiyarpalayam, a taluk[3] in what was Trichinopoly District; the region around Pulicat Lake, north of the city of Madras; and the coastal strip that lay between Madras and Pondicherry. The deforestation that occurred in these three places is representative of broad changes that reshaped the plains as a whole in what is today the state of Tamil Nadu. (Figure 7.1).

Deforestation in nineteenth-century South India is attributed in most accounts to either the commercialization of timber and wood or the expansion of arable farming. The tension between forests and cultivated areas is one of the great themes in the history of forests in India. In his global survey of deforestation from prehistory to the present, Michael Williams writes, 'In mainland India it was the increase in the area of cultivation … which more than anything else caused the destruction of the forests' (Williams 2003: 355). Nineteenth-century commentators in South India came to the same conclusion. In 1861, Hugh Cleghorn wrote that the denuding of the Western Ghats was due to 'the axe of the coffee planter and of the kumari [shifting] cultivator … devastating a large portion of the … primeval forest' (Cleghorn 1861: 2). Similarly, in the early twentieth century, S. Cox, the conservator of forests in Madras, wrote:

> During the early years of British occupation the Government, following the practice of native rulers, encouraged by every means in its power the increase of cultivation at the expense of the forests, with the result that the boundaries of the latter were gradually pushed back towards the hills and mountains, to which they are now almost entirely confined. (Cox 1914–15: 717)

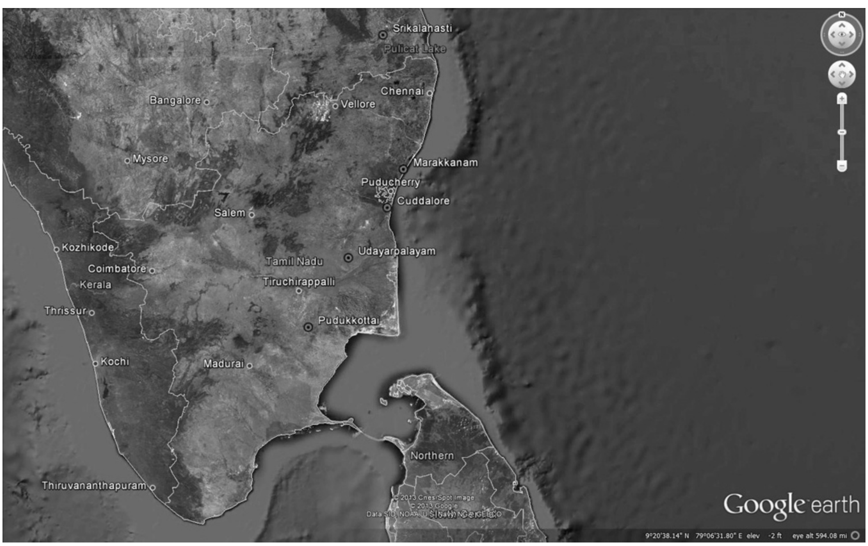

Figure 7.1 Tamil Nadu.

[3] An administrative division of a district.

The second frequently invoked factor in deforestation, the commercialization of timber and wood, was the product of new sources of demand in the nineteenth century. The expansion of shipbuilding, which began in the eighteenth century itself, increased the demand for teak from the forests of the Western Ghats. These same forests came under pressure from the mid-nineteenth century when the building of the railways created an enormous market in sleepers which in South India were made from teak. These two activities, shipbuilding and the railways, are often taken to be the decisive commercial activities that decimated the wooded areas of South India, as well as elsewhere in the subcontinent.[4]

To these two, this chapter adds a third development, the rise of a new energy economy, which was especially significant for the deforestation of the plains of Tamil Nadu. This new energy economy was a product of, first, the growth of new heat-intensive exports, the most important of which were iron and sugar. Both the smelting of iron ore and the boiling of cane juice demanded substantial quantities of wood fuel. Second, the rise and growth of the city of Madras and the construction methods used by the British created enormous demand for wood, which was drawn from the plains forests. The final element of the new energy economy was the coming of steam-based technologies to South India. Since these engines were driven by an organic fuel, wood, not by a mineral, coal, as was the case in Britain and elsewhere, their operation put enormous pressure on the woodlands of the plains. I call this phenomenon bio-steam power.

Before I get into the details of this new energy economy, I must first describe the forested areas in the plains of Tamil Nadu. The ecology of the Tamil state is conventionally divided into wet and dry areas. The wet areas were zones of rice cultivation and these were concentrated in the river valleys, ranging from the Palar to the Cauvery, Vaigai and Tambraparni, going from north to south. These valleys contained woodlands, but they tended to be on a limited scale. The dry areas, or plains, lay between the rivers and in the early nineteenth century were home to several extensive tracts of forest. Limited rainfall meant forests were not found in the plains of Tinnevelly, which lay in the deep south, and in the neighbouring region of Ramnad, but these were exceptions to the general rule. Elsewhere, the plains of Tamil Nadu contained either dense forests with little arable land or thick wooded areas which contained only pockets of cultivation. I am now working to reconstruct the species of trees that made up these forests, but they would have been far different from the large, hardwood trees that covered hill areas in the early nineteenth century. Nevertheless, these forests of the plains yielded a variety of woods that met a variety of needs.

Some sense of what these plains forests looked like may be gotten from maps and descriptions from the early nineteenth century of Udaiyarpalayam, which at that time was a taluk in the Trichinopoly District. Udaiyarpalayam lay immediately to the north of the Cauvery Delta, the major centre of rice cultivation in Tamil Nadu. While the area immediately to its south was a dense carpet of rice fields, in the early nineteenth century the most striking feature of Udaiyarpalayam was its forests, according to

[4] See, for example, Gadgil and Guha (1992: 118–23).

several reports. A survey of the area from the early nineteenth century found that the taluk encompassed 543 square miles, 435 of which were 'overrun by impenetrable thorny jungle intersected by roads and paths communicating with the villages which are numerous and scattered all over the country'. 'In short', the survey concluded, 'the whole country appears to be one impenetrable jungle, saving small cultivated tracts round each village. The country in every direction is intersected by good roads, all meeting at the capital and the jungle on each side so thick, it usual be [*sic*] impossible to go off it for a short distance'.[5]

The above description is confirmed by early-nineteenth-century maps. Figure 7.2 shows the town of Udaiyarpalayam and its environs from a map drawn around 1815. The most heavily forested areas have been circled in green to highlight the major concentrations of trees at that time. I should note that woodlands were also found in between the circled areas, but more interspersed with fields and small hamlets. Figure 7.3 shows the same areas in the vicinity of Udaiyarpalayam today. (This image is from Google Earth.) A comparison of Figures 7.2 and 7.3 makes evident the transformation in the landscape and is illustrative of the dramatic decline in forests in the plains of South India. It should be noted that Udaiyarpalayam was some distance from the Western Ghats and other hill areas in Tamil Nadu.

The forests of Udaiyarpalayam were by no means exceptional. An early-nineteenth-century survey of Pudukkottai reports that the kingdom 'abounds with woods and jungles' which were estimated to comprise a third of the kingdom. One

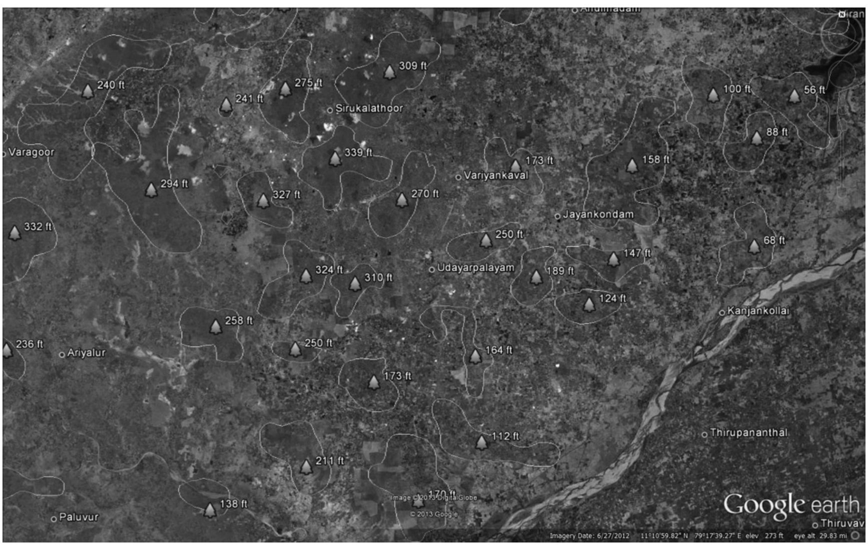

Figure 7.2 Udiayarpalayam, around 1815.

[5] B. S. Ward, 'Descriptive Memoirs and Registers of Villages of Trichinopoly': 'Udayarpolliam Talook', IOR X/2537, p. 1, British Library (hereafter BL).

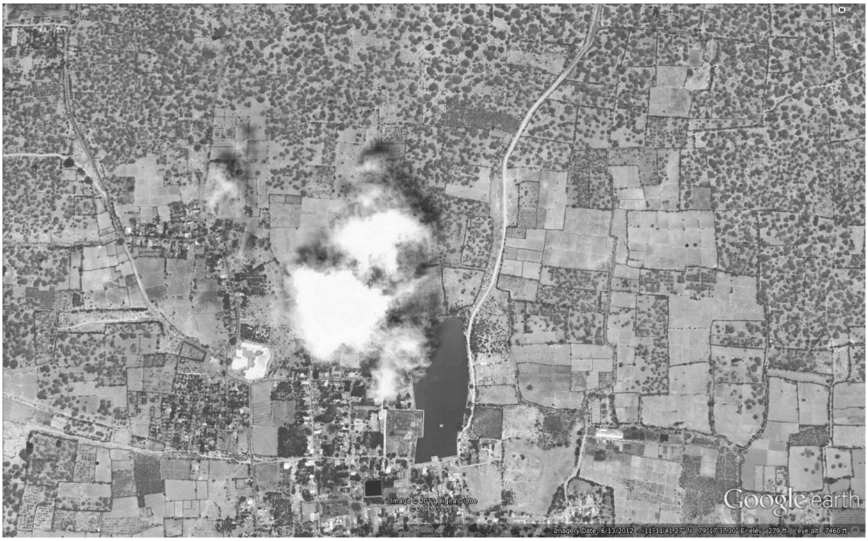

Figure 7.3 Udiayarpalayam, around 2014.

tract of forest extended from the town of Pudukkottai to the eastern limits of the kingdom and encompassed an area of 170 square miles. This area did not contain valuable timber, but supplied wood to inhabitants both near and far for construction, tools and fuel. These woods were also populated by several varieties of deer, hogs, porcupines, civet cats, jackals and wild cattle 'of the buffalo kind of an enormous size which are very ferocious'. This was just one of the dozen jungly zones enumerated in Pudukkottai, the total area of which came to 530 square miles. (For comparison, modern Pudukkottai district, which is larger than the early-nineteenth-century kingdom, comprises some 1,800 square miles.) One of these jungles, whose location is not specified, was reported to be much diminished because it had supplied sizeable quantities of wood to the town of Trichinopoly. This indicates that some amount of deforestation had taken place in the decades and centuries before 1800.[6]

I spent a lot of time in Pudukkottai as a child in the 1960s and 1970s – my mother was from there and I often visited my grandparents. And I can promise you that there were no forests and certainly no abundance of wild animals by then. In fact, you could hardly see a single tree. I should also note that heating water and cooking was all done with firewood, but that wood was likely to have been obtained from casuarina plantations that were established in Pudukkottai after the forests were cut down.

To return to Udaiyarpalayam, the forests in that area were chopped down in the nineteenth century, beginning in the late 1820s when wood began to be cut on a large

[6] 'Statistic and Geographical Memoir of Maravar or Ramnad, the Isle of Ramiseram and Tondiman's Country Surveyed in 1814', IOR X/2433, pp. 240–1, BL.

scale to supply charcoal to the newly established Porto Novo Iron Works. The Porto Novo Works, in contrast to pre-nineteenth-century iron furnaces, was located on the coast rather than in the hill areas where supplies of iron and especially fuel were more abundant. The iron ore (or more accurately iron sand) for the Porto Novo Works was obtained in Salem and sailed down the Cauvery and its branches to Porto Novo. The wood for the charcoal was obtained in Udaiyarpalayam and the Works received an exclusive privilege from the Madras Council to cut trees there.[7]

The iron that the Porto Novo Iron Works produced was exported. The quality was exceptionally high: experts at the Woolwich Arsenal in London declared it to be the equal of the best Swedish iron. However, it was unable to compete against the cheap coal-smelted pig iron imported from Britain and was thus unable to supply local markets. While South India had long been a major exporter of manufactured goods, the export of iron was a departure from the textiles that dominated the external trade of the region for many centuries. While textile finishing required some heat for the bleaching and dyeing of the cloth, it was nothing compared to what was required for iron smelting. From the 1820s, then, South India began to export a new energy-intensive product. (It should be noted that South India had previously exported high-quality steel, much of it most likely manufactured in the Golconda region, but in small quantities.) The Porto Novo Iron Works, then, represented two new developments: the location of an energy-intensive activity on the coast, as opposed to the hills, and the export of an energy-intensive good.

From the 1840s the forests of Udaiyarpalayam, as well as other nearby areas, came under pressure from another direction. After the decline of the West Indian sugar economy, which followed the abolition of slavery, Britain removed tariffs on Indian sugar and there was a boom in imports of that product. In the mid-1840s sugar from Asia, excluding China, accounted for more than a quarter of British consumption (Davis 1979: 122). To meet this demand cane cultivation was expanded in several regions of British India, including parts of Tamil Nadu. To process that cane several modern sugar mills were established in the town of Cuddalore, which lay on the coast just to the north of Porto Novo, approximately sixty miles to the northeast of Udaiyarpalayam. The most prominent were those of Parry & Co., which established two mills in the early 1840s, but others also went into the sugar business in that period (Brown 1955: 82–6, 201–2; Ramaswami and Muthiah 1988: 60–2).

The mills needed fuel to boil the cane juice and for this they turned to Udaiyarpalayam, where they were able to obtain wood when demand from the Porto Novo Iron Works was low. They faced this restriction because the iron works was awarded an exclusive privilege to cut in those forests. When the fuel demand of the iron works was high, the sugar manufacturers had to turn to other sources. The most important of these lay to the north of Cuddalore, including Marakannam, which is situated near the coast along the route to Madras. In the early nineteenth century this area contained thick forests, which lay close to the water, and wood could be loaded

[7] The information on the Porto Novo Iron Works is drawn from the account given in Parthasarathi (2011: 234–9).

onto boats for quick and easy transport to Cuddalore. This area also supplied firewood to Madras, which I will turn to shortly.[8]

As a consequence of this cutting, by the end of the nineteenth century the area of these forests had declined dramatically. In 1839, even before the construction of sugar mills, the inhabitants of Udaiyarpalayam expressed concerns about the fuel demands of the Porto Novo Iron Works, which they feared would leave them without wood.[9] These fears were not unfounded. By the 1870s, according to Lewis Moore, the wooded areas of Udaiyarpalayam had shrunk (Moore 1878: 26). In 1882 Dietrich Brandis reported that the demand for fuel from sugar boilers had 'denuded' parts of South Arcot, the district in which Cuddalore lay. Brandis also reported that sugar boiling had expanded into other parts of South India, including in North Arcot in the northern part of the Tamil state, where they had the same impact on the landscape. Brandis also noted that the trade in fuel, which could be obtained at no cost except those for cutting and transport, had not benefited poor ryots, but Chetties (merchants) and sugar proprietors, thus worsening inequality, which was an important impact of the deforestation of the plains in South India (Brandis 1883: 34).

The sugar mills of Cuddalore and the iron works of Porto Novo were not the only new sources of demand for energy on the coast of South India from the early nineteenth century. A third was the city of Madras, which became a major market for wood. The provisioning of Madras with fuel had environmental repercussions in the ever-expanding area from which the city drew its supplies. The wood trade to Madras appears to have been a continuation of an older trade of wood to urban areas in South India, but it was also a departure in terms of its environmental impact because of its sheer scale, which stemmed from the use to which this wood was put. The trade in wood to Madras then represents the second element in the new energy economy of the nineteenth century.

A report written in 1815 on the wood and timber trade to Tanjore gives us a glimpse of how this important commerce was organized in South India before the nineteenth century.[10] Tanjore was a deltaic area and it was criss-crossed by irrigation canals as well as branches of the Cauvery River. It possessed nothing resembling a forest, save in two places. One lay on the coast at the mouth of Coleroon River and the other was a wooded preserve for the Raja of Tanjore's hunting. Very few ventured into the former for fear of the tigers which infested the area and the entrance to the latter was restricted to the king and his court. Because of its limited forest land, Tanjore relied upon the timber of trees that were grown locally for the fruit they bore as well as imports of wood from outside the region. Different types of wood, for different purposes, were supplied from near and far.

According to the 1815 report, the better sort of houses in Tanjore was generally built of the wood of the jack, mango, neem, portia and Indian gooseberry trees. The

8 Proceedings of the Board of Revenue, 1846, vol. 2034, p. 10491, Tamil Nadu State Archives (hereafter TNSA).

9 Proceedings of the Board of Revenue, 1840, vol. 1691, p. 764, TNSA.

10 Tanjore Collectorate Records, vol. 3276, pp. 90–5, TNSA.

doors were made of mango and jack woods, some of which were grown in the district and some imported. Common houses were constructed with the wood of coconut palms and bamboo, both of which grew in the district. The tools of artisans were made of hard tamarind and orange wood, and again some of this grew in the district and some was imported. Weavers' looms used a harder wood, known in Tamil as *pila* or baby jackfruit, which was obtained in the Udaiyarpalayam jungle and was freely available to the weavers of Tanjore. Furniture was made of jack, jujube, neem and portia, which were all products of the district. A striking feature of this list is the number of trees which were grown for the products they yielded, whether fruits (jack, mango, gooseberry, jujube, tamarind, orange, coconut) or flowers, seeds and twigs (neem). The trees were cut down for their timber when they reached the end of their useful lives.

Missing in the 1815 report on Tanjore is any mention of firewood, but we know from a later source, a letter from the Collector of Trichinopoly written in 1839, that Udaiyarpalayam and its neighbouring taluk to the west, Arialore, supplied wood for fuel to the towns of Kumbakonam as well as other places in Tanjore.[11] Four decades later, the *Manual of the Trichinopoly District* reports that Udaiyarpalayam continued to be the source of fuel for the town of Kumbakonam as well as villages in Tanjore district (Moore 1878: 26).

In the case of nineteenth-century Madras, we face the opposite problem. We have a great deal of information on the firewood trade but very little on the trade in wood for other purposes, although this changes from the late-nineteenth century when substantial supplies of teak and other hardwoods from Burma, Siam, the Straits Settlement and Java became widely available. For its fuel needs, nineteenth-century Madras obtained enormous quantities of wood from a large and expanding area. Chingleput, which lay immediately to the west of the city, was likely to have been an early source, given its proximity. The detailed surveys that Thomas Barnard conducted of that district in the late 1760s reveal that about a sixth of the land area was forested.[12] This was to change rapidly and in a letter written in 1853, the collector of Chingleput reported that 'the jungles in the … District have of late considerably declined' and that 'no parts … are so densely covered with Jungles as to form … a sufficient source of supply for the consumption of Madras'.[13]

By the 1850s the impact of wood demand in Madras was felt in more distant places. In North Arcot, which lay to the west of Chingleput, the collector wrote in 1853 that 'firewood is sent to Madras from nine different jungles from the District', but these forests, which had provided wood to Madras for ten to fifteen years, were now 'nearly exhausted and consequently will not supply fuel for any further considerable period'.[14] The proprietors of some forests in North Arcot, fearing the destructive impacts of the demand from Madras, declined to supply wood to the

[11] Proceedings of the Board of Revenue, 1840, vol. 1691, p. 765, TNSA.

[12] Bajaj and Srinivas, 'Indian Economy and Polity in the Eighteenth Century: The Chengelpattu Survey: 1767–74'.

[13] Proceedings of the Board of Revenue, 1853, vol. 2361, pp. 2052–5, TNSA.

[14] Proceedings of the Board of Revenue, 1853, vol. 2392, pp. 13125–6, TNSA.

city. The Cavetunygur [Karvetinagar] Zamindar was one such individual and his zamindary contained an extensive forest of a hundred square miles, known as the Marecondah jungle. This tract was about sixty or seventy miles from Madras and it yielded the zamindar an annual revenue of about 2,000 rupees from tamarinds, gallnuts, honey, dyes, wax and other products. The forest also supplied resources that his tenants required for agriculture, including fodder, manure and wood for the manufacture of tools. The collector wrote that the zamindar was unwilling to 'allow any wood to be cut from this jungle for the purpose of exportation'.[15]

In the nineteenth century Madras also drew wood from two areas along the coast. One was to the north of the city in the vicinity of Pulicat Lake and the other was to the south on the route to Pondicherry where, as we have seen, an extensive tract of forest ran parallel to the Bay of Bengal near the shoreline. The latter area supplied wood to the sugar mills of Cuddalore, and also began to send wood to Madras. The proximity of both these areas to the Bay of Bengal meant that the costs of transport were low since the wood was loaded onto boats that plied the coast. To further facilitate the carriage of wood from points north of the city, a waterway, Cochrane's Canal, was dug to link Pulicat Lake to Madras. This canal was later extended south of the city and renamed the Buckingham Canal.

In the first several decades of the nineteenth century considerable cutting of wood took place in the Pulicat Lake area, specifically at Sriharikota, a barrier island that lies between the lake and the Bay of Bengal. In the early nineteenth century this area was covered with trees, but these numbers were considerably reduced within a few decades. By the late 1850s, according to Hugh Cleghorn, shortages of firewood in Madras had led to 'stunted trees, underground roots and stems, running along the loose sand' being pulled up for shipment as fuel to Madras. Cleghorn feared that if this was allowed to continue the land would be turned into a desert and the 'dry and loose sand be drifted into [Cochrane's] canal, and overspread the adjacent country' (Cleghorn 1861: 146). Nevertheless, Sriharikota and other areas to the north of Madras continued to supply the city with fuel for many decades, which is evident from data on the quantity of wood carried on the Buckingham Canal, the successor to Cochrane's Canal. Between 1888–9 and 1896–7 an average of 70,000 tons of firewood were transported to Madras every year via that waterway (Russell 1898: 85–6). (This, of course, was not the only source of fuel for the city at that time.) The largest firewood as well as timber market in the city is still today located in the Basin Bridge section of North Madras, which was the major disembarkation point for the goods carried on the Cochrane and later Buckingham Canal.

Why was so much firewood demanded in nineteenth-century Madras? Some quantity of fuel was needed for household needs, much of it for cooking and perhaps some for bathing, but the latter would have been minimal in the tropical climate of coastal Tamil Nadu. In the closing decades of the century wood was needed for the growing industrial sector of the city, which is taken up below, but even before the establishment of these modern workshops substantial supplies of wood were

[15] Ibid.

required for firing the bricks from which the city was built. From the seventeenth century European construction in Madras relied upon bricks. According to the leading architectural survey of the city, 'In Madras, [brick] is the most economical material available, and it can be adapted both to the formation of walls, towers and columns … Bricks were moulded and fired by the million' (Kalpana and Schiffer 2003: 56). This required extraordinary quantities of firewood.

Following local practice, Europeans covered their early brick buildings with chunam, a plaster made primarily from lime, which afforded protection from the heavy rains of the monsoon and the humidity of Madras. (Although in even very large houses, local builders encased the brick in clay, which was less expensive and saved the fuel of burning lime for making chunam [Best 1852: 60].) However, from the mid-nineteenth century the massive Indo-Saracenic structures which began to grace the city left the brick exposed to the elements. These buildings also lacked overhangs, which offered some protection from the damaging effects of heavy rainfall. For such construction, the bricks had to be made even more durable and impervious to the harsh climate, which meant firing at very high temperatures, requiring even more fuel.[16] The exposed-brick buildings of British Madras departed from indigenous methods for monumental construction, which used cut stone. The British substituted brick for stone because it was less expensive ('cut stone is much too expensive to be adopted to any extent in public works'), but this came at a high environmental price (Best 1852: 53).

The third and final element in the new energy economy in nineteenth-century South India was steam technologies which were powered not by coal but by wood. I call this bio-steam power and it forms part of a larger class of hybrid energy systems that I call the bio-mineral economy. Previous writings have noted that the introduction of the railway into South India, and India more widely, had a punishing impact on forests. The demand for wood for sleepers, in particular, has been noted for leading to widespread deforestation. In the south the trees that were suitable as sleepers, especially teak, came from the hills and the plains did not yield wood of sufficient hardness and durability for this purpose.

However, the plains did provide fuel wood to power locomotives, which has been, in contrast to sleepers, a neglected dimension of the impact of railways in the region.[17] Between 1863 and 1868 the demand for wood from the railways in the Madras Presidency (an area larger than Tamil Nadu) increased more than fivefold, from 9,821 to 54,358 tons per year (Brandis 1883: 32). In 1871 the Madras Board of Revenue noted with alarm that 'the operations of Railway Companies, as long as firewood is used by them for their locomotives, destroy the forests with startling rapidity' (Brandis 1883: 33). However, reports from the late nineteenth century indicate that the fuel demands of railways continued to be significant. D.P. Brandis

[16] I am grateful to Rahul Mehrotra for this insight.

[17] Cleghorn, for instance, has nothing to say about the demand for fuel in his discussion of the impact of the railway (Cleghorn 1861: 33–4). For a corrective, although very brief, see Gadgil and Guha (1992: 120). Also see Williams (2003: 36).

himself wrote, for instance, that it was important to protect the forests of North Arcot, Salem and Coimbatore because they were major sources of fuel for the railways (Brandis 1883: 13) and the problem of securing sufficient wood fuel for the railways would continue to dominate official thinking till the early twentieth century when coal began to replace wood.

Bio-steam power in South India did not begin with the construction of the railways and can be dated to the establishment of the Porto Novo Iron Works, which was an enterprise based on designs and systems developed for smelting iron with abundant and cheap coal in Britain. The furnace was much larger than local varieties and although it achieved higher smelting temperatures, this came at the cost of the wood that fuelled it. In addition, the Porto Novo Iron Works utilized blowers and rolling equipment that were powered by steam engines. These required supplies of wood.

Thus in the late nineteenth century the railways were not the only machines in Tamil Nadu that were designed for coal but operated with wood. The steam engines that powered cotton textile factories across the region also relied on wood as fuel. In the late nineteenth century textile mills were established in smaller cities and towns of South India to take advantage of their proximity to cotton-growing areas and their abundant supplies of low-cost labour. In Madurai, spinning factories were founded in 1892 and a source from the early twentieth century reveals that a sizeable proportion of the wood that was transported to the city was destined for its mills. The source also reports that demand from these establishments contributed to a rise in wood prices in the area. Because of their sizeable fuel needs, the mill owners found it more economical to cut out middlemen and procure the wood themselves and then transport it via rail to Madurai.[18] In the city of Madras, with the establishment of the Buckingham and Carnatic Mills, in 1876 and 1881 respectively, substantial supplies of wood were needed to power these as well as other factories.[19]

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Putting the above together, there was significant deforestation in Tamil Nadu in the nineteenth century. From Udaiyarpalayam to Chingleput and North Arcot as well as coastal areas both north and south of Madras, there was decline in wooded area. The deforestation of these plains had a profound impact on the agrarian order in the region. Rural dwellers faced higher prices and reduced supplies of essential forest products. Uneven access to the remaining woodlands worsened economic inequality and strengthened political hierarchies.

One clear development was an increase in the price of energy, which has been noted several times in this chapter. In 1855, Captain J. Campbell, assistant executive engineer in the Nilgiris, summed it up when he wrote, ‘It is questionable whether that which at first sight appears economical may not in the long run prove a very

[18] Report of the Forest Committee Appointed in G.O. No. 1677 R., Dated 5 June 1912, vol. ii (Madras, 1913), p. 293.

[19] Ibid., p. 581.

expensive process, when we reflect that while in 1854 the Commissariat Officer purchased ration fuel at 500 lbs per rupee, he now buys at 300 lbs per rupee.'[20] This represented a 67 per cent increase in price.

Campbell was only thinking of costs in terms of prices, which was of great importance, but we can in retrospect, and with greater knowledge, think of the costs in broader terms. A major casualty of the loss of the plains forests was the animal economy of Tamil Nadu. Forests and woods, either adjacent to or within close proximity of centres of agriculture, were prime grazing areas for cattle and goats. Kalki's short story from the 1920s, 'Mayilai Kalai' ('Grey Bull') begins with the protagonist searching for a bull which he had lost the previous day when he had taken his cattle to pasture in some nearby woods. The loss of grazing grounds would have had profound consequences for agricultural production because a smaller animal population meant less manure for the land. Animal manures were most critical for replenishing the soil on dry fields in which cultivation was largely rain fed. However, the loss of forest also had an impact on the wet cultivation of rice, which was dependent upon green manures, the leaves of trees and bushes, for restoring soil nutrients. These were gathered in the forests of Tamil Nadu and by the late nineteenth century were reported to be in short supply and more costly. According to one source, rice yields fell by a quarter if green manure was not applied, which had to be done annually.[21]

A second major impact of the loss of the forests of the plains in South India was the growth in rural inequality. Large landowners and rich peasants who owned or had access to woodlands were better off economically as they were able to obtain fuel, timber, grazing grounds, green manure and other forest products that were increasingly in short supply. At the same time, the cutting down of forests increased rural dependency as the tenants of big men were more likely to gain access to woodlands. A zamindar in the taluk of Ponneri, which was near the city of Madras, reported in the early twentieth century that his estate contained 1,000 acres of scrub jungle which were reserved for the grazing, firewood and leaf manure needs of his tenants. On another 5,000 acres of forest he demanded a user fee, which was lower for his tenants.[22]

The above developments in the South Indian countryside may be seen as some of the consequences of the Anthropocene, for the deforestation of the plains of South India was due in part to the deployment of the new fossil fuel technologies that have transformed our planet's geology. Bio-steam power is one path that was taken in the nineteenth century when engines that were designed for operation with coal were put to work with wood. It shows that the Anthropocene is multifaceted in its impact. While the global repercussion of the rise of fossil fuel use – the build-up of carbon dioxide and other heat trapping gases in the atmosphere – has received primary attention, there were also local effects that were profound, as the case of deforestation in nineteenth-century South India shows.

[20] Proceedings of the Board of Revenue, 1855, vol. 2489, pp. 14093–4, TNSA.
[21] Report of the Forest Committee Appointed in G.O. No. 1677 R., 5 June 1912, vol. ii (Madras, 1913), pp. 302, 417.
[22] Ibid., 576.

The bio-steam power economy may be seen as a subset of a larger phenomenon, the bio-mineral economy, in which fossil fuel technologies are combined with biological or organic fuels. These hybrid methods – in our time biodiesels and ethanol are conspicuous examples – do not abolish the land constraint while enormously increasing the demand for fuel and thus pressure on the land. This suggests that these hybrid technologies are not a viable solution to our present crisis and the true path forward is new technologies that depart from the fossil fuel foundation that has been laid since the eighteenth century.

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8

Land Quality, Carrying Capacity and Sustainable Agricultural Change in Twentieth-Century India

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Economic activity and the environment are often related in feedback loops. For example, natural resource abundance enables economic growth; but by using up finite resources or by degrading their quality, growth can become unsustainable. Agricultural expansion in an arid tropical setting can give rise to a particularly hazardous chain: agricultural change depletes the very resources (water, loamy soil) that are in short supply to begin with, inducing intensity of cultivation to rise more, causing more environmental stress, and so on. A historian who wants to include the environment in accounts of economic change may wish to uncover some of these loops.

One such feedback mechanism is particularly significant for those regions of the world that were drawn into the international trade system of the nineteenth century as primary product exporters. Initially, a condition of land abundance enabled growth and commercialization of agriculture. In the long run, that condition was modified in many cases because of either land degradation through overuse or land improvement through technological change. This long-term pattern raises two questions. When was the environment an enabling condition, and when was it a limiting condition? Why was sustainability, that is resource-intensive growth without impairing the resources, possible to be achieved in some conditions, and difficult in others? Indian economic history, this chapter shows, offers useful answers to these questions.

The literature on the environmental history of colonial India (1858–1947) is yet to address questions like these. In fact, it pays rather little attention to the environment-economy feedback loop. The scholarship is impressive for the quality of narrative research. It is also diverse in range of interest. But it has a problem, it places too much stress upon the state, specifically, the direct or indirect agency of the British colonial empire in the region. With some exceptions, environmental history has developed as a state-centric historiography, as a branch of imperial history more than that of environmental history. The state centrism tends to obscure geographical agency in economic change.

This chapter – a stylized history of agriculture in colonial and post-colonial India – is a response to this problem. Borrowing the concept of carrying capacity from ecological economics, I show that in the long run agricultural expansion was intricately bound up with concerns over land degradation and land quality. These concerns were raised by and often remained confined to agronomists and scientists. The trade-off between economic growth and land quality was often linked by them to the tropical monsoon setting for agricultural operations in India. Economists paid attention to the links in recent times, but the problems had longer antecedents. Because they did, these issues lend themselves to historical treatment.

The project undertaken in this chapter is located close to the term Anthropocene, insofar as it emphasizes the capacity of human action to induce changes in the environment. In agriculture, the capacity of human action to affect land quality reached a peak in the modern era because of growth in trade, revolutions in science, mass consumption and changes in preference and population growth. The chapter considers the last 120 years in Indian agricultural production to illustrate the dynamic interaction between exploitation of land and environmental sustainability. The study speaks to other contributions in this book on several points, suggesting scope for a connected narrative. The two obvious connections are with Gareth Austin's chapter on Africa, especially on the point of soil quality, and Ken Pomeranz's on China, which stresses water. Parallels can also be found in the stories of forest conservation and deforestation in India and Southeast Asia, the latter explored in Boomgaard's chapter. I will have occasion to refer to some of these cross-connections further on.

The next section presents a short and selective survey of the environmental history of India to show why it speaks to economic history rather poorly. The remaining part of the chapter returns to and develops the agriculture-environment interaction.

Environmental history of India: A brief survey

The body of scholarship that forms the environmental history of South Asia is large and diverse in focus. But with few exceptions, contributors to the field anchor their work in the history of the British colonial empire in the region. India never saw European settlement on a significant scale, nor did the region experience European intrusion quite in the same way as the 'Columbian exchange'. If anything, the demographic balance of payments was against the Europeans in this case. That is, European life in India was more deeply affected by the tropical pathogens than native life in India was by the organisms the Europeans carried with them. Instead of disease and other types of exchange engendered by settlement, the point of interest has been the institutional policies of the state. The British Empire is seen, rightly, to represent a series of interventions that altered the mode of use of and structure of rights to the commons.

The overarching motivation behind these interventions was to 'peasantize', to 'commodify' and to regulate Indian society.[1] In turn, commercial exploitation of minerals, forest products and crops and new forms of property right in land disturbed traditional practices of sustainable use of the commons. A second driver of intervention was growth of knowledge, especially the growth of scientific forestry in continental Europe, and the evolution of forest management and conservation as an academic discipline. In turn, the birth of scientific forestry itself has been traced to a set of ideas called 'desiccationist', held together by the belief that there was a link between tree cover and soil erosion and drought (Grove 1995). A third driver yet was representation of nature as a wild space occupied by autochthonous inhabitants located on the margins of settled agricultural society. Integration of spaces like these needed efforts to regulate them, often with consequences for the environment (Sivaramakrishnan 2000).

The key 'take-way' for the economic historian from this literature is the implication that the access to commons before, during and after colonialism mattered to modes of use and conservation of the commons. The British defined private property in land differently from previous regimes. They defined it as an ownership right rather than as a right to use the produce of land. But access to village grazing land, cultivable wastes and forests required setting out rules of use rather than of ownership, and this task was left incomplete. A variety of consequences resulted from the anomaly. Peasants grabbing village commons was rare (Chakravarty-Kaul 1996). But more usually, a sharp division came into being between nomads, pastoralists and forest-dependent peoples on the one hand, and the peasants on the other, the last mentioned being the more favoured by the new institutional regime (Bhattacharya 1995).

There is no question that imperial policy had a great impact on the commons. The first Forests Act was framed in 1865. The authorities decided that the precolonial system was for the ruler of the land to exercise absolute ownership right to the commons. In effect, proprietary rights were established in forests. The people most affected by this move were the hunters-gatherers and the population subsisting mainly on forest resources. There then followed a strange mixture of destruction and conservation. In the early nineteenth century, forests were often felled under British supervision for reasons of defence. This was the case in the eastern part in the Ganges-Jamuna inter-fluvial tract, or submontane north Bihar (Mann 1998). The exploding demand for railway sleepers, wood fuel for railway locomotives and timber for shipbuilding led to the destruction of trees in large numbers (Das 2010). In several parts of India, the destruction upset the pattern of vegetation and wild life. At the same time, reservation was also used as a means to regulate commercial exploitation and conservation.

But what was this a change from? What rights were there before? Who were the people who gained or lost in the process and how similar or different were they

[1] For a selection of writings, all carrying a strong empire-orientation, see Kumar, Damodaran and D'Souza (2011), Grove, Damodaran and Sangwan (1998b), Arnold and Guha (1995) and Rajan (1998). One new collection breaks out of the empire-fetish somewhat, but in an eclectic fashion, and with little relevance for economic history, Rangarajan and Sivaramakrishnan (2014).

before the change? The colonial answers to these questions were possibly based on preconceptions about Indian society. Environmental historians have tried to break that mould. How far have they succeeded?

Conceptual frameworks developed in the 1980s, especially through the work of Madhav Gadgil and Ramachandra Guha, who proposed two ideas: that collective bodies such as village communities negotiated right of access and that designated castes specialized in the maintenance of forest resources, before colonialism (Guha 1989; Gadgil and Guha 1992). For some, specialization in resource use made them take care of the resource responsibly. The notion of a precolonial equilibrium brings into sharper relief the disruption caused by colonial rights regime that weakened the community by empowering owners of land, weakened traditional conservation practices by reserving forests for the use of the state, and in both these ways destroyed an indigenous moral economy about responsible use of nature.

But the notion of a precolonial equilibrium has been deeply controversial. It is not clear at all how far the village community or traditional communities were pre-existing or recreated by the colonial state in an attempt to define customary property rights (Singh 1998; Grove, Damodaran and Sangwan 1998a). In a significant analytical critique, Sumit Guha disputes the notion of a precolonial equilibrium marked by a separation between agriculture and forest dependency into distinct fields of specialization (Guha 2006). Forests, instead, were tied to the agrarian landscape through a set of dynamic relationships. People combined livelihoods and identities, and peasants used forests as a resource as well as a political domain. In many regions, dominant peasant clans had superior rights to the forests, and retained these rights in the colonial regime. Sustained criticism of the concept of the forest dweller as a relic from times before agricultural civilization, or attempts to 'essentialize' the original dweller as 'tribe', has also helped blur the boundary (Das Gupta 2011). Present-day scholarship on nomadism confirms that agrarian and nomadic environments can coexist and exchange people between them (Robbins 1998).

A similar discourse has emerged also on water management, in particular, flood control and embankment construction in riparian northern India. It is suggested that the colonial state embarked on such projects in order to raise revenues, assist railways or govern and control peasant societies, and that a disregard for indigenous knowledge, practices and rights degraded land by preventing alluvial formation, speeding up siltation of river bed, obstruction of drainage and by making waterborne diseases and parasites more prevalent (Hill 1997; D'Souza 2006a; Singh 2008). The plot repeats in the small but important scholarship on the environmental effects of agricultural growth. Again, the focus falls mainly on the adverse ecological consequences of colonial public works programmes (Whitcombe 1972; Agnihotri 1996).

A surprising case of purging geography, indeed everything but empire, is the history of natural disasters, that is famines and floods. Natural disasters, one would think, represent a class of events where nature would play some role. However, the most commonly used analytical framework for understanding the origin of floods places more emphasis on ill-designed colonial construction projects than on geography (see D'Souza 2006b, for a discussion), while famines are seen as 'entitlement failures', an approach popularized by Amartya Sen (1981). Both perspectives offer mainly political accounts of natural disasters. A partial exception to this approach is the interesting work by Mike Davis (2000), which traces the origins of nineteenth-century famines to the ENSO (El Niño Southern Oscillation) in the eastern Pacific, and consequent climatic disturbances in the rest of the world, especially in monsoon wind patterns in India. Davis proceeds to attribute the mass death and human misery that followed these events to politics, specifically, adherence to capitalist ideology by the imperial states. ENSO, according to one set of simulations in a contentious scholarship, may intensify due to global warming, potentially causing disasters on a scale with which states do not yet have the means to cope. This debate foregrounds variability in the scale of natural events. For the economist and the historian, variability of scale means that there is a problem of matching capacity with the scale. In a similar spirit, I have argued that the human misery following the nineteenth-century famines in India had more to do with the limited means – poor information, infrastructure and small fiscal capacity – that the British imperial state had at its disposal when dealing with natural disasters of such magnitude than with liberal ideologies or capitalism (Roy 2012).

Any general assessment of this literature must recognize that the decision to focus on the British Empire has distinct advantages. The role of the empire as a sponsor of economic globalization, and India's important position in the imperial trading system of the nineteenth century, implies that an empire-oriented environmental history is simultaneously a study of an interaction between European and Indian ideas about nature, and a study of an interaction between globalization and the environment. Furthermore, the empire bias gains from access to an enormous body of archival sources, only a part of which has yet been fully explored. By comparison, the density of sources falls away drastically as we move further back from the nineteenth century.

Precisely for that reason, a story of environmental change that makes imperial policy the centrepiece cannot be entirely credible. It gives rise too easily to a post-colonial grand narrative of colonial-modernization-gone-wrong. This is a useful theory because it connects similar stories that emerge from other parts of the world, usually with some form of European and colonial agency, and building connections between diverse geographical contexts. The hypothesis that the colonists misunderstood nature, applied the wrong types of borrowed ideas upon it, destroyed conservation practices, and that their own version of conservation was driven by the desire for power, is useful also because it connects together contexts as diverse as land, forest, water, embankment and the commons. And yet, there is a mythical quality about it.

For one thing, it rests largely on constructions of the precolonial world based on thin and speculative foundations. For another, an environmental history narrative with state power rather than geography as the subject is a limiting framework. There were many forces of change relevant for environmental history that the imperial state did not directly influence. These factors included population growth, world trade, migration and mobility of communities, industrialization and natural disasters. Some of these variables the empire adapted to, others it enabled in a highly indirect way and still others it just coincided with. Painting environmental history with a uniform coat of imperial design does not lead to either an elegant or a useful model.

More broadly, if environmental history is expected to be about geography, nearly all of Indianist environmental history treats geography casually. The scholarship does not tell us how key stylized facts about the physical reality – say, its tropical monsoon climate – make for a distinct pattern of interaction between environment and the economy. One example of the distortion would suffice. Colonial India witnessed large-scale famines in 1876, 1896 and 1898, all three concentrated in the arid Deccan plateau. Why was a particular geography more likely to trigger mechanisms that led to mass starvation and disease? In the entitlement approach mentioned before, the question disappears from view, and attention falls on what are often called, misleadingly, 'man-made' factors. An alternative view emphasizes high information and trade costs involved in the provision of relief in a geographical region characterized by few large towns, few administrative centres, many princely states, low density of roads and railways and where the principal means of moving bulk goods was bullock caravans (Roy 2012).

While not disputing that states matter as agents shaping the link between the environment and the economy, and that the British Empire reshaped these links fundamentally, we need to explore other ways of connecting the two spheres. This is necessary in order to discover patterns of interaction that do not neatly fit imperial history. This is necessary also to show how geography can play an independent role in abetting or limiting economic change. In effect, I share the same motivations that have induced others to broaden the discourse on environmental history beyond imperial agency when studying the non-Western world (Carey 2009). My response, however, follows a different strategy from the one pursued by others, because of the particular interest in this chapter in economic history.

It is necessary to define the scope of the task first, beginning with the conceptual problem involved.

The concept of carrying capacity

In the 1990s, a series of works appeared in ecological economics that made use of time-sensitive concepts, especially the Environmental Kuznets Curve (EKC), and carrying capacity (Arrow et al. 1995; Stern, Common and Barber 1996). Although a historical concept in principle, EKC did not make ecologists or economists take much notice of economic history, but the potential for a dialogue was created.

Carrying capacity is defined broadly as the scale of human activity that a given natural resource endowment can sustain before it starts to degrade or deplete in the course of use. The EKC predicts an initially positive statistical relationship between average income (economic growth/change) and environmental degradation, the slope reflecting the resource-use-bias of rapid development and perhaps poor institutional safeguards against overuse. Carrying capacity indirectly shows how far the EKC's upward phase can carry on without serious societal problems. The former has never been easy to implement statistically except with few emission agents, and the latter has remained a tool for ordering thought rather than a tool for policy. In either case, scholarship using or testing these ideas rarely showed an interest in national, even global, economic history, and remained planetary and ecological in scope.

More narrowly, the carrying capacity of an agrarian ecosystem (mainly soil and water, but also climate) is the scale of human and animal life it can sustain without being degraded in the process of agricultural use (Daily and Ehrlich 1992). The carrying capacity is approached with population growth, increasing trade and rise in consumption. And carrying capacity can be raised if agricultural technology changes and production becomes more efficient. These influences interact between themselves. For example, technological change is often the cause of degradation and depletion of resources. This is so because technologies can be inherently resource intensive, for example, Green Revolution technology is intensive in the use of groundwater. Technology can also induce environmental degradation because rapid productivity gains can set off price and income effects that increase consumption, change lifestyles and put further pressure on resources (Rees 1996).

Carrying capacity is clearly a useful concept for economic history. The concept 'kicks in' when exogenous factors such as technology, trade, consumption and population growth induce a rise in agricultural production and the productivity of land. This starting phase has been described by Hla Myint in the context of nineteenth-century tropical export economies as a 'vent for surplus' pattern of economic growth, one in which natural resources are available in abundance, that is are cheap to use and can sustain an export-led growth (Myint 1958).[2] Mynt's notion does not admit of environmental costs. The way to include them is through carrying capacity. As the growth process continues, the carrying capacity is reached, and degradation of the quality of soil and water could begin. That does not necessarily stop economic growth. But if these degradations are of a serious order, we operate in a phase of history in which environmental degradation can begin to adversely affect production possibilities or human welfare.

The arrangement of these two 'stages' – sustainable use and unsustainable use – in a sequence is a stylization no doubt. But it suggests two useful lessons for economic history. First, because all the major variables influencing carrying capacity – population, commerce, science and consumption – experienced enormous changes during the nineteenth and twentieth centuries, it makes sense to ask, has the modern world reached the frontier, gone beyond the frontier or has it succeeded in pushing the frontier further out? Second, it allows the economic historian to avoid having to choose between a Malthusian and a counter-Malthusian outcome, when population growth makes natural resources relatively scarce. In the Malthusian scenario, carrying capacity is a static frontier. The counter-Malthusian scenario, popularized by Ester Boserup and proponents of 'induced innovation', is one in which population growth (and/or factor price shifts) induces innovative response that extends carrying capacity.[3] The

[2] The historical narrative is more fully developed, with Southeast Asia and West Africa as the main examples, in Myint (1965).

[3] For a discussion of these perspectives, see Hayami and Godo (2005).

former approach is ahistorical because it assumes that the carrying capacity is static. But, then, the latter approach builds on a false confidence. Boserupian response and induced innovation may or may not be environmentally neutral, may or may not be sustainable.

The sequential model outlined above obviates the need to make an either-or choice between pessimistic and optimistic views on resource-led growth. Both these responses are possible. The fundamental lesson of the 1970s Green Revolution in the world was that an extension of carrying capacity of land was possible to achieve by the application of science, but not everywhere. A rise in agricultural production and productivity stemming from population or factor price shifts is feasible, but the extent of success depends on the quality of soil and water. Even in the best of conditions, agricultural improvement entails a trade-off in the shape of degraded and depleted resources, even though technology may be able to counteract that process with varying degrees of efficiency. That efficiency appears limited in the arid tropical regions. For in the arid tropics, the trade-off could set off an adverse chain reaction, what I called a feedback loop at the beginning of the chapter.

The history of Indian agriculture offers illustrations of these points. Given that agriculture is still the largest single category of land use in India despite a big decline in the proportion of population dependent on agricultural livelihoods, agriculture is an important example in speculations on how human action upon nature can change both human society and the natural world.

Illustration 1: Water, animal power and the limits on carrying capacity in colonial India

Within India at two different times in the twentieth century, there emerged discourses suggesting that agricultural change gave rise to pressure upon resources. The first time was the interwar period. Why in the interwar period?

In the nineteenth century, the whole world was transformed by revolutions in transport and communication, and by industrialization in the British Isles. The resultant growth in world trade, along with migration of capital and labour, was aided by the expansion of British political and military power. By 1858, the British ruled over much of India. Between 1860 and 1940, the ports of India had been connected with the interior by railways and telegraph. They shipped abroad huge quantities of cotton, grain, seeds, indigo and opium. Agricultural commodity exports grew in volume about three times, and land under cultivation possibly by 60 per cent. A string of irrigation canals together with the railways transformed areas like Punjab from grasslands into wheat baskets.

The dynamism came to an end in the 1920s. According to the best estimates available, India's national income increased between 1870 and 1914 at a rate of 1–2 per cent per year, and per capita income at the rate of 0.5–1 per cent per year. In interwar India, rate of growth of per capita income declined to near zero. There was a shift in the trajectory of economic growth. The immediate source of the crisis was agriculture, which virtually stopped growing. From 1930 onwards, stagnation in real agricultural wages set in and remained unbroken until the mid-1970s. The proximate cause of the stagnation was shortage of land. The growth phase had been made possible by extension of land area, and the stagnation was an effect of exhaustion of land area. Land yield was not completely static, but any change in yield was highly sensitive to crop and region. At the peak of the commercialization process, regions had become more unequal in the capacity of their land to produce commercial crops in sufficient quantity.

Land yield was higher and steadier in regions that received canal and well water, mainly Punjab, western Uttar Pradesh, the Krishna-Godavari basin and one or two river valleys in central and south-central India. The new seed-fertilizer package, for which the Green Revolution of the 1960s was famous, was still in the distance. And yet, the huge inter-district differences in yield, the low Indian average yield by international comparison and limited diffusion of contemporary improved seeds all went to show that most parts of India were trapped in a situation that prevented them from using the available options most efficiently.

This was the problem that a group of agronomists and a large governmental enquiry (the Royal Commission on Agriculture in India) were trying to understand better. To paraphrase their views, the carrying capacity of land had reached its limits in most regions of India around 1930. There were two reasons for this. Problems associated with pastures limited the efficiency of the most important capital, livestock. And the high cost of accessing groundwater made efficiency gains in agriculture impossible.

The main power used in pulling the plough was bullock. In the 1920s, India used 67 head of cattle per 100 acres of net sown area, whereas the Netherlands used 38 and Egypt, where conditions were similar to that in many parts of India, used 25. Holland used, in addition, horses, but that would not have bridged the gap. Contemporary experts believed that one of the factors behind the huge divergence in efficiency was the declining quality of the bullock in India (Sundara Ram 1928–9). From the late nineteenth century, the scarcity of fodder worsened, it was believed, because of the disappearance of the commons, peasantization of pastoralist communities and disappearance of traditional knowledge concerning cattle health and maintenance of stock. In 1930, there were an estimated 200 million cattle in India, and only 60 million working cattle. While a large part of the remaining must have been milch animals, 'the proportion of animals not capable of paying their way must be very large indeed' (Ware 1941).

In 1916, an economics professor in Madras (Chennai), Gilbert Slater, attributed the pasture problem in South India, not to enclosure and a scarcity of common lands, but to free riding, or demographic pressure on open commons.

> Throughout most parts of South India there is little pasture except common pasture; … cows generally have to struggle for a scanty living … The tendency to overstock, which is general in all countries where pasture is held in common, is specially rampant in South Asia, where the co-operative spirit and power of organization are especially weak. (Slater 1918: 8)

A decade later, witnesses before the Royal Commission in Agriculture confirmed the presence of a similar contest in other regions. In the Central Provinces 'rice tract free grazing and cheap grass has led to a custom of judging social position by the number of head owned rather than by their individual utility' (India 1927, VI: 18).[4] Open commons and overstocking thus went hand in hand, leading to a progressive deterioration in the average quantity and quality of fodder. Overstocking was also encouraged by deteriorating quality, 'as cattle became smaller, the cultivator increased their numbers to offset their inefficiency' (Mukherjee 1936–7).

Fall in bullock quality led, it was suggested, to 'uncontrolled breeding'. '[F]or many years now the tendency has been to produce more and more to compensate for the low productive power of the existing ones' (Ware 1941). The disappearance of custom sometimes played an adverse role. Indigenous systems of breeding depended for their effectiveness on customs such as protecting the 'Brahmani bull', a young bull dedicated to the temple when a prominent villager died. The bull had to be in sound health and roamed free to graze wherever it wished, and grew up to be a good breeding bull. However, the custom was coming to an end where expensive crops were grown and the cost of prime quality bulls had increased (India 1927, III: 50, Evidence of Director Agriculture, Madras). One indication of a general quality problem was the small amount of milk that most Indian cattle produced on average. That this was a reversible condition was proven in experiments conducted at the Imperial Institute of Veterinary Research, Muktesar, and at the military dairy farms, wherein it was found that the Indian cows and especially buffaloes responded remarkably well to controlled nutrition.

The pasture and animal quality problem partly reflected the typically arid nature of the territory. Water showed this even better. The greater part of the Indian subcontinent combines three months of monsoon rain with extreme aridity in the rest of the year, which dries up much of the surface water. The rains make one sowing relatively easy (the usual practice is to have two sowings in the monsoon, of which one is a major grain), but growing another crop is dependent on irrigation that requires expensive systems of harvesting and storage of water. Thus, the monsoon in a tropical region made earning subsistence rather easy, but improvements in yield difficult. The average peasant 'has five months hard work. If he has a share in a well he is busy for three more months' (India 1927, VIII: 71).

In the nineteenth century, government engineers constructed a network of canals in Punjab, at the meeting point of two large river systems, the Ganges-Jumna and the Indus, leading to the emergence of large and prosperous agrarian settlements. But this solution needed rivers that depended less on the monsoon rainfall and more on Himalayan snow melt. Elsewhere, the prospect of construction of canals was seriously limited by the fact that the rivers carried little water in the dry seasons. The solution to the scarcity of water in the dry seasons, therefore, was groundwater extracted from wells. Wells avoided the large capital cost involved in canals and tanks. Wells avoided the evaporation and percolation losses involved with water storage tanks common in South

4 Evidence of F.J. Plymen, Director, Agriculture, Central Provinces and Berar.

India. Why, then, was not more than 1.5 per cent of the total volume of rainfall being extracted from wells in 1900, while the subsoil reservoir was practically untouched?

Well irrigation was relatively affordable in the alluvial lands. In 1920, the percentage of area irrigated by wells was the highest in the alluvial tracts (7.3), and smallest in the Deccan trap (2.4). The former received more rainfall and the latter little rainfall. In short, wells did not bridge the inequality in water but possibly made it worse. The reason for this pattern was that well construction was easiest and the returns from wells most secure where subsoil water was plentiful, and the seasonal variation in the water level was moderate. In parts of the riparian Gangetic plains, this condition was fulfilled. The water table varied between 10 and 30 feet in those districts of Uttar Pradesh that received canal water. It was easy to construct a temporary well in a year of shortage in northern India. In Punjab, the winter rains rarely failed, and the cold and moist climate of winter requires less frequent watering. In the Deccan trap, on the other hand, the water table was 40–50 feet even in the monsoon months, and here locating a well site was not easy. The winter was drier and hotter. Nearly all wells in dry South India were permanent constructions, and very wide (20–100 feet). Whereas in Punjab the average area cultivated by a well was above 10 acres, in Madras Presidency it was 3, and in Bombay (Mumbai) Presidency it was 2.6.

There is considerable evidence that well construction was unprofitable in the dry zones. In 'the black soil plains and stony uplands of the Deccan trap and crystalline areas ... wells are impossible or will never pay' (India 1903: 20). Slater, while agreeing that 'more wells could be sunk with advantage', concluded that 'they are not sunk owing to lack of funds with the ryots'. He further qualified that 'it would not pay to sink wells in [dry lands] and take out water according to the existing methods. If cheaper and more efficient methods are possible, then it would be worth attempting' (Slater 1918: 102, 201). In Central Provinces, not normally a dry zone, the Chief Irrigation Engineer declared that according to cost calculations, 'the only place where wells can reasonably be adopted is in the bed of rivers' (India 1927, VI: 136).

A perennial well needed to be very deep in South and Central India. According to some calculations I have made, the capital cost per acre irrigated could be ₹100 in 1900 in the southern Deccan. The interest plus operating cost of this well could add to a further ₹30–40 per acre. At prevailing prices, the decision would be justified if an additional rice crop yielded 500–800 kilograms per acre. Rice yield averaged 400 kilograms. The risks were huge, as a case from Central Provinces in 1927 would show. A cultivator owning 600 acres dug four wells for ₹22,000 to irrigate 20 acres (India 1927, VI: 323–5). On average a well could irrigate 7–8 acres in the dry season. But if the rains failed, the wells dried up, leaving the average about two acres. This made the interest cost by itself so high as to turn the well into a disastrous economic decision. There were numerous contemporary examples of peasant bankruptcy due to well construction.

Well construction was not only costly but also involved a rather low success rate. How did one find the site to dig a well? A 'water-finder' of the village was called. There was a great deal of uncertainty about how effective local knowledge of subsoil water could be. The Irrigation Commission went into this issue and believed that in the alluvial tracts of northern India, local knowledge was good enough. But in the dry areas, local knowledge was inadequate. The problem of failed wells was compounded by the fact that in a famine year, wells tended to be dug indiscriminately (India 1903: 11).

Wells were still being built. The estimated returns would increase somewhat if all labour was supplied from within the family, and all capital cost came from own savings. The portfolio of highly profitable crops was changing in South India late in the interwar period, and that factor may have reduced the risks of a well. Some farmers may have held subsistence during famines at a higher value than the economic returns from wells. But wells were not being constructed on a large enough scale to have any effect on carrying capacity.

Again, the tests of effectiveness of wells produced contradictory results. An agronomist and influential writer on agriculture, Harold Mann, cited two sets of surveys that arrived at contradictory conclusions about the effectiveness of irrigation on yield per acre and peasant incomes (Mann 1955). In one set of official surveys, it was stated that the effect was significant and positive, the extent of gain being much larger in dry Madras and Bombay. In another set of surveys conducted by D.R. Gadgil and his associates in the Gokhale Institute of Politics and Economics in villages near Pune, it was found that the returns did not justify the costs of well construction.

What other systems could raise the prospects of a second or third crop? Tanks were common in South India. But it was poor insurance against repeated failure of crops. The Irrigation Commission concluded that a tank meant for drought insurance would involve so enormous a wastage of water through percolation and evaporation that it would not be economical to maintain (India 1903: 15). Tank maintenance was an organizational challenge on a massive scale, and the response was often inadequate.

A forward-looking solution to the problem was borewells combined with a power-driven pump. A.C. Chatterton, the Director of Industries, Madras, tried to popularize the idea with partial success, especially in regions where subterranean artesian wells were discovered.[5] Although not extensively used for irrigation, the demand for oil engines in agriculture popularized their use in a wide range of agro-industries, including rice and oil mills. Outside South India, interest in borewells was growing. Farmers who grew summer paddy in Bengal once approached the Agricultural Department demanding help with borewells. An experiment with tube well and pumps conducted in Rohilkhand found the running cost of irrigation for an acre of sugarcane crop to be ₹25, which made the proposition break even providing capital could be raised cheaply to finance the cost (India 1927, VI: 436).[6]

There were two long-term legacies of this conversation. First, there was a clear sense that geography set a carrying capacity of agriculture, mainly because high investment cost in intensive growth made a market-based approach to extending the production possibility frontier impossible. The key message for someone who read

[5] Chatterton organized demonstrations of three technologies suitable for small businesses during his career as an industrial advisor to the governments of Mysore and Madras. These were power loom for weaving factories, chrome tanning and borewells. A hundred years after his experiments, the power loom had emerged the largest textile producer in India, chrome tanning had changed Indian leather industry and borewells acted as foundation of a green revolution in rice.

[6] Evidence of Director of Agriculture, and Howard Vick, Agricultural Engineer, United Provinces.

this story in the 1950s would be to advocate large-scale government intervention in reducing the cost of investment. This was given concrete shape in the fiscal planning of the Green Revolution. Second, the most promising and democratic field of intervention was not canals, but help in the construction and operation of wells to extract subsoil water. This too was given shape during the later phases of the Green Revolution package.

Resources did not just set a carrying capacity, but variable resource quality made that capacity variable too.

Illustration 2: Land degradation in colonial India

An offshoot of the interwar discussion on what ailed agriculture considered – or rather hypothesized – the process of land degradation. More than agronomists, economics professors in universities, notably, Radhakamal Mukherjee of Allahabad University, contributed to this idea. The general argument was that in riparian northern India, trade and demography had increased the exploitation of land to such an extent that soil fertility and river morphology had been adversely affected. Parts of the Gangetic plains and the Ganges delta were home to settled agriculture for well over two millennia, and at the limits of natural productive powers when the great opportunity of exporting grain to the industrializing West reached it in the 1850s. This extension could only occur at a cost. In the next century, land degraded in some regions and cultivation expanded in inferior lands.

In the 1920s, when this argument was articulated, the evidence was anecdotal and localized. The Royal Commission on Agriculture (1927) did consider whether or not the average fertility of the Indian soil was declining. The Commission found no definite evidence of a declining return to land. But it took no issue with another prevailing view among scientists and economists that land yields had remained stagnant through the expansion in cultivation, and that Indian yields were significantly smaller than yields of similar crops in East Asia, North Africa, Europe and North America. The Commission did not conduct a serious statistical survey of the question. In the 1960s when agricultural production and yield data were reconstructed by George Blyn, confirmation of diminishing returns was found from major crops grown in much of India, especially in Eastern India, where population density was the highest.

In the Bengal delta, the proximate causes of ecological stress were well documented. Deltaic Bengal became fertile and retained fertility through a natural process, change of course of the rivers. In the monsoons, numerous small channels carried excess river water into depressions, turning them into tanks. As the tanks were drained again, the dried up tank-beds provided excellent fields for rabi crop. In some tracts, particularly in western Bengal, the nineteenth century had begun to see a restraint on this twofold process, with the result that the soil surrounding the rivers had begun to deteriorate. In turn, the steady deterioration of the water courses owed to some extent to the continuous process of deforestation and land reclamation that the western districts of Bengal had seen throughout the nineteenth century. An example of the man-made crisis was the Damodar river, which deteriorated into a narrow and fixed channel on reaching lower Bengal. In Jessore and Nadia, many agricultural tracts were said to be 'dying', and the reason was that the tanks neither had enough water nor did they dry in time. In turn, this was a result of the silting up of the rivers, and the silting of the channels that carried river water. The tanks became swamps in the dry season, and good breeding grounds for mosquitoes carrying malaria. 'There is little doubt that deltaic Bengal has become populated a geological age before its time, and the legacies of fever, deterioration of rivers, etc., is [*sic.*] at least partly due to this' (India 1927, IV: 7).

Among the most influential academic proponents of the degradation story was Mukherjee, who, with some of his colleagues, developed an account of riparian northern India. There were two main sources of degradation. First, changes in cultivation practices and crop choices induced by profitability had affected the natural processes of restoration of fertility. 'The introduction of commercial crops has upset the ancient system of rotation which served very well for fertilizing the soil' (Mukherjee 1926). And second, there was overharvest of water. Here, unlike in Bengal, cultivation depended largely on subsoil water, where canals were not available or even where canal water was available (India 1927, VII: 377–9). Groundwater exploitation, however, had reached unsustainable levels in some of the most densely populated parts of the Indo-Gangetic plains.

Mukherjee and others preferred an institutional explanation for land degradation, which, it must be said, has not been conclusively tested. Farming, according to this view, ordinarily offered increasing returns to scale because water, manure, livestock and pasture could be more efficiently used on a large farm. To compensate for this disadvantage, the poorer peasants tended to work harder to extract more from the soil, and damaged the soil the more. The association existed because 'in the heavily populated areas of India, the cultivation unit is rarely of the optimum size and more often uneconomic' (Mukherjee 1939). His own empirical tests to prove this were tentative and did not establish the claim. In the 1970s, a scholarship that grew as an offshoot of the land reforms in India showed that there was in fact a negative association between farm size and yield in cross-section data (Rudra 1982). However, his tests did seem to show that holding the quality of monsoon, soil quality and trade costs constant, the association between profitability and farm size was a positive one, but only showed up over relatively large differences in farm size. There was a larger point in the argument – that poverty was bad for the environment and the poor took and caused more ecological stress by working land harder and by operating in inferior land. Recent scholarship has revived the argument, without establishing that this is always true, but then, the tests are not perfect either and are rarely historical in scope.

When economists fail, historical geographers may succeed. Reconstruction of geographical data sets has led to pioneering research on long-term patterns of land use in northern India, which suggests, unambiguously, that population growth was bad for the environment (Richards, Hagen and Haynes 1985). This project covers Bihar, Punjab and Haryana between 1850 and 1970, combines different types of data set and draws a number of results. The commonly-held view that there was deforestation is confirmed. In Bihar, forest cover declined by 30 per cent between 1890 and 1970.

However, forests retracted not due to conversion of forests into arable land, which changed little in extent, but due to degradation of forests into scrubland, attributed to the demand for timber and demographic pressure.

In Punjab and Haryana in the same period, arable expansion occurred at the cost of all forms of woods and grasslands. In this region, the proportion of land area under forest was much smaller than Bihar to begin with. The declining proportion of grass and scrublands showed that significant expansion of arable land had taken place on the fringes of deserts. 'Decade by decade', the study concludes, 'depletion and land conversion have proceeded hand in hand. Vegetation cover moved down the scale of abundance: from forest to woodland; from woodland to scrub; from scrub to grasslands; from grasslands to barren areas. Simultaneously, cultivated lands have made large absolute and relative gains' (Richards, Hagen and Haynes 1985).

Between 1960 and 1990, agrarian history in India remained preoccupied with institutional and political variables. A dominant Marxist-Leninist perspective set the research agenda to a large extent. Environmental issues linked with agriculture were sidelined. Thereafter, the spectre of land degradation returned, with a vengeance, from the end of the twentieth century. The Green Revolution package, whether or not it caused degradation, is widely held to be unsustainable.

Illustration 3: Land degradation in contemporary India

The promotion of high-yielding seeds that formed the mainstay of the 1960s Green Revolution worked wonders together with water and nitrogenous fertilizers. Fertilizers were supplied by the state at a subsidized price. Initially the strategy succeeded in wheat-growing Punjab where British engineers had earlier constructed canals out of Himalayan rivers. In the same region, major canal projects were taken up soon after 1947 to resettle migrant farmers from Pakistan. Later, the revolution spread to rice-growing deltas where peasants erected tube wells, at a subsidy from the state, to extract groundwater. Overall, the package raised farm output, yield and wages above historical levels. The Indian government was a partner of the US government that had made a large food loan in the mid-1960s and therefore had some stake in India's long-term agricultural prospect. The cooperation enabled research collaboration between Indian scientists and land-grant universities in the United States, where the strategy had first taken shape.

The Green Revolution was significantly more successful in the relatively water-intensive crops (rice, wheat, sugarcane) and in areas better served by groundwater than in the dryland crops (millets) and areas where groundwater extraction was costly. More interestingly, even when dryland crops experienced rise in productivity, thanks to new technology, the variability of productivity increased at the same time, because the optimum use of new seeds and fertilizers depended on moisture, which came from monsoon rainfall in the arid regions. In other words, farmers applied more fertilizers in good rainfall years (Ninan and Chandrasekhar 1993). Another illustration of the geographical specificity of the Green Revolution comes from the comparative situation of dry tropical lands across the globe. Agricultural productivity is higher and has risen faster in the arid districts of Tamil Nadu than in parts of sub-Saharan Africa where average temperature and levels of moisture supply are comparable, raising hope that the Tamil Nadu experience can serve as a model for the arid tropics. On closer examination, it appears that the difference owes to soil quality, and is likely to remain.[7]

The literature on agricultural ecology shows the presence of an environmental trade-off on a growing scale in South Asia. Between the two phases of the environment-agriculture trade-off – interwar and late twentieth century – there was a difference. Almost all studies on the sources of agricultural growth in present-day India suggest that government expenditure and input pricing policy were the most active variables behind agricultural change today. The government was absent as a significant agent in the 1920s, or indeed, at any period of Indian agricultural history before 1960. Demography was a more important driver of agricultural intensification. In short, the general model of innovation or intensification followed Boserup more closely before 1960, and followed the induced innovation model more closely after 1960, except that in the latter phase, government policy changed factor prices. Through both these phases, intensification led to adverse ecological effects.

India has about one-fifth of the world population, 2.3 per cent of the world's land area and 0.5 per cent of the world's pastures. Availability of land per head has fallen from 0.9 ha in 1950 to 0.3 in 2001, and is expected to fall to 0.1 in 2050. These figures convey some sense of the scale and trend in absolute land scarcity in the region. Relative land scarcity depends on the productive power of agricultural and grazing land, which has increased manifold between 1950 and 2015. There is indication, however, that between 1980 and 2005, the rate of growth in average grain yield – the definition of Green Revolution – was falling, in some cases to near zero (Mathur, Das and Sarkar 2006–7). Among other factors, the diminishing returns syndrome owes to land degradation and overextraction of groundwater.

The exact scale of land degradation is a matter of dispute. Estimates suggest that of the 329 m ha of land area, anything between 121 m ha to 190 m ha is subject to levels of soil and wind erosion that can impair the productive power of land. Like the scale, the precise reasons for land degradation remain controversial. In the long run, population growth and agricultural expansion should act to deplete vegetation cover and increase land degradation. Between 1950 and 2020, population in India has grown from 265 million to 1,250 million. But the historical relationship between population and land quality remains an open question. Partly, the problem stems from an uncertainty over the theoretical relationship between land use and land cover. In the long run, increasing land use for agriculture and settlement has led to decline in forest cover. And yet, there are local examples showing that increased density of settlement can lead to better conservation of vegetation. Research on the history of common property resources in arid western India tentatively concludes that population growth matters

7 http://www.rural21.com/english/news/detail/article/why-the-green-revolution-failed-in-sub-saharan-africa-0000822/ (accessed 15 June 2015).

to the fall in such resources, in the presence of changes in the property right regime (Jodha 1985).

One thing is certain though, the problem of degradation in India is more serious in vulnerable environments, where soil and water supply quality is already low. Empirical tests in this field are often inconclusive, even unreliable. An econometric test using cross-section data has regressed degradation on density of population and concludes that population density does not aggravate land degradation. The underlying model is questionable. The result should mean that irrigated areas that suffer less from degradation tend to be more densely populated (Reddy 2003). But the result does tell us something about the geographical incidence of degradation. Land degradation is a more serious problem in the drylands, where soil and water quality is already low. Over shorter periods, the measurable extent of soil degradation depends also on pollution levels, maintenance of canals and soil type. About 80 per cent of the degraded land lies in rain-fed or dry zones, where fall in soil quality has led to productivity loss and loss of nitrogen, phosphorous and a host of minerals in the soil.

The connection between population, agricultural growth and water supply is rather more direct. About 70 per cent of the water used for irrigation and all the water put to non-agricultural use is extracted from underground. Groundwater extraction has led to fall in the underground water levels in many districts of India. Climate change and global warming, it is expected, will affect agriculture by reducing the recharge level in the rain-fed river basins, whereas the non-agricultural and urban demand for water is expected to increase its share in total water use from the present 15–20 per cent to over 30 in 2050. Even without the effects of global warming, which are unpredictable at the moment because the extent of temperature change cannot be accurately measured until at least 2035, nearly a fifth of the population of India and a much larger proportion of the urban population are expected to live under conditions of extreme water scarcity by 2050 (Venkateswarlu and Prasad 2012).

The consequences of the environment-agriculture trade-off in India are potentially serious. Contests for water between agricultural and non-agricultural uses, and between dry regions that share rivers are already fierce, and growing in intensity. The trade-off sets off a Malthusian inequality process. When the trade-off combines with a fall in land-to-person ratio because of population growth, the ability of poorer land-dependent households to live on agriculture erodes, leading to increased supply of wage seekers to the workforce. This tendency has been present in India at least since the 1980s. This is Malthusian in the sense of increasing labour dependency and pressure on wage rates as population growth occurs (Krishnaji 1990). In India the pressure on wage rate was counteracted somewhat by the rise in demand for labour outside agriculture after the economic reforms began about 1990. But the capacity of agriculture to absorb labour has also approached a limit because of diminishing returns. Personal income inequality is rising in India, which causes anxiety in the media and is often seen as a failure of liberal economic policies. If the trade-off continues, and skill barriers prevent easy absorption of rural labour in urban jobs, wage inequality will rise further. It will rise not because of market failure but because of land degradation.

Conclusion

I show in this chapter that the environmental consequences of agricultural growth in India were recognized as a problem at least from the 1920s, but that the environmental history scholarship, being preoccupied with the mechanics of imperial power, largely ignored it. These, along with other feedbacks between economic growth and environmental effects further shaping growth, need to be recognized as mainstream issues in both environmental history and economic history. One way to perform that task is by means of the concept of carrying capacity of an agrarian ecosystem. The tropical monsoon climate of India limits carrying capacity and makes it particularly sensitive to groundwater extraction cost. Geography, in other words, imposes strict limits on economic growth; not, as economic historians would admit, via the market cost of resources, but via resource quality and sustainability.

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9

The Forests of Southeast Asia, Forest Transition Theory and the Anthropocene, 1500–2000

Peter Boomgaard

The forests of Southeast Asia today

Unless a country is small, with a high GDP per capita, or has a well-equipped, politically independent forest department, the chances are that it has bad to very bad forest statistics. The countries of Southeast Asia – mainly Myanmar (Burma), Malaysia, Thailand, Cambodia, Laos, Vietnam, the Philippines and Indonesia – are no exception to this rule. These countries are large, income per capita is low and their forest departments are under a lot of political pressure, owing to rent-seeking based on tree-felling licences being in the gift of politicians, civil servants and/or the military, and the condoning of illegal logging. A less friendly way of formulating this is to say that their forest departments are corrupt.[1]

Therefore, forest statistics are rather unreliable, particularly on the details (percentage old growth, [re]afforestation, canopy cover etc.), but even ballpark figures can show inexplicable deviations.[2] This chapter deals mainly with those countries that have the most reliable data, regarding both the past and the present (Myanmar, Malaysia, Thailand, Vietnam, the Philippines, Indonesia), but even then the forest statistics are often of a rather dubious quality. No one should be surprised, therefore, to find different figures in different publications. A nice example is the percentage of annual forest cover change in Indonesia. In a 2007 publication, that percentage is given as -2.0 per cent (-2.0) for the period 2000–5, or an average annual loss of 1,871,000 hectares (Stibig et al. 2007: 7). In a 2011 publication, annual forest cover change for the same years (2000–5) is given as -0.3 per cent, or an annual average loss of roughly 270,000 hectares (*Southeast Asian Forests* 2011: 8). In an article, dated 2014, in *Nature Climate Change*, deforestation in Indonesia was said to

1 According to *The Economist*, 23 August 2014: 51, the Indonesian Forestry Ministry was rated the most corrupt among twenty government institutions by Indonesia's Corruption Eradication Commission in 2012.

2 For a detailed discussion of contradictory forest statistics for the Philippines, see Kummer (2005); for the same regarding Indonesia, see Boomgaard (2005a: 213–16). This problem is dealt with on a global level by Peter Holmgren (2015).

have occurred at the rate of 240,000 hectares in 2000, 840,000 in 2012 and on average 500,000 hectares per year between 2000 and 2012.[3] According to *The Economist*, in the same year average annual primary forest loss in Indonesia during the period 2007–12 was 600,000 hectares (*The Economist*, 23 August 2014: 51). The first figure quoted, therefore, is evidently an outlier, possibly based on a misunderstanding or a typographical error. Nevertheless, the figures presented in Table 9.1 convey, in this author's opinion, a rough idea of a number of forest characteristics of Southeast Asian countries today.

The following observations seem to stand out. Southeast Asia has by now lost about half its potential forest cover, which should not be read as original forest cover, given the fact that every country contains areas where forests were never present. The figures given here represent that proportion of the land area that is still covered by forests. The forest cover percentages of Indonesia (52) and Myanmar (48) are close to this average value (49). The Philippines (26), Thailand (37) and Vietnam (42) are (far) below average, while Laos (68), Malaysia (62) and Cambodia (57) score above the regional mean. If we look at the last column, the figures suggest that the countries with a below-average forest cover (the Philippines, Thailand, Vietnam) show a – sometimes very small (Thailand) – net increase of forest cover, while all other countries, with cover percentages around or above the regional mean, show a net loss.

The net increase for the three countries mentioned here is the balance between deforestation and forest regrowth including forest plantations. In the case of Thailand, a logging ban was imposed in 1989 (Usher 2009: 17–20).[4] Vietnam issued a logging

Table 9.1 Forest Areas in Southeast Asia: Forest Cover and Rate of Change, 2005–10

Area	Forest area 2010 (000 ha)	Forest cover (%)	Annual change forest area (%), 2005–10
Indonesia	94,432	52	–0.7
Myanmar	31,773	48	–0.9
Malaysia	20,456	62	–0.4
Thailand	18,972	37	0.1
Laos	15,751	68	–0.5
Vietnam	13,797	42	1.1
Cambodia	10,094	57	–1.2
The Philippines	7,665	26	0.7
SE Asia	214,064	49	–0.5

Source: Southeast Asian Forests (2011: 8).

[3] Quoted from the Dutch newspaper *NRC Handelsblad*, 30 June 2014, section Wetenschap, p. 18.

[4] Thailand is another case of puzzling forest statistics. According to the most recent data its forest cover is now 37 per cent, but older statistics suggest that it was 25 per cent in the late 1970s and early 1980s, and even 15 per cent in 1986. An official estimate for 1998 has about 25 per cent (Hirsch 1993: 27; Usher 2009: 6). That is not easily squared with 37 per cent now, even if the rate of reforestation is now larger than the deforestation rate.

ban in 1993 (Phuc and Sikor 2006: 1). In the Philippines such a ban was imposed in 2011, and by the end of 2014, 1 million hectares were supposed to have been reforested. So while logging slowed down – surely nobody believes that the ban was adhered to everywhere – reforestation was speeded up (*Jakarta Globe*, 6 May 2014). It is not unthinkable, therefore, that there was a net increase in forest cover, as reported in Table 9.1.

On the other hand, it should not be supposed that a logging ban works always and everywhere, as witness the example of Indonesia. There, a logging ban was declared, also in 2011, but since then, deforestation has actually increased (*The Economist*, 23 August 2014: 51). But even in countries where the ban appears to have worked, illegal logging remains a big problem, as witness the situation in Vietnam (Phuc and Sikor 2006: 1).

Deforestation and population growth

A scatterplot for tropical Asia, linking forest loss and population density in 1990, already shows the highest figures of forest loss in Southeast Asia for the Philippines, Thailand and Vietnam. It also shows that these countries had the highest population densities of the region.

This points us in a direction that to some people will be unexpected: population growth as the main cause of deforestation, a conclusion drawn by Krishna Pahari and Shinji Murai the authors of the article in which the scatterplot was published, for deforestation and population growth in general, and not only for Southeast Asia. They give detailed data for Thailand for the period 1949–90, showing a high correlation between rates of population growth and rates of forest cover loss (Pahari and Murai 1999: 318, 321–2). As is shown presently, deforestation in the Philippines, Malaysia and Indonesia strongly increased after 1950 because of growing volumes of commercial logging, and some scholars, who are mainly interested in post-1945 developments, believe that, generally speaking, commercial logging is the main cause of deforestation.

However, if we go further back in history, that position is untenable. Locally, and in a number of cases in the second half of the twentieth century, it is certainly true. For instance, for the island of Borneo, of which the northern part belongs to Malaysia and the southern section to Indonesia, there is no doubt that commercial logging is at the root of large-scale deforestation. But again, this causation cannot be generalized or projected backwards. For Europe, it can be easily shown that, as a rule, the main cause of deforestation was the expansion of the arable lands, which was caused by population growth. A recent article shows this for England and France for the period from around 1000 to around 1850, when reafforestation set in (on which more below). It also applies to Japan and Southeast China (Lingnan). And although forest and population statistics for Southeast Asia prior to, say, 1800 leave much to be desired, a similar correlation has been posited for that region before the Second World War as well (Boomgaard 2007: 168; Saito 2009: 384–91).

Compared to China (heartland), the population density of Southeast Asia around 1600 was very low: about six persons per square kilometre (today it is 115) compared to forty-five in China. Then Southeast China had a forest cover of around 50 per cent, while in Southeast Asia it must have been around 90 per cent (Boomgaard 2007: 117; Saito 2009: 386). Here, again, forest loss was largely caused by land clearing, which was directly linked to population growth. I am not arguing that there was no commercial logging at all, but that the quantities logged commercially were dwarfed by the forest cover lost because of subsistence agriculture, and, of course, the increased felling of trees for timber and fuel, for and by the local population, for housebuilding and cooking.

The Forest Transition Curve

Getting back to deforestation and forest regrowth, it would appear, based on the Southeast Asia data in Table 9.1, that effective, net (re)afforestation does not occur until forest cover has reached a low point, which in the case of Southeast Asia turns out to be a forest cover proportion lower – occasionally far lower – than the average value for the entire region.

This phenomenon, usually called the 'Forest Transition Curve', is well documented for many developed and developing countries in the recent past, and was discussed from the early 1990s (Mather 1992). It happens at different stages in different places, but the trajectory is similar in most cases: if shown as a curve, each country represented as a spot on a graph with stage of development on the x-axis and forest cover proportion on the y-axis, one gets a curve like a reverse J, first going steeply down, then bottoming out and finally up, but only part of the way (*The Economist*, 23 August 2014: 51).[5] On such a graph, Indonesia and Myanmar would be on the part of the curve that goes down steeply, Thailand would be the trough and Vietnam and the Philippines would be located on the short leg going part-way back up.

The following quote regarding Vietnam confirms that a forest transition has taken place, referring to reforestation from the 1990s. It also suggests that the trough from which the short leg upwards departed was not as deep as the one found in earlier European forest transitions, which is good news if we may expect that this is going to apply to other Southeast Asian countries as well.

> The most consistent data on forest cover in Vietnam for the 1991–2001 period and available data before and after that suggest that a forest transition indeed took place. Deforestation occurred at least since the 1930s, with the highest rates during the 1970s and 1980s. Reforestation during the 1990s and 2000s occurred at a higher rate, due to a combination of a rapid increase in plantations and regrowth of natural forests. This high rate of reforestation, and the fact that it was higher

[5] Sometimes it is called a U-curve. It has also been suggested that the Forest Transition Curve could be regarded as a type of Environmental Kuznets Curve (Mather et al. 1999).

than the rate of deforestation for the previous decades, are unique to the forest transition in Vietnam … In other forest transitions, forest recovery is slower than the earlier deforestation. In 2005, the total forest cover was already larger than that of 1980 and the area of natural forests was similar … the remaining forest cover at the turning point was higher (25–31 per cent) than for the nineteenth or early twentieth-century forest transitions in Europe (around 0–25 per cent). (Meyfroidt and Lambin 2008: 1329–32)

The Great Acceleration (1945 to the present)

In the quotation just presented, it is pointed out that deforestation had occurred at least since the 1930s. That is certainly true (and also much earlier), and not only in Vietnam, as is shown below. But let me first present a few statistics going back various decades. They are, alas, not available for all the individual countries dealt with above, but only for the region as a whole and for its two subdivisions (Mainland and Island Southeast Asia).

An overview is given in Table 9.2, with Southeast Asian forest cover percentages from 1880 onwards. As can be seen, the loss of forest cover was accelerating over time. In the forty years between 1880 and 1920, somewhat over 5 per cent was lost. There is no point in trying to be precise here, as the figures upon which the cover proportions are based are relatively rough estimates to begin with (as one can imagine, given how bad the present-day figures are). In the thirty years between 1920 and 1950 – a shorter period, therefore – the loss was very similar (5.5 per cent), which is surprising given the fact that this period includes the Depression of the 1930s, when commercial logging might be expected to have been decreasing. Between 1950 and 1980, the next thirty-year period, forest cover dropped by almost 10 per cent, or double the change of the 1920–50 period. And finally, between 1980 and 2010, yet another thirty-year period, there was a slightly larger drop of over 10 per cent. The total decline in forest cover between 1880 and 2010 was about 30 per cent (from 80 to 50) of the total surface area. Obviously, average annual forest loss prior to 1880 was lower than afterwards (otherwise forest cover would have been 100 per cent in 1780, and, as I argue below, this was clearly not the case).

Table 9.2 Forest Cover in Southeast Asia: Selected Years, 1880–2010, Percentage

Region	1880	1920	1950	1980	2010
Mainland Southeast Asia	77.5	69.5	63.9	55.6	
Island Southeast Asia	84.0	79.0	74.1	64.9	
Entire region	81.2	75.0	69.6	60.9	49.0

Source: Boomgaard (2007: 216), based on Richards and Flint (1994); and from *Southeast Asian Forests* (2011: 8). Island Southeast Asia includes Malaysia.

Regarding the 1930s Depression, it can be easily shown that in colonial Indonesia (the Dutch East Indies), wood production figures showed a considerable drop after 1929, both for Java and for the Outer Islands. Forest exports from Myanmar showed a considerable drop as well. However, in French Indochina (Vietnam, Cambodia and Laos), timber production remained high up to 1938 (Boomgaard 1996: 149, 169; Saito and Lee 1999: 180; Cleary 2005: 271). Under Japanese occupation during the Second World War, the teak forests of Java were overexploited, the Japanese going way over the Maximum Sustainable Yield (MSY), and one supposes that that happened in other Japanese-occupied areas as well.

The acceleration in the drop in forest cover after 1950, shown in Table 9.2, is part of what has been called 'The Great Acceleration' (1945 to the present), which is seen as Stage 2 of the Anthropocene, or even as the beginning of the Anthropocene (Steffen et al. 2007; see also pp. 1–6 of this book). In the forests of Southeast Asia, this was, and still is, a major phase in their commercial exploitation, during which the MSY was entirely disregarded in countries such as the Philippines, Malaysia and Indonesia. For detailed information how this came about and how it worked, I can refer the reader to the excellent studies of Dauvergne (1997) and Ross (2001). A few details will suffice here.

In 1951, the Philippines became the world's leading exporter of hardwood logs. In 1956, the timber boom started in Sabah (part of Malaysia), and in 1967 in Indonesia (Ross 2001: 48). Japan was one of the most important importers of Southeast Asian timber from the moment the boom started (Dauvergne 1997). Although timber and other forest product exports from some of these countries had not been unimportant before 1950, they represented only a fraction of the share of forest products in the various economies after 1950. In 1940, timber exports from the Philippines constituted 3 per cent of all exports in terms of value, probably at that moment an Island Southeast Asian record. In 1973, timber constituted 18 per cent of all Indonesian exports. Between 1960 and 1975, Philippine timber export revenue fluctuated between 20 and 30 per cent of all Philippine export revenue (Boomgaard 2007: 247).

A special case is presented by Thailand, where the proportion of timber (teak) exports of all exports peaked shortly after 1900, constituting 10–11 per cent, dropping to around 4 per cent in the interwar period. Exports peaked again in the early 1950s, and then dropped again (Ingram 1971: 94–7; Hafner 1990: 79; Usher 2009: 75–7). Myanmar largely followed the pattern of Island Southeast Asia: in 1938/9 exports of timber (mainly teak) represented 7 per cent of total exports, dropping to 4 per cent in 1951/2, rising to 25 per cent by 1970 and to 42 per cent in the late 1980s (Bryant 1997: 174).

Absolute figures for the surface areas under forest cover in Southeast Asia between 1880 and 1980 are given in Table 9.3. We can see that between 1880 and 1950 the loss of forest cover in absolute terms was more or less equal in both subdivisions of Southeast Asia (i.e. Mainland and Island Southeast Asia). But it is also evident that between 1950 and 1980 many millions of forest hectares more were logged in Island Southeast Asia than on the Mainland, a confirmation of the importance of the timber export boom from Indonesia, Malaysia and the Philippines during this period.

Table 9.3 Wooded Areas in Southeast Asia: Selected Years, 1880–1980 (in millions of ha)

Region	1880	1920	1950	1980
Mainland Southeast Asia	150.3	134.7	123.3	107.8
Island Southeast Asia	215.4	202.8	190.0	166.4
Entire region	365.7	337.5	313.3	274.2

Source: Boomgaard (2007: 215), based on Richards and Flint (1994).

The Anthropocene and the forests of Southeast Asia

The Anthropocene is a relatively recent notion, of which Nobel Laureate Paul Crutzen is the spiritual father, arguing that 'it seems appropriate to assign the term 'Anthropocene' to the present, in many ways human dominated, geological epoch, supplementing the Holocene – the warm period of the past 10–12 millennia', starting from the moment 'when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane. This date also happens to coincide with James Watt's design of the steam engine in 1784' (Crutzen 2002: 23). Other criteria to support such a date would be the size of the human population (1 billion in 1800 versus 7 billion now) and the degree of urbanization (3 per cent in 1800, 50 per cent now). Many of those who came up with or were early adopters of the notion of the Anthropocene appear to agree that it started somewhere around 1800 (although 'the latter part of the eighteenth century' [Crutzen 2002] could be any time after 1750) (Steffen, Crutzen and McNeill 2007).

This is not to say that the human influence on nature was negligible before 1800 or so. Limiting ourselves to the human impact on the forests, there are various relatively recent studies to show that large-scale deforestation caused by humans is of ancient pedigree, at least dating back 6,000 years (Perlin 1991; Williams 2003; Ruddiman 2005). Neither is the idea that the strongly increased human impact, starting with the early years of the Industrial Revolution, is of recent date, entirely new, as witness, for instance, the writings of John Bennett, who, however, dates what he calls the ecological transition a bit later than the Anthropocene scholars do (e.g. Bennett 1976). But establishing a new geological epoch in order to emphasize the grown human predominance is, indeed, a new idea.

So what we would like to see here is disaggregated data on the Southeast Asian forests from around 1800. Alas, numbers are not (yet) available for most of the countries concerned. Crude figures for a number of areas around 1700 are presented in Table 9.4. From the data, it is easily shown that the expansion of arable lands between 1700 and 1850 was much larger in absolute and relative terms in the temperate zone (from 137 to 375 million ha, or an expansion of almost 200 per cent) than in the tropical zone (from 128 to 180, an increase of hardly 50 per cent). The concomitant loss of forest cover was also much larger in the temperate zone. Between 1850 and 1920 it was the other way around: forest loss slowed down in the temperate zone (in all

Table 9.4 Cropland and Forest Change: Selected Areas, 1700–1920 (in millions of ha)

	Cropland			Forest change	
Area	**1700**	**1850**	**1920**	**1700–1850**	**1850–1920**
Europe	67	132	147	–25	–5
China	29	75	95	–39	–17
Temperate total	137	375	618	–180	–135
South Asia	53	71	98	–18	–28
Southeast Asia	4	7	21	–1	–5
Tropical total	128	180	295	–70	–152

Source: Data based on Williams (2003: 277, 335).[6]

likelihood the beginning of the forest transition there), but speeded up in the tropical regions. This certainly also applies to Southeast Asia, where forest loss according to Table 9.4 was minimal, but increased after 1850 (still being low, however, in absolute terms: here the big *kladderadatsch* (crash) would not come until after 1950).

This is in accordance, therefore, with the findings I presented based on Table 9.2 – that loss of forest cover prior to 1880 was lower than after that date. If we take the percentages of loss per period found in Table 9.2 as our starting point, and project those backwards, assuming that the further we go back the lower the rate of loss will be, it is plausible to assume that Southeast Asia would have had a forest cover of about 90 per cent around 1770.[7] As I said earlier, there was never a time that the whole of Southeast Asia was under forest cover, given the fact that some places can be too dry, too wet, too steep or too high for forests to grow there. Let us suppose that that part of the region's surface area was 5 per cent. If we then accept that agriculture started in Southeast Asia from 4000 BCE, it took almost 6,000 years to deforest 5 per cent of the surface (from 95 to 90 per cent), given that by 1770, 90 per cent forest cover was still there. As this percentage is obviously based on 'guestimates', it could have been slightly lower, but, in my opinion, not higher, as that would imply that hardly any logging had occurred before 1770, which was not the case as is shown presently.

Earlier deforestation

Deforestation is a phenomenon to be found in many historical epochs, and not just after the late eighteenth century. Earlier deforestation episodes are difficult (or, rather, impossible as a rule) to quantify, but locally they could be quite large, leading to the

6 Williams's figures for Southeast Asia are much too low in my view.

7 The total loss of forest cover in the thirty-year period from 1920 to 1950 was 5 per cent. The same percentage was lost during the forty-year period from 1880 to 1920. If we assume that the loss would be roughly the same during the fifty years from 1830 to 1880, and the sixty years from 1770 to 1830 (heroic assumptions for sure!), forest cover in 1770 would have been 90 per cent.

fall of great civilizations through the effects of erosion or siltation. However, these were localized phenomena, and on a global scale deforestation is usually not regarded as impressive prior to 1800 or even 1850.

However, William F. Ruddiman, a climate scholar with an abiding interest in history, has written an entire book to show that the two greenhouse gases carbon dioxide (CO_2) – from cutting and burning forests – and methane (CH_4) – from irrigated rice cultivation and livestock keeping – already began their slow rise thousands of years ago: carbon dioxide 8,000 and methane 5,000 years ago, in such a way that 'the total effect of these earlier changes nearly matched the explosive industrial era increases of the last century or two' (Ruddiman 2005: 5). Ruddiman, who does not mention the notion of the Anthropocene in his book, does not deny the increased human impact through industrialization (sometimes he says 'after 1850', sometimes 'during the last 200 years', or '100–200 years'), but he argues that the slow accretion before 1800 or 1850 so far has not been sufficiently emphasized.

There is no doubt that the exploitation of the Southeast Asian forests started a long time prior to 1850 (or 1800, or 1770). For instance, the island of Singapore, which was made a British colony shortly after 1800, and is now an independent and very prosperous city-state, witnessed 'rapid and almost complete destruction of the primary forest habitats within the first century of colonization' (O'Dempsey 2014: 46). This was mainly done by Chinese smallholders and woodcutters and by Europeans. By the middle decades of the nineteenth century, Singapore, which had been almost entirely covered by forests around 1800, was importing logs in the form of rafts comprising 2,000 logs each. They arrived regularly from Johor (Malaysia) and were floated to Singapore sawmills (Kathirithamby-Wells 2005: 39). Much earlier (before 1500), the Red River Delta in northern Vietnam (the region that used to be the kingdom of Tonkin) was already a densely populated, almost entirely deforested, irrigated rice-growing and urbanized area. My own research regarding the history of the forests of Java (Indonesia) from 1500 suggests that between 1657, when the Dutch East Indies Company (VOC) seriously started the felling of teak in Java, and the year 1840, two-thirds of the 3.5 million hectares of teak forest disappeared.[8] The VOC needed the teak for ship repair and shipbuilding, for the construction of houses, warehouses, churches, hospitals and other buildings, and for bridges, embankments and so on. During the sixteenth century, the Javanese had been building hundreds of large sea-going vessels, also made of teak.

In fact, ship and boat building was being carried out in many Southeast Asian countries before 1800. The use of teak for boat building was reported from Burma (now Myanmar) in 1786, but the construction of relatively large sea-going vessels – no doubt also made of teak – in Pegu (now part of Myanmar) was already well established by 1500, and continued during the sixteenth, seventeenth and eighteenth centuries (Andaya 1992: 377; Dijk 2006: 89; Bryant 2007: 145). Large sea-going ships were made in Siam (Thailand) at least from 1638, when 120 sea-going vessels were built for an

8 Data on the – much larger – non-teak forests is lacking prior to 1840.

assault on Patani.[9] Around 1820, the capital, Bangkok, had a sizable shipbuilding industry, using teak, which was also exported in large quantities (Terwiel 1989: 38, 256; Terwiel 2007: 49). Already in the sixteenth century there were shipyards in the Philippines, and it would appear that in the seventeenth century they were building larger ships, such as galleons in 1616 (Bankoff 2007: 105–6).

Shipbuilding, therefore, mainly but not exclusively using teak, was an indigenous Southeast Asian tradition predating the arrival of the Europeans in the sixteenth century. The same thing could be said about India and China. It is highly likely, however, that the coming of the Portuguese, the Spaniards, the Dutch and the English to Southeast Asia (and India) led to an increase in shipbuilding, and therefore of timber felling, particularly of teak. It is less clear what happened to indigenous shipbuilding after the arrival of the Europeans. For Java, it is not difficult to prove that the role of indigenous construction of ships (as opposed to boats), particularly on the orders of local rulers, diminished after, say, 1675, but whether that also applies to other Southeast Asian countries I am not in a position to say. Nevertheless, I regard it as likely that the total volume of shipbuilding increased for the region as a whole, but it is important to have established that it did not start from zero around 1600.

One should also be aware of the multiple other uses of wood prior to 1600, something that also applies to India, China and Japan. The two main categories of wood use were the construction of buildings and the need for wood fuel/firewood for cooking and industrial (artisanal) purposes (heating of houses was unimportant in the tropics). Wood, bamboo (technically speaking a grass, not a tree, but often part of a forest) and palm leaves (as thatch) were in most areas of the region the main building materials for private dwellings. But even palaces, mansions and religious buildings (mosques, churches, temples) were usually made of timber, although people who visited Borobudur (Java) or Angkor Wat (Cambodia) might think that building in stone or brick was the rule for palaces and religious buildings. Given that houses and other buildings burned down with sad regularity, and that timber was subject to rot and termite damage, the replacement rate of dwellings was quite high. And although the average population density of the region around 1500 was rather low, some regions (Red River Delta of Vietnam, Central Java) had several millions of inhabitants, which meant that even at low rates of population growth, many new households were generated regularly, needing houses. Again the need for firewood, even in a tropical climate, can easily be underestimated. For cooking alone 25 million people (Southeast Asia's total population around 1600 [Reid 1988]) needed prodigious quantities of (wood) fuel! And even at a very low annual rate of growth of, say, 0.1 per cent, some 25,000 people were added annually, who, although breastfed during their early years, would eventually turn into additional cooked-food-eating adults.

These 'pre-industrial' economies contained extensive artisanal manufacturing such as pottery, brick and tile making, metal-working (tin, zinc, iron, bronze, copper, silver, gold), tanneries, sugar production (both cane and palm), arrack distilleries, indigo production, silk production, tobacco curing, processing coffee beans, salt, saltpetre

[9] Then a Malay Kingdom, now covering a part of southern Thailand and northern Malaysia.

and sulphur making, the production of gunpowder and boat and shipbuilding. In all these cases some form of heating took place, for which firewood – and occasionally charcoal – was usually employed. Estimating quantities used would be difficult, but again it can be assumed that those quantities were large and growing almost continuously (except during and shortly after wars, epidemics, famines and other large-scale disasters).

We know that capital cities of 'Malay' dynasties were often moved, because there had been an epidemic, a volcanic eruption, a conflagration, or a flood, the death of a monarch, destruction due to a war, the place thus having been spiritually polluted, or because it was believed that a capital should be moved after a certain period of time, even if there were no specific reasons to do so (Hall 2011: 142). The literature on this topic does not mention exhaustion of (timber and firewood) resources, but it stands to reason that if all mansions, palaces and mosques were wooden constructions – which needed frequent repairs, or had to be replaced after a fire – the environs of the *kraton* (palace) would soon be deforested, thus suggesting yet another explanation for the repeated translocation of (capital) cities. Such a connection is well documented for pre-modern Japan as well (Totman 1989: 12–16).

Natural (re)afforestation and tree plantations

We tend to think that in the remote past tree planting on any scale, in the sense of (re)afforestation, did not occur. We usually suppose – without always spelling it out – that in an unspecified past perhaps 95 per cent of the surface area of any region had been under forest cover, and that thereafter it was downhill all the way. But that is not necessarily true (although there may be countries for which it is true).

In the first place, in many pre-industrial societies, calamities of one sort or another occasionally wiped out large percentages of the population, which then took perhaps a century or more to recover and return to its pre-disaster level. Good examples are the Black Death (the Plague), in Europe from 1346, and the great dying in the Americas after, and caused by, the arrival of the Europeans since 1492. Epidemics in the 1330s, possibly including the Plague, killed 25 million Chinese and other Asians. Wars, such as the Thirty Years' War in Germany from 1618, could play a similar role. The Mongol conquest of China in the thirteenth century killed perhaps 30 million people (Hudson 2014: 948). High level and prolonged crisis mortality, although probably not on a comparable scale, occurred in Southeast Asia as well. Based upon my own research I can mention two episodes in seventeenth-century Java, and one dating from the eighteenth century – the years 1657–65, 1674–9 and 1754–61. Only for the last episode do we have estimates of the death toll, which was reported to be between 100,000 and 150,000, which would be less than 5 per cent of the entire population, and thus much less than the mortality levels obtained in fourteenth-century Europe and fifteenth-century America (Boomgaard 2001, 2005b). This type of data is also available for other Southeast Asian areas (Lieberman 2003; Newson 2009).

From American and European evidence, we know that during such large-scale and long-lasting mortality episodes, economic growth was reversed, entire regions became depopulated and agriculture disappeared, arable lands reverting to forest cover. Here, therefore, we encounter episodes of natural reforestation. Climate scholar Ruddiman, mentioned earlier, found evidence that these episodes were large enough to show up as lower CO_2 levels in the ice-cores employed for climate history studies. This might be (part of) the explanation of the so-called Little Ice Age (Ruddiman 2005: 139–46). To my knowledge, no one has studied this kind of natural reforestation for Southeast Asia, but given the mortality episodes just mentioned, such 're-wooding' must have occurred as well. As a consequence, the graph representing the changing proportion of forest cover over time was not a smooth downward sloping line, but must have shown ups and downs. We will need more evidence before we can establish whether there was at least a downward trend, and if so, for which period(s).

However, there is also early evidence for the laying out of tree plantations, way before the nineteenth century. The case I am most familiar with, the Indonesian island of Java, might not be typical for what went on in the rest of Southeast Asia. There are good reasons to believe that teak, which would play such an important role from the sixteenth century, is not indigenous to the island but was introduced, probably from India. Teak is never mentioned in the many inscriptions dating from around the year 1000, but it was certainly present by the fourteenth century, and it is highly likely that by then it had multiplied considerably, presumably largely through the laying out of tree plantations, probably on the orders of the rulers (Boomgaard 1988: 61). Other evidence strongly suggests that teak tree planting took place on some scale around 1600 (De Graaf 1971: 118). This could be linked to the fact that during the sixteenth century the Javanese had fought many sea battles against the Portuguese, which the former had lost. Thus, they also lost most of their sea-going vessels each time, having to build new ones. This must have resulted in an onslaught on the teak forests, which then needed restocking.

I have seen no evidence for the planting of teak by Javanese rulers dating after about 1650, when such an occurrence might have been mentioned in VOC reports. By 1650, according to Dutch testimonies, forests covered the island from West to East in a broad belt (De Graaf 1956: 182), and planting might have appeared superfluous. Soon thereafter, Javanese rulers stopped building ships.

Serious teak tree felling on the orders of the VOC started, as we saw, in 1657. In the 1670s, we encounter the first complaints about depleted forests. Statements regarding forest depletion, apparently now on a larger scale, were repeated in 1705, 1708, 1714, 1717 and 1719. While in the Rembang area (Java's north coast) in 1686 it had taken six to eight hours to tow logs to the coast (dragged by buffaloes), by 1708 deforestation had increased so much that by then it took twelve days to drag large-dimension timber to the coast, and by 1738 it was even fifteen days. In response to these complaints, the Company initiated a series of forest closures. In 1722, the VOC 'closed' a forest to all logging for the first time – the first (albeit local) Indonesian moratorium on logging so to speak – a period of closure that would last thirty-three years (De Haan 1910–12, IV: 34).

By treaty with the ruler of Mataram (central Java), dated 1743, the Company acquired the teak monopoly for his entire realm. One clause of this treaty is particularly interesting; it states that the monarch would order his regents (local officials) to reafforest those sections of their woods that had been depleted to such an extent that it might lead to future timber shortages. To my knowledge this is the first time that replanting of teak during the VOC period is mentioned in any source. Whether this order was ever implemented is unknown (De Jonge 1862–95, IX: 445). During a forest survey, carried out in 1776, it was reported that forest tracts that had been cleared were sown with teak seeds, but more detailed information on these plantations, if we can call them that, is lacking. Neither is there any mention of weeding, thinning or interplanting. Was this teak seed sowing the result of the ruler's orders mentioned above? In a proclamation regarding the forests of Rembang, Lasem and Tuban (on the northern coast of central Java), dated 1787, the VOC included a specific clause that empty spaces in the teak forests should be used for teak plantations. A detailed report of a survey of the forests of Jepara and Kudus (in the same area), dated 1797, mentions well-cared for teak plantations, as does a report from Pekalongan (again on the north coast), regarding plantations laid out in 1795. Various attempts at regenerative forestry are dated shortly after 1800. Although perhaps not all plantations laid out just before or after 1800 were equally successful, it would appear that at least a serious start had been made.[10]

However, in the meantime logging had been going on as usual, with harvests far above the MSY, even though in 1776 the VOC had already stated its intention to arrive at sustained yield forestry in the teak forests. And although there were several attempts undertaken after 1800 to introduce a more systematic and 'scientific' system of teak forest management and exploitation, under the umbrella of two short-lived forest departments (1808–13, 1819–26), the forest regulations issued in 1829, dealing extensively with the planting of young teak trees, could not curb the increasing demand for (teak) timber. Thus, the average annual loss of teak forest cover was higher between 1840 and 1870 – the period of the so-called cultivation system – than it had been between 1776 and 1840 (Boomgaard 1988: 79). Replanting, however, appears to have been taken seriously: it could be argued that from 1836, when the director of cultivation demanded annual reports from the local government officials regarding teak planting, teak had become one of the many cash crops grown under the cultivation system. Planting increased somewhat during the last decades of the nineteenth century, when a new forest department – the third one – had come into being. But the real increase came around the turn of the century, when the laying out of plantations had become a matter of routine teak forest management. Around 1895, the trough of the teak forest cover curve had been reached, and the area under teak started to grow. However, the non-teak forests still saw their cover percentage declining (Boomgaard 1996: 25–6, 153–9).

[10] National Archives, the Netherlands: Collection Nederburgh 379, 1, Report 3 November 1797; Coll. Reinwardt 19, Report 1798; NA, Coll. Van Alphen/Engelhard, 1916, 78: Report 1801; Coll. Van Alphen/Engelhard, 1900, 244: Report 1807; Coll. Baud 40, Report 1 November 1818.

In other Southeast Asian areas – Myanmar, Thailand – teak occurred naturally, and the need for teak plantations might, therefore, have been less pressing. On the other hand, just as happened in Java, locally, naval battles, or conflagrations, might have destroyed local resources on such a scale that the people either had to move away or start (teak) tree plantations. And, after all, we do know that teak occurred naturally in those countries at an early date, but we do not know where exactly. It is certainly possible that local rulers with no teak at their disposal started teak plantations. The same reasoning applies to India, presumably the origin of Java's teak trees.

It is worth noting that, elsewhere in Asia, convincing evidence for relatively early reforestation exists for at least one country, Japan. Here, during the – at least partly government-sponsored – building boom of the early Tokugawa period, forest depletion had set in on a considerable scale, and to such an extent that local officials stimulated tree planting from the 1660s, initially using corvée labour. By the 1750s this type of reafforestation became more widespread, labour now being paid. Reforestation on the initiative of central government got under way from the 1740s. Commercial afforestation took off in the eighteenth century as well, but it did not become large scale until after 1800 (Totman 1989: 165–9; Totman 1995: 31, 102–4; Saito 2009: 385, 392–6).

Tree growing and tree plantations – often as a commercial venture – are also mentioned for China in the seventeenth and eighteenth centuries. Locally, deforestation was already mentioned under the Song dynasty (960–1279). If we limit ourselves to the most highly developed regions in the eighteenth century, we find that Jiangsu province, consisting largely of part of the Yangzi Delta – an area that always had fewer trees than most of South China – had only 5 per cent forest cover around 1700. Lingnan was doing somewhat better, still having 30 per cent forest cover in 1813 (Menzies 1994; Pomeranz 2000: 228–30).

Conclusion

In Europe's early developing economies – the Dutch Republic, England, France – regenerative forestry often started late (at least compared to Japan), and the trough of the forest cover graph was not reached until cover levels were very low, between 5 and 15 per cent. Southeast China (Lingnan) had not much forest cover left in 1930, and it is not clear whether there was an upturn at all (Williams 2003: 279; Saito 2009: 386–7). We saw already in passing that Vietnam did better than Western Europe (and Lingnan). We can confidently state that Southeast Asian countries in general performed better, given that the turnaround, if and when it came, came at values between 25 and 45 per cent. But as far as Asia is concerned, the jackpot goes to Japan, where the lowest level recorded by Saito (2009: 386) was 65 per cent.

However, some (re)afforestation had occurred much earlier, at least locally. Whether or not teak was introduced to Java from outside – and there are strong indications that it was – we are fairly certain that teak plantations were laid out around 1600. There are signs of (intended) reforestation in 1743 and 1776, while there is mounting evidence that regenerative forestry was taken up seriously around 1800. This timing is close to that found for Japan, but the latter country started its reforestation when its forest cover was much higher still than the level it had reached in Java at the time (about 50 per cent around 1800).[11] In Java reafforestation increased in various stages during the nineteenth century, to such an extent that it had become a routine matter around 1900, when the teak cover percentage had started to rise.

Regenerative forestry is probably almost always a sign of – often local – deforestation, although for instance in China tree planting could be an advantageous proposition, even if there was no serious deforestation. In Japan and China it occurred on some scale from the seventeenth century (and possibly earlier).

In Southeast Asia the general picture appears to be that before the 1980s reforestation was very rare, and only undertaken locally. I have only seen evidence for Java going back to the eighteenth century, but I assume that something similar could have occurred in that other high-density area, the Red River Delta in Vietnam. In Java it was clearly linked to a dwindling teak forest cover, at a moment that the general forest cover for the island was around 50 per cent.

At that moment (late eighteenth century), the average forest cover for the whole of Southeast Asia must have been something like 85 or 90 per cent, much of which was 'old growth', what we used to call 'pristine'. During the nineteenth century, the average annual rate of deforestation increased continuously, but gradually, and there does not seem to be a point at which deforestation gets in higher gear, although until we have more detailed data by country, we cannot be sure that it did not occur in one or two of the countries in the region, for which Myanmar and Thailand (teak again!), in my view, would be good candidates.

The big acceleration took place from the 1950s and 1960s, thus joining the 'Great Acceleration' on a global scale (and not just for the forests). The last twenty-five years have seen the beginnings in the region of large-scale reafforestation, hopefully a turning point for Southeast Asia in general, which would be much earlier than the Forest Transition and Environmental Kuznets Curve literature predicted (Sunderlin et al. 2005: 1394). If so, as was the case with the Demographic Transition that occurred from the 1950s, Southeast Asia again will have taken the world by surprise (Boomgaard 2014: 92–4).

As deforestation, certainly in Southeast Asia prior to 1950, was primarily caused by land clearing for and by a growing population, at very low rates of population growth before 1800 and in many areas even before 1900, high rates of deforestation were not to be expected either. With very low population densities, the human factor hardly made itself felt prior to 1880, when over 80 per cent of the region was still under forest cover (Table 9.2). Therefore, an Anthropocene based on Southeast Asian forests did not occur until at least a century after the date set by those who came up with the term, and one could even defend the proposition that it post-dated the Second World War. However, it should be emphasized that considerable human influence on the forests is locally in evidence from at least the fifteenth or sixteenth centuries, as witness the case of Java. Such a late date as the 1950s for the beginning

[11] This was the general forest cover: the teak forest cover was only 10 per cent (Boomgaard 1996: 26).

of the Anthropocene is now supported on a global level by recent publications, for which this chapter provides additional ammunition (cf. Leinfelder 2015; Lewis and Maslin 2015: 176–7).

In this chapter we have only discussed the forests of Southeast Asia, and not an economic sector as important as agriculture, including livestock keeping, or, for that matter, mining. Certainly in agriculture, international market forces were quite extensive from an early date, and totally reshaped the natural environment, at least since the sixteenth century. But that is a different story, one I have told elsewhere (Boomgaard 2007: 111–202).

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10

Developing the Rain Forest: Rubber, Environment and Economy in Southeast Asia

Corey Ross

Amidst the plethora of critiques that have swirled around the concept of the Anthropocene, one of most common (at least in the humanities and social sciences) is that it tends to posit the 'human species' as an undifferentiated biological agent collectively responsible for altering various Earth systems to an unprecedented and probably dangerous extent (e.g. Bonneuil and Fressoz 2013: esp. 82–91). Whatever the merits of this approach from the perspectives of 'deep history' and 'big history', it is of course crucial to recognize that some groups have driven these changes much more than others. Obviously, most of the societies in Southeast Asia, as in the rest of the global South, have not been in the driver's seat (literally), at least not until recently. This no doubt goes some way towards explaining why the region has featured only marginally in the leading surveys of modern global environmental history (McNeill 2000; Richards 2003; an exception is Burke and Pomeranz 2009).

Despite this common criticism, the concept of the Anthropocene can nonetheless helpfully capture a sense of the immense environmental and economic transformations that have taken place in Southeast Asia since the late nineteenth century, on at least two different levels. First, it serves to highlight the dramatic changes within the region itself, above all the rapid stepping up of land conversion and the explosive rise in population – especially during the 'Great Acceleration' of the second half of the twentieth century – as well as a marked shift towards industrial development and urbanization since the 1960s–70s. Second, it underscores the many ways in which these changes were linked to the central processes of industrialization taking place elsewhere in the world, and how the exploitation of the region's forest and mineral resources fitted into the wider intensification of the human planetary footprint over the past century or so. Given the overriding importance of primary commodity exports for economic growth in much of Southeast Asia, it is useful to approach these regional and global perspectives in tandem. Throughout this period, the interconnected processes of environmental change and economic development have been closely related to the region's role as a supplier of raw materials to global markets, even after certain countries moved their export-oriented economies onto a more industrial footing from the 1960s onwards. At the same time, some of the natural resources that were shipped overseas played a vital role in the economic development of the industrial societies that truly led the way into the Anthropocene.

The prime example in this respect was rubber, which will be our focus here. For much of the twentieth century rubber was not only the leading export from Southeast Asia but also, from the perspective of the main industrial powers, the most important raw material emanating from the region. Since the 1910s Southeast Asia has utterly dominated the global production of natural latex. For over a century it has provided between 80–90 per cent of world supplies, most of which (on average around two-thirds) went into car, bus and truck tyres. The swelling flow of Southeast Asian latex into the industrial economies – a flow that continued to grow even after the expansion of synthetic rubber from the 1940s onwards – not only served as a central engine of economic development in the region; it also represented a vital resource subsidy that underwrote the radical economic and social transformations of the automobile age more generally.

While the huge economic opportunities presented by rubber production drove far-reaching environmental changes across large parts of Southeast Asia, its consumption simultaneously helped to remake entire economies and landscapes in the major importing countries. This alone makes rubber a useful vehicle for thinking about the entangled transformations of the Anthropocene. But what renders it even more fruitful as a case study is that it also offers a particularly vivid illustration of how the relationship worked in the other direction; that is, how environmental parameters also shaped economic opportunities and behaviour. This has not been a central focus of the literature on the Southeast Asian rubber industry, which has by and large concentrated on its economic and commercial aspects.[1] To be sure, existing works take account of the region's natural endowments, its suitability for rubber cultivation and some of the agronomic problems that planters encountered, but environmental factors have not been integrated to the same extent as they have been in studies on rubber production in the Americas (Dean 1987; Finlay 2009; Garfield 2014).

Here we will briefly consider two aspects of this relationship. First, the chapter will outline how a particular set of biophysical conditions played a fundamental role – alongside other factors such as prices, labour and productivity – in the development of the natural rubber industry. Simply put, its emergence and rapid growth in Southeast Asia cannot be properly understood outside this broader environmental context. The second point, however, is that within this basic biophysical framework there were still quite different ways of exploiting the region's environmental advantages. In turn, the decisions that were made about how to do so could generate quite different social and ecological effects.

[1] The principal studies are weighted towards Malaysia: Barlow (1978), Drabble (1973, 1991) and Tate (1996). Exceptions, with an environmental focus, are Aso (2014) (on colonial Indochina); also Beinart and Hughes (2007: 233–50).

Ecology and the establishment of the Southeast Asian rubber industry

To start, we can get a basic sense of the overarching environmental and economic changes in the region by turning to survey data on shifting modes of land use since the late nineteenth century. Although the figures should be regarded as indicative rather than definitive – especially the farther back they go – they nonetheless demonstrate some clear patterns. From 1880 to 1980, the total cultivated area in mainland and island Southeast Asia rose from 16 to 78 million hectares (ha), while forest cover correspondingly shrank from 365 to 274 million ha (the total area of the region surveyed is 450 million ha, and includes Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Brunei, Singapore, Indonesia and the Philippines). Within the cultivated area, the extent under temporary crops (mostly rice and maize, the bulk of which was destined for local consumption) rose from 14 to 60 million ha, while the figures for perennial crops (mostly silvicultural crops bound for export: e.g. rubber, coffee, oil palm, coconut) increased from 2 to 18 million ha. The rate of expansion of the cultivated area was highest between the benchmark years of 1880 and 1920, and again between 1950 and 1980, which broadly accords with patterns of global economic expansion more generally. Although annual crops still accounted for around three times more area than perennials at the end of the period, the growth rate for perennials between 1880 and 1980 was more than twice as high. Since annuals roughly corresponded to what we might call subsistence crops, and perennials to commercial crops, this difference reflects the remarkable boom in exports from the region – though growing food for a swelling population (which rose from 57 to 356 million over the period in question) remained the most important driver for overall land conversion (figures from Richards and Flint 1994: esp. 34, 36; also Boomgaard 2007: 214–18).

Among other things, what these figures illustrate is the highly land-extensive character of Southeast Asian economic growth throughout most of this period. Despite intensive paddy farming in the region's rice baskets (mainly river deltas), a sharp rise in mineral (and later petroleum) production, as well as a shift towards industrial manufacturing since the 1970s, a high proportion of economic activity has centred on the exploitation of plentiful forest land, which in most areas was far more abundant than labour or capital. This was true of agricultural expansion in general, but it was especially evident with the expansion of export crops. Among the various cultivars that were grown for overseas markets, rubber was not, of course, the first or only vehicle for tapping the immense forest capital of the region. Pepper, coffee, sugar and resins had long been exported from the region, and continued to play an important role in certain areas well into the twentieth century. But rubber quickly assumed, and for most of the century retained, a dominant position, especially in Malaysia, parts of Indonesia (Sumatra and Kalimantan) and later Thailand. In the most extreme case, Malaysia, it still accounted for over half of all export value as late as the 1960s and utterly dominated all other crops with regard to land and labour use (Barlow 1978: 439; Drabble 2000: 216). Of course, a whole bundle of factors contributed to the supremacy of Southeast Asian rubber production over competitors in other parts of the world, including well-established trade networks, available land and access to adequate labour (much of which came from outside the region). But environmental advantages, and the relative resource rents they generated, were also fundamental.

The origins of the industry are perhaps familiar, but they are nonetheless worth rehearsing in order to appreciate the importance of biophysical factors in its creation and evolution. Before the 1910s most latex was collected from a variety of wild plants scattered across the world's tropical lowlands: *Hevea brasiliensis* and *Manihot glaziovii* in South America, *Castilloa elastica* in Central America, *Ficus elastica* in Southeast Asia (which was also cultivated on a small scale), *Landolphia* vines and the *Kickxia* tree (*Funtumia elastica*) in Africa. Among all of these candidates *Hevea* yielded not only the most latex but also the highest-grade rubber, labelled Pará rubber (the standard on international commodity markets) after the Brazilian state that dominated its production. Partly due to the superiority of *Hevea* latex for most industrial applications, and partly to the system of coercive labour that enabled local strongmen to funnel the collected latex to purchasing agents in Belém and Manaus, Brazil was by far the leading rubber producer in the world at the turn of the century, accounting for nearly 90 per cent of world exports (with Sub-Saharan Africa supplying most of the rest) (see generally, Weinstein 1983; Dean 1987).

Nonetheless, by the 1900s the wild rubber industry faced a growing number of challenges. For one thing, it was increasingly dogged by political scandals, most famously the campaign against 'red rubber' in the Congo Free State, but also the Putamayo Affair in the upper Amazon and the M'Poko investigation in the French Congo (Morel 1906; on the Putamayo, Stanfield 1998: 131–78; on M'Poko, Coquery-Vidrovitch 1972: 177–84). Although the humanitarian atrocities that accompanied rubber collection may have drawn the bulk of public attention, ultimately it was the mounting incongruity between the industrial scale of demand and primitive methods of supply that posed the most fundamental problem. Thanks principally to the invention of the pneumatic tyre, demand for rubber rose sharply after the 1890s and then exponentially from around 1905 onwards with the growth of the automotive industry. Global production had already risen from just 10,000 tons in 1875 to over 50,000 tons in 1900. It reached 120,000 tons on the eve of the First World War, and as most investors fully expected, the market for rubber continued to surge over the following quarter century (in 1939/40, 1.1 million tons of rubber was absorbed on world markets) (Bauer 1948a: 380, 392; Drabble 1973: 222; Barlow 1978: 10–16; Loadman 2005: xxviii, 66). The existing system of wild latex collection was in no position to meet demand; there was only limited scope to boost wild latex collection in Amazonia, and in parts of Africa production had already begun to decline due to overexploitation (Chevalier 1906: 4–5, 7).

In response, many observers pinned their hopes on plantations as a more rational basis of production, and sought to establish concentrated *Hevea* estates in the areas of Amazonia where the tree grew naturally. It was a seemingly obvious solution, yet in the event none of these plantations were successful. In part this was because of commercial obstacles and difficulties in recruiting adequate labour supplies, but it was principally due to a fundamental ecological problem: namely, the South American leaf blight (*Microcyclus ulei*), a fungus endemic to the Amazon basin that kills or severely weakens stricken *Hevea* trees. Despite the high susceptibility of *Hevea* to the fungus, for thousands of years it nonetheless shared the Amazonian rainforest with *M. ulei* through a reproductive strategy of dispersing itself thinly (generally no more than a few per acre) among a host of other tree species. Some strains of *Hevea* are more resistant than others, but minimizing infection through the maintenance of low concentration levels was the tree's primary natural defence. As a result, the attempt to cultivate a dense monocrop of *Hevea* was diametrically opposed to a survival tactic that had developed over many millennia of co-evolution, and essentially created an enormous, paradisiacal habitat for the leaf-blight fungus. If, in strictly commercial terms, the establishment of *Hevea* plantations in Amazonia seemed eminently sensible, it proved a non-starter from a biological perspective. All subsequent efforts to control the disease via fungicides, seed selection and protective barriers resulted in failure, and planters quickly lost interest (Dean 1987: ch. 4, esp. 58–9). During the inter-war years Henry Ford made a final valiant effort to establish concentrated commercial *Hevea* stands in Brazil's Pará state, but even his multi-million-dollar 'Fordlandia' plantation soon succumbed to the humble leaf blight fungus and was eventually converted into a cattle ranch after he sold it to the Brazilian government in 1945 (Dean 1987: 72–84; Grandin 2010).

In the meantime, other planters sought to circumvent this biological obstacle by growing *Hevea* elsewhere. Around the turn of the century there was a series of attempts to grow *Hevea* in various parts of equatorial Africa, but planters found that it suffered from the longer dry season and performed less well than latex-bearing *Funtumia* or *Manihot* species (Jumelle 1898: 77–123; du Vivier de Streel 1917: 32–4; Coquery-Vidrovitch 1972: 428–31). As it turned out, nowhere else proved more suitable than parts of Southeast Asia – initially Peninsular Malaysia and Sumatra – where climate and soils were appropriate (namely consistent rainfall of over 1,500 millimetres per year, well-drained soil and little seasonal temperature variation), land was abundant, access to labour was adequate and, crucially, there was no leaf blight. In biological terms, the absence of *Hevea*'s primary enemy in Southeast Asia created the conditions for 'ecological release', or the rapid expansion of a population into new ecological niches unchecked by the competitive constraints of its previous habitat. In economic terms, this environmental advantage gave Southeast Asia a vast differential rent vis-à-vis *Hevea*'s Amazonian home – as well as an advantage over rival planters in Cameroon, Equatorial and East Africa growing less profitable latex-bearing species due to the different climatic conditions there (Ranniger 1907: 113–22; Deeken 1914: 22–6; Warburg 1918: 7–8; Kautschuk und die deutschen Kolonien c.1917: 2–3; Marckwald and Frank 1911: 250–1).[2] Indeed, the adoption of rubber as a major commercial cultivar in Southeast Asia was further boosted by another biological factor unrelated to *Hevea* itself: namely, the spread of the coffee rust fungus,

[2] It has, however, been argued that in central Africa the disadvantages vis-à-vis Southeast Asia were principally related to political and labour structures, which hindered the development of rubber in spite of similar factor endowments: Clarence-Smith (2013).

which was ravaging many of the region's coffee estates around the turn of the century and thereby made rubber all the more attractive as a plantation crop (McCook 2006).

The result was a frenzy of *Hevea* planting from around 1905 onwards. Overall rubber acreage in Southeast Asia rose from 1.1 million acres in 1910 to 4 million acres in 1920 to around 10 million acres – an area roughly the size of the Netherlands – in 1940 (about 8 million acres were in Malaysia and the East Indies, with most of the balance in Sri Lanka, Thailand and Indochina). Given the lag time of several years between planting and full production, it was only in 1914 that exports from Southeast Asian estates first surpassed those of wild rubber. From then on, however, the shift was dramatic. Three years later they outstripped wild rubber by a ratio of nearly 4:1, and by the end of the 1920s over four-fifths of world rubber exports came from Malaysia and the Dutch East Indies alone, whereas wild rubber had declined to a trickle (Drabble 1973, 1991; Barlow 1978).

Rubber plantations and their problems

Southeast Asia's rubber industry was, then, based on a particular set of favourable conditions, among which the biological ones were crucial. But how best to capitalize on these advantages remained an open question. Like all crops, rubber has a number of characteristics that influence where and how it can be grown, as well as the scale at which it is cultivated. In common with fellow tree perennials coffee and cocoa, rubber seedlings require several years (usually five to seven) before the trees are mature enough to yield an income, which tends to encourage more long-term and individualized tenure arrangements (either of the land or the crop itself). Yet in partial contrast to cocoa, which became a predominantly smallholder crop during this period (especially in the epicentre of West Africa) (see Austin, this volume, also 1996; Ross 2014: 49–71), and unlike sugar, whose cultivation tended to be more centralized due to processing and harvesting needs (though there were exceptions: Bosma 2013), rubber cultivation was (like coffee growing) simultaneously practised on widely different scales ranging from vast, carefully engineered corporate estates to countless smallholdings otherwise used primarily for subsistence agriculture. By and large these different scales represented two distinct sectors of the rubber economy, both in terms of their ethnic ownership (with estate production dominated by Western and Chinese proprietors and smallholdings mostly by indigenous farmers) as well as their different organizational forms and cultivation techniques. One of the keys to understanding the evolution of the rubber industry, and its impact on the social and physical landscape, is the relationship between these two sectors.

During the early decades of the industry, land concession practices, trade policies and research efforts were all primarily geared to the needs of large estates. By contrast, rubber smallholdings were broadly treated with either passive neglect or outright discrimination throughout the colonial period. To some extent this differential treatment reflected contemporary notions of a 'dual economy' that distinguished between a dynamic, export-oriented European sector on the one hand

and a conservative, subsistence-based indigenous sector on the other, each of which served quite different economic and social needs (Boeke 1942; Moon 2005). It also reflected the prevailing conviction among most colonial observers that, in the words of a 1904 survey of agriculture in Malaya, 'two or three large planting enterprises will do more to open up and enrich the country than thousands of villagers can do' (Willis 1904: 90).

As the principal beneficiaries of colonial concession policy and fiscal stimuli, it was initially the large- and medium-scale plantations that pushed most rapidly into the forests. From 1904 to 1910 Malaysian estates acreage swelled from 28,000 to 540,000 acres and continued to grow by around 100,000 acres annually over the following years, much of it driven by a handful of large firms (Guthries, Harrisons and Crosfield, Barlow and Co.) (Drabble 1973: 216; Barlow 1978: 30–3, 308). The planting boom in the East Indies, which took off around half a decade later, was also initially led by estates, above all in the hinterlands of the existing 'cultuurgebied' of Northeast Sumatra (Volker 1928: 77, 151). Yet the proportion of rubber grown on smallholdings steadily increased over the first half of the twentieth century, and eventually matched or outstripped estate production in the leading export countries of Malaysia, Indonesia and later Thailand. By the late 1940s even some colonial observers were calling for a shift of emphasis towards smallholder cultivation, and this trend was generally reinforced in the post-colonial period by national governments keen to encourage smallholder rubber as a means of boosting rural incomes (Bauer 1948a).

As one might expect, the economic strategy of the large foreign-owned rubber plantations was to exploit their comparative advantage to the full by focusing (albeit not always exclusively) on a single output, and to maximize income by deploying wage labour and capital as efficiently as possible. As far as organization and technique were concerned, planters generally followed a familiar 'orchard' model that emphasized orderly rows, low tree density, clean weeding and straight-edged drainage ditches wherever soils were heavy or water tables high. There was, as contemporaries remarked, something of a mania for tidiness and order on the foreign-owned estates, which partly derived from the quest for operational efficiency but which also undoubtedly reflected a deep-seated cultural desire to achieve mastery over a wild and undisciplined tropical nature (e.g. Székely 1979: 29, 274). Once the plantations were established, the methodical systems of production and maintenance were carefully systematized over years of experimentation (Swart and Rutgers 1921; Bauer 1948a: 254–6; Drabble 1973: 8–9). Madelon Lulofs' contemporary portrayal of life on the Deli plantation belt in northeast Sumatra conveys a sense of the obsession for rationalization: 'The days succeeded one another monotonously: tapping, weeding, tapping, weeding. The old rubber plantations needed no other attentions. But the tapping and the weeding were done to perfection. […] Everything went with the simplicity of well-oiled machinery' (Lulofs 1987: 145).

The machine analogy, though appealing, is only partly appropriate, for despite all their industrial pretensions the rubber estates were far from mechanical systems brazenly intruding onto the natural landscape. Their reliance on a host of biological, chemical and physical processes meant there was always a sizeable element of the 'garden in the machine' as well (Marx 1967). What is more, given that many of these processes were not well understood, managing them proved more difficult than was initially assumed. Some of the intensive cultivation practices that had been developed in very different (often temperate) ecological contexts were poorly suited to the high rainfall and fragile soils of the tropical lowland environments in which the estates were situated. The result was a series of unanticipated effects that often damaged the productivity of the land as well as the efficiency of the plantations themselves.

Erosion was perhaps the most serious problem in the early years, and was clearly exacerbated by the clean-weeding regimes that were widely deployed on the plantations. Removing all unwanted vegetation was standard agricultural practice in many temperate zones and had also been commonly – if often imprudently – used on commercial estates growing export crops throughout the tropics. During the early rubber boom, European planters employed it almost unthinkingly despite various admonitions to the contrary (for an early warning, see Carruthers 1908). The warnings soon proved to be well founded, for clean-weeding was highly inappropriate for the soil and rain conditions of the main rubber districts. It was not long before sheet erosion, gully formation and the exposure of roots reduced latex yields and sometimes killed entire stands (Ormsby Gore 1928: 30). By 1939 it was estimated that erosion from rubber plantations in Peninsular Malaysia amounted to 33 million tons annually, and around 1.1 billion tons in total since 1905 (to give some sense of scale, 33 million tons is approximately three times as much earth as was removed by the entire Channel Tunnel project, including all three tunnels) (Fermor 1943: 152–4). Although planters in the East Indies were somewhat quicker than their Malaysian counterparts to adopt soil conservation techniques, pedological studies in the inter-war period showed that rubber plantations still remained a major source of erosion and river siltation in the Deli region (Edelman 1947: 285, 288–9).

Disease outbreaks were another unintended consequence of the rubber boom, for in many ways the transition from forest to plantation provided an ideal habitat for certain pathogens and their vectors. Malaria was one of the most serious problems, and despite the introduction of controls in Malaysia in 1901, high mortality rates of 50/1,000 among estate workers were still common during the 1900s and 1910s. Morbidity levels were of course higher still; in the late 1920s they occasionally went as high as 600 per cent among estate workers in Indochina (Grijns and Kiewiet de Jonge 1914: 134–55; Mingot and Canet 1937: 51–4, 73–4; Barlow 1978: 51–2; Chollet 1981: 211–20). Disease rates of this magnitude posed not only a health hazard but also a threat to the development of the rubber industry itself, inasmuch as workers knew which areas were unhealthy and tried to avoid them. Malcolm Watson, the physician who led the vector-based anti-malaria campaign in colonial Malaysia, put the matter plainly: 'the labour problem is nothing but the malaria problem, and […] the solution of the malaria problem will also be the solution of the labour problem' (Watson 1921: 365). But solutions that worked in different environmental settings took years to develop and refine. On the estates near the coast, where the industry was initially centred, swamp drainage and brush clearance proved highly effective against the shade-loving *Anopheles umbrosus* mosquito, the principal vector on the coastal plain. As planters pushed further inland, however, these tried-and-tested measures proved not only ineffective but even counterproductive, for the main vector in hilly areas was not *A. umbrosus* but rather the sun-loving *Anopheles maculatus*, which was eventually controlled by retaining vegetative cover along streams and gullies. It was only in the 1930s that mortality rates on the plantations finally dipped below 10/1,000, not least due to the complexities of disease aetiology (generally Watson 1921: 254–65; Foong Kin 2007).

Plant pathogens posed similar difficulties, though none were as lethal as the leaf blight that ravaged *Hevea* in its native Amazonia. The most serious problem was a root fungus (*Fomes lignosus*) that spread from old infected stumps and that could weaken or eventually kill the trees if left untreated (van de Leemkolk 1914: 31–2; Drabble 1973: 119–20; Barlow 1978: 154–6; generally Smith 1911). While fungal infections of one sort or another were largely unavoidable in the moist conditions of lowland Malaysia and Sumatra, they were nonetheless exacerbated by the practice of intensive mono-cropping. The hazards of mono-cropping were not lost on contemporary observers, some of whom had recently witnessed the demise of once-thriving coffee and cocoa estates due to coffee rust and cacao canker. In 1908 none other than the editor of the *India-Rubber Journal* remarked that 'the system is an unnatural one – that may or may not enable planters to get better results than if they strictly imitated nature – and strikes the visitor as being dangerous from the plant sanitation standpoint' (Wright 1908: 30). Yet mono-cropping remained standard practice on the rubber estates, and despite the fact that it raised the risk of disease, the losses to plant pathogens never reached epidemic proportions.

To combat these problems, estate managers generally turned to modern agronomic science for solutions. By the inter-war period the expansion of colonial agricultural departments and private research institutes funded by the planters' associations formed an important infrastructural underpinning for the industry throughout the region. Together, the teams of botanists, agronomists and mycologists working in Southeast Asia corrected some of the planters' initial mistakes and generally helped to keep their estates functioning. But keeping the plantations profitable was another challenge, and in this respect the main threats were not plant diseases or erosion but rather the volatility of international rubber prices and the growing competition from the smallholder sector. From the early 1920s onwards the colonial powers made significant efforts to control production levels and stabilize international markets in a bid to maintain the long-term health of this key export industry. Yet smallholders were ultimately the greater of the two challenges, for the threat they posed was not only commercial. To be sure, the fact that their supposedly primitive cultivation methods produced rubber at highly competitive prices was irksome enough. But the gradual realization that their practices also entailed a number of agronomic advantages posed a more general threat to the assumed supremacy of the modern mono-cultural agro-estate.

Natural rivals: The smallholder challenge

Rubber smallholdings and estates differed on a variety of levels. The most basic and obvious distinctions were related to their size and internal organization, but they also contrasted markedly with respect to cultivation practices and overall economic strategies. As a general rule, the large plantations specialized solely or at least predominantly on rubber while importing most of their basic needs, whereas smallholdings sought to spread their risks by growing rubber alongside rice, fruit and other crops. Estates required high outputs to pay for their overheads and recoup their investments in roads, drainage ditches, processing buildings, workers' housing and the like. By contrast, smallholders needed little of this, and most of the actual tapping was carried out by family labour or on a sharecropping basis. The lack of expensive overheads allowed smallholders to produce rubber at much lower cost. In the mid-1920s it was estimated that smallholders in the Outer Isles invested only £5–6 per mature acre of rubber compared to £60–80 per acre for European estates (Bauer 1948a: 68; Drabble 1973: 100; Touwen 2000: 158). Although at one level the organizational and commercial differences between the two sectors seemed to reflect the basic distinctions of the so-called colonial 'dual economy', upon closer inspection their relative productivity undermined conventional assumptions about which sector was superior.

The key to the rapid growth of smallholder rubber was not only the lure of high market prices but also the fact that *Hevea* growing was readily compatible with existing patterns of itinerant and semi-itinerant cultivation. The conventional 'ladang' system common throughout much of the region consisted of clearing and burning a forest plot, growing one or two dry rice crops on the ash-enriched soil, and then abandoning the plot to natural re-growth once the soil nutrients were depleted. To fold rubber into this system, cultivators planted *Hevea* seeds in fresh clearings along with the first rice crop, usually at a far higher density than on the corporate estates. Once the rubber seedlings broke the soil surface they provided shade for other crops while also benefitting from the removal of aggressive weeds by the farmers. By the time the second rice crop had been harvested, the rubber seedlings were already over one year old and therefore had a head start over the natural successor (or 'blukar') species that would otherwise have colonized the abandoned plot. The close planting pattern quickly formed a dense crown that suppressed such undergrowth and thereby minimized subsequent maintenance (Tayler and Stephens 1929: 3–4; Van Gelder 1950: 446–9; more generally Purwanto 1992: 114–16, 202–3). After another three to five years all that was needed was to slash the low-lying undergrowth for access to the mature rubber trees. In the words of P.T. Bauer, one of the most astute observers of the colonial rubber economy, 'to add rubber to this system costs nothing in effort, cash or displaced alternatives' (1948b: 17). Although Bauer's assessment arguably underplays what were nonetheless considerable start-up costs for smallholders, especially for the purchase of planting material, it is undoubtedly correct in emphasizing the remarkable compatibility of *Hevea* with existing subsistence and cash-cropping practices (Purwanto 1992: 115–6).

Given this high degree of complementarity, smallholders near the main planting districts were quick to spot the opportunities presented by the rubber boom. Although it is difficult to know precisely when the process began in many localities, it was generally only three to five years after the establishment of foreign-owned estates. In Malaysia the smallholdings were, like the plantations, initially concentrated in the western areas of the peninsula, and eventually overtook the estates in terms of overall acreage in the 1960s. In the East Indies they were far more widespread, stretching from the hinterlands of Deli's plantation belt across large parts of central and southern Sumatra (Djambi, Palembang) as well as western (Pontiniak) and southern (Banjermasin) Kalimantan. By the 1930s official statistics attributed 54 per cent of East Indies rubber acreage to smallholdings, though 'native rubber' (which was essentially coterminous with smallholdings) was almost certainly underestimated here.[3]

As the smallholder sector expanded, colonial officials and estate owners became increasingly concerned about the threat it posed to the profitability of the large rubber plantations. What the proper relationship between these two modes of production should be, and the extent to which governments should try to regulate it, were constant sources of debate. In Malaysia, a 1913 enactment ostensibly geared towards protecting 'ancestral' Malay land from outside speculation entailed a ban on rubber planting within reserved areas that were suitable for wet-rice cultivation. Although enforcing this prohibition was difficult, the policy nonetheless reduced the ability of indigenous farmers to grow rubber legally from 1917 onwards (Bauer 1948b: 39–40, 87–9; Ghee 1977: 50–1, 74; Drabble 1991: 104–10). During the post-war price slump of the early 1920s, and even more conspicuously during the depression of the early 1930s, international trade and production agreements (the Stevenson Scheme and International Rubber Regulation Agreement, respectively) were based on production estimates that clearly discriminated against smallholders and were structured in a manner that principally shored up the estates. Nonetheless, smallholders relentlessly continued to expand their market share – if anything, the maintenance of higher prices through production restrictions actually encouraged a further expansion of smallholder planting, especially in parts of Sumatra and Kalimantan (Bauer 1948a, 370–5; Ghee 1977: 106–16, 143–54; Barlow 1978: 57–62; Purwanto 1992: 212–14; Touwen 2000: 159).

For many observers it was difficult to understand how the dense and weedy 'native' rubber groves were able to compete so successfully with some of most modern agro-estates in the entire tropical world. After all, the large foreign-owned rubber plantations were underpinned by hefty amounts of metropolitan capital and were accordingly armed with the latest scientific knowledge. The attempt to rationalize this state of affairs took many forms (see also Dove 1996: 40–2). One was the common refrain that smallholder rubber was of lower quality and was frequently adulterated, though the evidence suggests that contamination was not a serious problem; indeed, smallholders generally had little trouble in selling their product. There was also the oft-repeated assertion, echoing the colonial forestry discourses of the era, that the extensive cultivation methods used by smallholders represented a 'wasteful' use of the land that generated lower yields and destroyed

[3] Due to the broad distribution of rubber planting in the East Indies, acreage statistics must be treated with caution; the first systematic survey of smallholdings in the East Indies was only carried out in 1937: Bauer (1948a: 3–8), Drabble (1991: 1), Touwen (2000: 149–50, 158–9), Purwanto (1992: 184–9, 216–18) and Grist (1933).

more forest than was necessary. But this view, too, was dubious in at least two respects. For one thing, a high proportion of smallholdings were planted not on old growth forest but rather on secondary growth lands that had long been used for hill rice cultivation and that could more accurately be described as forest fallow plots. Second, although latex yields per tree were lower on smallholdings than on estates, the greater tree density on most smallholdings meant that yields per acre were considerably higher. Discoveries such as these eventually prompted the suggestion that the high yields on indigenous smallholdings resulted from tapping too deeply and too frequently for the bark to sustain itself over the long term. As it turned out, however, extensive investigations soon established that bark renewal rates were in fact faster on smallholdings than on estates owing to the higher humidity levels resulting from their denser planting patterns. Probably the most common allegation of all was that the untidy-looking rubber smallholdings functioned as reservoirs of disease. Yet once again, extensive studies found that they actually suffered significantly *fewer* disease problems, due in large part to the presence of other species that served to hinder rather than promote the progress of root disease (contrary to the assumptions behind clean weeding, one of whose justifications was to minimize root contact between *Hevea* and other plants) (Bauer 1948a: 34–41, 58–9, 72–3, 200–2, 257–8; Barlow 1978: 76–7, 444–5; Drabble 1991: 253–4; Tayler and Stephens 1929: 3–8; Meads 1934: esp. 39–42; van Gelder 1950: 449; Purwanto 1992: 247–9).

In view of the mounting smallholder challenge, it was inevitable that the plantation sector would respond by mobilizing its considerable resources to full advantage. Yet the basic difficulty it faced was that the very nature of rubber production severely limited the opportunities for doing so. Compared to most other crops, *Hevea* cultivation presented few economies of scale and little scope for mechanization (apart from certain aspects of latex processing). This left the plants themselves as the principal target for further capital investment. The development of high-yielding *Hevea* strains was therefore vital for the future of the plantations, and was accordingly a central focus of research at AVROS (the Sumatran rubber growers' experiment station) and the Rubber Research Institute of Malaya from the 1920s onwards. In scientific terms, the results were impressive: by the late 1930s botanists had managed to develop bud-grafted (or 'cloned') *Hevea* strains that were capable of yielding around four times more latex than average trees. In commercial terms, however, the high-yielding varieties hardly constituted a silver bullet for the estates. Although the plantations initially held a monopoly on the improved strains, replanting was a costly, slow and financially risky process. The effects of the Depression-era planting restrictions also ensured that the proportion of rubber acreage planted with HYVs rose only gradually. Indeed, most of the yield gains they brought the estates were only felt in the post-colonial period (Michaux 1937: 4; Bauer 1948a: 275–85,1948b: 42–9; Graveline 2006: 70–81).

While some scientists focused on further intensifying production, others – primarily within the colonial forestry departments – began to advocate a move in the opposite direction. From around 1930 onwards there was a swelling chorus of calls for abandoning the conventional 'agricultural' approach to rubber growing in favour of low-intervention 'forestry methods', which largely meant planting at higher densities and leaving much of the natural ground cover intact. Although the technique resulted in smaller average tree size and less latex per tapping, it had the advantage of raising yields per acre and, most importantly, dramatically reducing operating costs. To some extent this shift of emphasis reflected the commercial pressures of the 1930s: with prices down, planters could no longer afford the labour-intensive maintenance regimes (and the Indian labourers who carried them out) on which they had hitherto relied. By the end of 1932 the average nominal cost of upkeep for an acre of mature rubber in Malaysia dropped to only one-sixth of 1929 levels (Bauer 1948a: 367). But the advocacy of 'forestry methods' was also based on an ecological rationale: namely, to improve exhausted soils and maintain long-term fertility. It was well known that the maintenance of perennial ground cover and the continual deposition of vegetable debris retained nitrates in the soil and minimized erosion (Anon 1932a: 292–4; Watson 1934: 206–10, 1935a: 78–9, 1935b: 75–7; Oliphant 1934: 3–6). By the mid-1930s the rubber research institutes themselves began to recommend 'controlled natural ground cover' systems as a matter of best practice (Haines 1934; Bauer 1948a: 258–9).

Yet despite the rising scientific acceptance of 'rubber forestry' methods, they still met with considerable scepticism, especially within the planter community. In part the suspicion arose from the sheer force of habit, and in part from doubts about the short-term effect on output. But perhaps the most important source of reluctance was the fact that these techniques were remarkably similar to what the supposedly 'primitive' smallholders had long practised. In the early 1930s the rubber economist H.N. Whitford noted that many planters 'claim forestry methods are not aristocratic, implying that if the European has to go native to compete with the native, the European has no business to be in … rubber planting' (Drabble 1991: 55). The idea that certain smallholder techniques, however disorderly they may have appeared, were not only cheaper to operate but also agronomically preferable was deeply unsettling. As France's leading tropical agronomy journal put it, many found it surprising that large corporate estates were having 'to abandon intensive cultivation with its carefully perfected processes devised by progress, because they are too expensive, in order to go back (*revenir en arrière*) to extensive cultivation with its primitive processes as practiced by the natives' (Anon1932b: 226).

It is worth highlighting the remarkable tenacity of these assumptions about the innate supremacy of large-scale, labour- and capital-intensive estates, for they were ultimately part of the racialized technological hierarchies that structured colonial society more generally – in Southeast Asia as elsewhere in the tropical world. At the same time, when viewed alongside the rather different assumptions and strategies that structured smallholder rubber cultivation, they are also a useful reminder of the importance of cultural dispositions and expectations in shaping how environments and economic opportunities are exploited. If Southeast Asia's rubber industry was ultimately based on the suitability of the region's lowlands for commercial production, these broad ecological parameters nonetheless allowed a variety of different approaches, scales and outcomes.

Smallholder rubber and economic development since the 1950s

Although Southeast Asia's *Hevea* plantations quickly vanquished Amazonian rubber at the start of the twentieth century, from the 1940s onwards they steadily lost ground to the competition on their doorstep. By 1980 smallholders accounted for no less than two-thirds of the rubber acreage in Malaysia, 80 per cent in Indonesia and 95 per cent in Thailand (the chief new producer, with 1.24 million ha of rubber that year) (figures from FAOSTAT; Barlow 1978: 444–5; Grilli, Agostini, Hooft-Welvaars 1980: 16–20). A similar scenario prevailed among the lesser producers of the region; only in Vietnam did estates continue to dominate post-war rubber production, and even here smallholders quickly gained ground on the state-owned plantation sector after the reformist experiments of the 1990s.

Low costs remained an important part of this smallholder triumph, for they enabled most growers to turn a reasonable (albeit continually fluctuating) profit even from ageing and relatively low-yielding stands. Granted, this advantage was partly eroded by the spread of high-yielding varieties after the war, which were first used by large plantations for replacing aged *Hevea* stands. During the 1960s and 1970s in particular, the plantation sector – much of whose rubber acreage was slightly older than the average smallholding and therefore needed to be replanted earlier – was able to improve its profit margins and mount a partial comeback once the new HYV stands had matured and come into full production.[4] Over the following decades, estates generally managed to maintain a higher proportion of HYVs than smallholders, though it was not long before the gap narrowed. By the 1980s the bulk of smallholder acreage had also been replanted, often with high-yielding strains made available by state extension agencies and/or supported by special replanting grants.

The deliberate attempt to boost smallholders' productivity was, then, another factor that contributed to their success. This strategy was perhaps most systematically pursued in Thailand via its Office of Rubber Replanting Aid Fund, established in 1960. Malaysia's Rubber Industry Smallholders Development Authority, set up in 1973, was similarly influential, and effectively coordinated the hitherto diverse efforts to support smallholders that had first begun in the 1950s (Drabble 2000: 220–1). Such policies developed more slowly in Indonesia, where government attention long focused overwhelmingly on rice production. Nonetheless, during the 1980s successive Smallholder Rubber Development Projects, launched with support from the World Bank, sought to emulate the programmes in Thailand and Malaysia on a smaller scale (World Bank report). In all three countries, smallholders increasingly relied on government agencies not only for financial grants and planting material but also for fertilizers, pesticides and technical guidance. Like the spread of 'Green Revolution' technologies more generally, the initial advantages that the HYV strains gave to large producers – who enjoyed better access to credit and could more easily afford the extra inputs necessary for achieving higher yields – were gradually diminished once

[4] In Malaysia in particular, the development of new cloned varieties – some of which could surpass 2,000 kilogram of latex per hectare – enabled plantations to outstrip the average smallholder yield by around 50 per cent in the early 1970s (Barlow 1978: 76–7, 115–27, 444–5).

these technologies were disseminated more widely. In socio-economic terms, this is largely a positive development. From an environmental standpoint, however, it is far less encouraging, for although higher yields in principle allow production to rise without claiming as much forest land as would otherwise be necessary, the trade-off is that many rubber smallholdings have adopted a more intensive 'package' of mono-cropping techniques and agro-chemical inputs that threatens greater damage to soils and downstream water courses than more diverse agro-forestry systems.[5]

The various attempts to increase productivity point to another set of reasons for the increasing dominance of smallholder rubber since the middle of the twentieth century, namely the changing policy and institutional context. Whereas colonial governments had generally been unsupportive or at best ambivalent towards 'native rubber', the post-colonial regimes that replaced them actively encouraged it as part of their efforts to reduce rural poverty and develop their economies. As a general rule, the restructuring and revitalization of key agricultural export sectors – foremost among them rubber, but increasingly oil palm and to a lesser extent cocoa and coconut too – served two important purposes in the economic development plans of the region. They were vital not only for boosting employment and domestic purchasing power but also for furnishing the financial resources necessary to support the growth of an emerging industrial sector.

In several Southeast Asian states (especially Malaysia, Indonesia and Thailand), the ability to tap the 'forest rent' – that is, the differential advantage conferred by fresh soils and low concentrations of pests and pathogens on newly cleared land – through an expansion of smallholder rubber crucially helped governments to balance the requirements of economic modernization against the political need to raise rural living standards (on 'forest rent', see Ruf 1995: 91–159; Austin's chapter, this book). In Thailand, where successive administrations purposefully pursued a smallholder-centred strategy, rubber smallholdings have dominated the industry ever since the take-off stages of the 1950s and 1960s. In Malaysia, the independent government incentivized rural smallholders to open up new lands through the Federal Land Development Authority (FELDA), including in Sarawak and Sabah after their incorporation as East Malaysia in 1963 (although oil palm eventually became the country's leading export crop, rubber was nonetheless one of the chief cultivars for those taking advantage of the scheme). By the early 1970s, Malaysian authorities had also subdivided 146,000 ha of foreign-owned rubber estates into smaller parcels, many of them purchased by ethnic Chinese who leased them out to tenants (Ricklefs 1981: 215–16, 296; Drabble 2000: 216–24). In Indonesia, too, Sukarno's government redistributed much of its foreign-controlled estate land as the original leases expired, and forcibly confiscated the remaining Dutch estates in 1957. Although General Suharto's 'new order' after 1965 adopted a much more favourable stance towards foreign investment than Sukarno's regime, the unrelenting growth of rubber in

5 The relationships between agricultural intensification, deforestation and economic strategies are notoriously complex. For recent analyses see Byerlee, Stevenson and Villoria (2014: 92–8) and Cairns (2015).

Indonesia – which reached 2.4 million ha in 2000 – was still overwhelmingly the work of smallholders (generally Vickers 2013: 137–45, 162, 165–73).

Clearly, these policy imperatives and institutional arrangements have played a central role in maintaining Southeast Asia's dominance in a rapidly expanding world rubber economy, and also in shaping the social and physical landscape across large areas of the region. Southeast Asia as a whole still produces roughly 90 per cent of the global supply of natural latex.

Since the early 1970s, the sizeable investments in high-yielding strains – coupled with the long-term upward trend in petroleum prices – have even enabled natural latex to claw back market share from synthetic rubber, which accounted for no less than two-thirds of overall rubber output on the eve of the great oil shocks of the 1970s (Barlow 1978: 408, 412). By 2012 world output of natural rubber reached 11.6 million tons, and continued to gain ground on the 15.1 million tons of synthetics produced at the time (data from *Rubber Statistical Bulletin*, April–June 2014 edition). In many ways this is good news from an environmental perspective. After all, natural rubber is around ten times less energy intensive than synthetic rubber, and moreover the trees that produce it have a significant carbon-sinking capacity (estimated at around 90 million tons/year worldwide in the mid-1990s) (Loadman 2005: 274–6). Yet in other ways the news is less good, for although synthetic rubber is far more energy and carbon intensive, it nonetheless reduces the pressure for forest clearance and thereby helps – however indirectly – to preserve the exceptional biodiversity of Southeast Asia's woodlands.

In any event, as rubber cultivation continues to expand in the region – especially in Vietnam, northern Thailand, Cambodia and Laos – the extent to which states provide smallholders with technical help, planting material, loans and secure tenure (what might be called the Thai model), or instead put their backing behind large, intensively managed state-run plantations (as in Vietnam, whose companies have also opened estates in Cambodia and Laos), will have a major impact on the landscape, on the well-being of farmers and on the kind of economic development that will result from rubber planting. Recently, tensions have risen both within and between the various rubber-producing states of the region due to a fall in prices as the effects of expanded planting by Vietnamese growers are felt (Pardomuan and Minh 2014).

Much therefore rides on these political and economic decisions. Yet for all their indisputable importance there is still a large element of ecological good fortune at work. So far the rubber-producing countries in Asia (and Africa) have remained free of the dreaded South American leaf blight, which continues to preclude large-scale commercial *Hevea* cultivation in the Americas despite significant efforts to overcome it. The pathogen is universally recognized as a severe threat to the global industry, and one that rises with each airline flight between the American and Asian tropics. The ongoing attempt to prevent it from wrecking Asia's *Hevea* landscapes is a major operation, including not only the rigorous screening of international freight and air traffic from South America to other humid tropical areas but also a wide-ranging programme of genetic research focused on the selection and breeding of blight-resistant varieties. Indeed, the ramifications of an outbreak for both the regional and global economies are so severe that the UN has included the South American leaf blight on its list of biological weapons (for an overview: FAO 2011; Lieberei 2007: 1125–42; Onokpise and Louime 2012: 3151–7). One can hardly imagine a starker reminder of the importance of ecological conditions for the shape of the global rubber industry, and of the potentially devastating economic consequences for Southeast Asia if these conditions were to change.

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11

The Development of Energy-Conservation Technology in Japan, 1920–70: An Analysis of Energy-Intensive Industries and Energy-Conservation Policies

Satoru Kobori

This chapter presents a historical perspective and analysis of the development of Japanese energy-conservation technologies. The energy intensity of Japan in terms of total primary energy supply per unit of GDP is well known to have improved drastically from immediately after the oil shock of 1973 to around 1990, reaching the lowest level among International Energy Agency (IEA) countries (IEA 2008: 53–8; Sugihara 2009).[1] Although some debate has arisen about whether Japan's energy intensity today is still the lowest, even critical observers would agree that it had achieved that status by the beginning of the 1990s (Morotomi and Asaoka 2010: ch. 3).

The decrease of energy intensity in the Japanese economy resulted mainly from the improvement of energy efficiency in manufacturing. This chapter emphasizes and discusses the following two characteristics related to this improvement. First, the improvement stemmed partly from the development of energy-conservation technology in energy-intensive industries such as iron and steel, cement, and thermal power generation, and partly from a change of industrial structure which meant the growth of energy-saving and high-value-added industries or relatively labour-intensive segments of capital-intensive industries, especially the machinery, automobile and computer industries (Hashimoto 1991: ch. 3; Sugihara 2013). Japanese energy consumption per unit of output in these energy-intensive industries represents the best practices in the world even today (Oda et al. 2012). Second, these

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1 The IEA was created, essentially by the OECD, in response to the 1973 oil crisis. Membership is open only to OECD member countries, most of whom belong to it. Thus it represents essentially the most technologically advanced and wealthiest economies.

improvements were achieved without strong regulation or taxation by the government. An important characteristic of Japan's energy-conservation policy to end-users is voluntary regulation. Although the government obliges users of large amounts of energy to have an energy manager responsible for the improvement and supervision of methods for using energy through the Act on the rational use of energy in 1979 (Energy Conservation Act), and although the Energy Conservation Centre of Japan (ECCJ) offers technical guidance for energy use mainly to small- and medium-sized enterprises, no legal penalty has been applied on amounts of energy consumption (IEA 2008: ch. 3; Kikkawa 2011: ch. 11).

This approach was nevertheless not generated suddenly after the OPEC oil crisis. Japanese energy-intensive industries were already world-leading in energy efficiency during the early 1960s (Figures 11.1 and 11.2). The predecessor of the Energy Conservation Act, the Heat Management Act, had already been enacted in 1951 (AIST 1971). Moreover, as explained below, these same approach applied originally to the technical improvements and policies that were undertaken in the 1920s.

Therefore, we should discuss the path from the 1920s to the 1970s when we analyse, from a historical perspective, why Japan was able to improve national energy efficiency radically after the oil crises. Japan's recent history in this regard can be divided into four sections: the interwar era, the war years, the reconstruction period and the era of high-speed economic growth. The discussion addresses

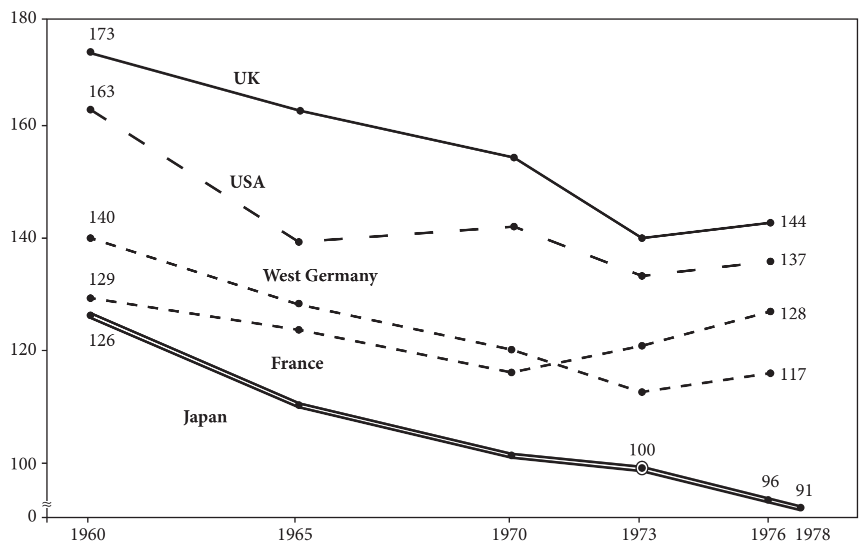

Figure 11.1 Energy consumption per tonne of steel in five countries, 1960–78 (Japan in 1973 = 100).

Notes: 1. Using IISI's figures which are modified by the ratio of iron production to steel production of Japan in 1973; 2. Coke: the amount bought; 3. Ferroalloy: excluded.

Source: Shinoda (1979: 27).

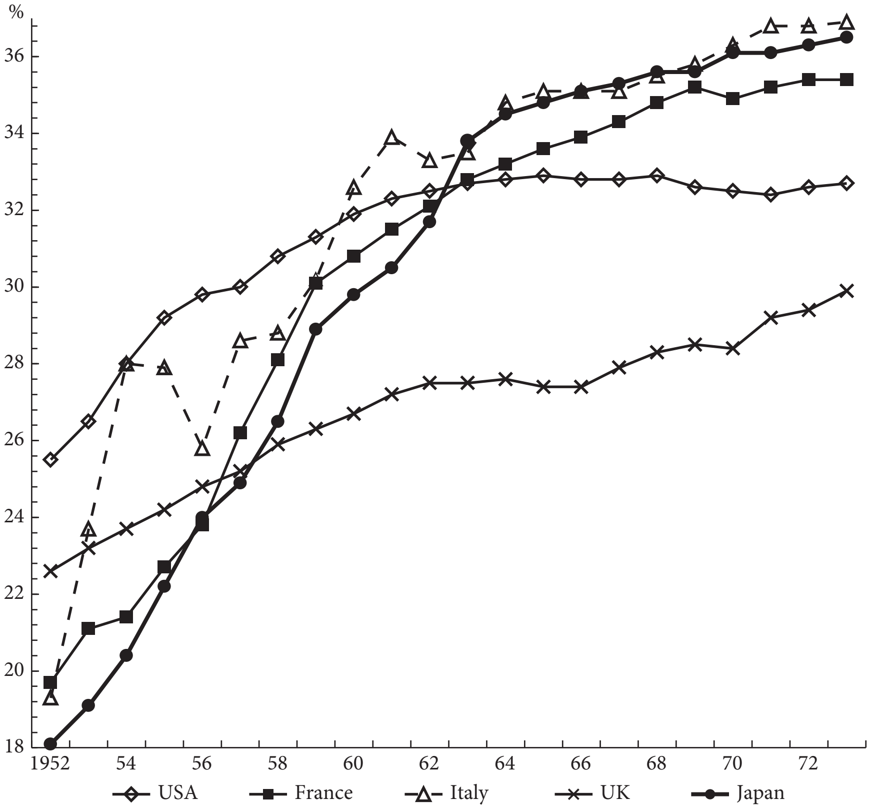

Figure 11.2 Average thermal efficiency of thermal power generations in five countries, 1952–73.

changes in the energy-intensive industries and in the energy-conservation policies as they related to the end-user. We regard the iron and steel industry as the archetype of the successful marriage of energy efficiency and economic efficiency because the Japanese iron and steel industry has remained internationally competitive since the high-speed growth era despite its diminishing energy intensity.

Energy-conservation activities in the interwar era

Increasing interest in energy-conservation technology

After the 1910s, Japan took an increasing interest in energy-conservation technology for three reasons. First, the demands of industrialization and an increase in the cost of producing coal domestically during the First World War combined to raise the price of coal. The relative price of coal in terms of the wholesale price index rose from 1.02 in 1913 to 1.35 in 1919. Second, the degree of coal self-sufficiency in Japan proper fell below 100 per cent. Japan had been a coal exporter from the Meiji era but coal imports exceeded exports in 1923, 1924 and continuously after 1927 (Kobori 2010: ch. 1).

Third, these coal problems could not be solved merely by switching to other energy sources, although the consumption of alternatives fuels increased (Table 11.1). To investigate why, we should specifically examine electricity, heavy oil and wood as alternatives. The growth of electricity consumption was facilitated by supply-side improvements: advances in hydroelectric generation and power transmission systems. Steam engines were replaced almost completely by electric motors around 1930, and electrochemical industries started to grow (Kurihara 1964: 254–65; Minami 1976: ch. 4; Kikkawa 2004: ch. 2, sec. 1). However, boilers and furnaces continued to use coal (Kobori 2010: 42). Although utilization of heavy oil for shipping increased, oil was hardly used for industrial boilers or furnaces at that time because it was too expensive relative to coal. Indeed, the price of heavy oil was 2.85 times that of coal in 1931 (Kobori 2010: 63–4). Wood was not considered as an alternative to coal at all during the interwar era. The amount of wood consumption as energy had already been exceeded by coal during the early 1900s. In the case of the Nagano silk-reeling industry, coal had become the main energy resource during the second half of the 1900s because deforestation in neighbouring districts had progressed and steam boilers had improved (Sugiyama and Yamada 2015).

Therefore, Japanese engineers and bureaucrats took a growing interest in two related matters: increasing fuel costs and diminishing domestic coal resources. For example, in 1920, Saishiro Sakikawa, the chief of Mining Bureau, Ministry

Table 11.1 Gross Primary Energy Supply of Japan, 1895–1973

				Thousand tonnes of oil equivalent		
Year	**Total**	**Coal**	**Oil**	**Hydro**	**Wood & Briquette**	**Others**
1895	7,643	3,032	175	0	4,435	0
1905	10,978	7,424	411	6	3,137	0
1915	16,719	13,241	628	155	2,694	1
1925	25,572	20,900	892	624	3,140	16
1938	48,095	35,208	6,270	2,042	4,534	41
1950	35,288	24,619	3,021	3,268	4,323	57
1960	90,056	41,522	37,929	5,026	3,625	1,954
1966	173,671	47,566	114,395	6,856	931	3,923
1973	375,665	59,587	298,235	6,028	481	11,334

Note: Calorie conversion of hydro was modified from 4,150 kcal/kwh during 1905–50, 2,700 in 1960, 2,300 in 1966 or 2,250 in 1973 to 860 kcal/kwh. This applies also to the sources referred to in Table 11.2

Source: Energy Data and Modelling Center, the Institute of Energy Economics, Japan (2014).

of Agriculture and Commerce (MAC), was concerned that Japan would not be able to continue mining domestic coal for many more years and stated that Japan should 'reduce demand for coal' as well as making plans to 'acquire foreign coal mines' (Lower House of the Diet 1920). For their part, engineers and researchers interested in combustion engineering organized a group called the Fuel Society of Japan (FSJ), to exchange their research results and also to enlighten ordinary people about the importance of energy conservation (Kobori 2010: ch. 1).

Technical guidance for fuel combustion by the Osaka Prefecture

It was not the government but local authorities that conducted specific policies for developing energy-conservation technology before the Second World War. The first case, and a typical one, was the Osaka Prefecture, which was often designated as the 'Manchester of the Orient' at that time. Osaka Prefecture founded the Technical Guidance Division for Fuel Combustion belonging to the Osaka Prefectural Institute for Industrial Management (OPIIM) in 1929 and started to guide local factories to more efficient methods of combustion with a boiler.

The purpose of technical guidance for fuel combustion was not only the industrial rationalization of small factories clustered in Osaka but also the decrease of their smoke emissions. Because air pollution by smoke in Osaka became severe after the Japanese Industrial Revolution, officers of Osaka Prefecture carried out some campaigns against smoke during the 1900s and 1910s. These initiatives failed, however, because the Osaka Chamber of Business was opposed to them as they sought to impose economic burdens on factories, for example, by forcing them to install smoke-prevention equipment (Oda 1983: ch. 6). However, in the smoke-reduction campaign during the 1920s, the officers of Osaka Prefecture cooperated with the engineers and researchers grouped in the FSJ and devised methods to prevent smoke without extra costs to factories. Therefore, Osaka Prefecture eventually succeeded in gaining entrepreneurs' consent to enforce the Regulation for Boilers and the Regulation for Smoke Control, in 1932, which were the first regulations on air pollution in Japan.

What were the methods of smoke prevention? Osaka Prefecture emphasized that smoke released by imperfect combustion with a boiler meant not only air pollution but also fuel wastage because grains of smoke were unburned coal that had been released from chimneys. The officers of Osaka Prefecture and the FSJ engineers and researchers urged that more efficient combustion reduced both production costs and smoke.

Some fuel engineers became regular or non-regular staff members of OPIIM's Technical Guidance Division in order to encourage factories towards more efficient combustion. They visited factories to provide practical on-site guidance, and offered a training course for the boiler men, accompanied by a licensing system. Practical guidance was given to 192 factories during five years. Most trainees were small firms that had only simple and cheap boilers. The guidance was provided after application by the factory, free of charge for four to seven days on site. Osaka Prefecture emphasized that it was possible to decrease fuel costs by more than 10 per cent merely by changing working methods for combustion: for example, the kind of coal, the method and interval of throwing coal into the boiler, and the mode of regulating draughts (OPIIM 1936: 106–32). Osaka Prefecture showed that even if new equipment were not installed, developing employees' skills so that they understood combustion would contribute considerably to decreasing fuel consumption.

The boiler men's training course was the other method of developing human resources to reduce both smoke release and fuel consumption; Osaka Prefecture established a licensing system for boiler men in 1932, based on the Regulation for Boilers. Factories using boilers located in Osaka City were required to employ only boiler men who held a licence under this regulation. OPIIM started the course at the same time. It entailed more than 100 hours of lectures and practicals, and more than 4,000 students graduated in three years. Moreover, the training and the licence system should be evaluated as indirect and enforced guidance in fuel combustion at factories that did not apply the practical guidance. Osaka Prefecture's development of guidance on fuel combustion was emulated during the 1930s by several local governments such as those of Tokyo, Kyoto and Dalian. The Ministry of Home Affairs extended the licence system nationally in 1935.

Even so, the guidance was aimed only at small and medium-sized factories. The government officials and fuel engineers thought that guidance to large factories was not necessary because such factories had the capital to reduce coal consumption by investment in new equipment (such as a water tube boiler or a stoker) (Kobori 2010: ch. 1).

Development of energy-conservation technology in the iron and steel industry

The iron and steel firms, being in a quintessentially energy-intensive industry, were also interested in energy conservation. Specifically, they were interested mainly in German energy-conservation technologies. For example, Kuniichi Tawara, an outstanding metallurgical engineer, travelled to Europe and North America from June 1921 to July 1922 and reported that Germany had developed energy-saving and resource-saving technologies aggressively under the constraints of a resource set that differed from those of the United States and United Kingdom, which had not introduced many resource-saving facilities. Although he would, of course, have known that Germany had coal as well as iron ore in the Ruhr, he emphasized that Germany had less coal than either the United Kingdom or United States. He thus highlighted the international differences in natural resource endowments and technological responses (Tawara 1922: 815–16). Tawara added, 'Japan is short of resources for iron and steel and its quality is bad, so we have to study hard like the German engineers' (1922: 815–16). He thought that the Japanese iron and steel industries were compelled to follow not the US model of using large amounts of natural gas and heavy oil, but the German one, trying to conserve coal to the greatest degree possible. (cf. Kudo 2008: 114–15)[2]

The Verein Deutscher Eisenhüttenleute (German Iron and Steel Institute) had established the Hauptwärmestelle (Central Heat Management Office) in Dusseldorf to promote energy conservation. Its tasks comprised not only research but also the training of engineers, the exchange of best-practice technology among iron and steel mills, the advertising of heat management, and so on. Each iron and steel facility also established a Wärmestelle (heat management centre) and used specialist heat engineers to improve heat management beyond what they thought would be achieved by the intuition of skilled workers (Kobori 2010: ch. 3).

Some Japanese firms emulated German heat management technology. Two outstanding cases were the Yawata Iron and Steel Works in North Kyushu district and Showa Steel Works (SSW) in Manchuria.[3] The Yawata Iron and Steel Works started to reuse surplus energy, especially blast furnace gas and coke oven gas, for other iron- and steelmaking processes. The average rate of consumption of coal per tonne of steel product was reduced by half from the 1920s through the early 1930s (Figure 11.3).

Yawata, however, established no department such as a heat management centre, which investigates and guides the heat economy of all plants of a factory. A company that fully installed German heat management technology was SSW. It started an integrated iron and steel works in 1935, and planned to give heat management 'the first trial in the East' (Showa Steel Works, Iron Division 1940: 235). SSW's heat management centre conducted repair and control of instruments, research and development in some plants, and on-site guidance. More than 100 staff members worked at the heat management centre. Thus, in the later 1930s, SSW installed and expanded German heat management technology more rapidly than Yawata had done (Kobori 2010: ch. 3).

The progress in heat management at SSW was recognized gradually in the Japanese homeland through the Iron and Steel Institute of Japan (ISIJ), which consisted of company engineers as well as academic researchers. During the late 1930s, each division of the ISIJ started to place energy conservation on the agenda and a dedicated Fuel Economy Division was created in 1938 (ISIJ 1945). The

[2] Some bureaucrats of the Ministry of Commerce and Industry (MCI, the successor of MAC) took the same view. A notable case was Nobusuke Kishi, who was a proponent of industrial rationalization policy at the beginning of the 1930s and became prime minister between 1957 and 1960. Kishi made an overseas tour in 1926 and recalled it as follows: 'At that time, Japan's annual production target for steel was one million tonnes, but it was impossible by any stretch. The US however produced about five million tonnes of steel a month … We could not plan an economic policy to catch up with the US because the US had much more resources than Japan, e.g. coal and iron ore. I was overwhelmed by the greatness of the US and also had an ill feeling … [But] Germany tried to develop its economy by its advanced scientific management on technology and business although Germany has few resources, just like Japan. I was convinced that Japan's model was Germany. Japan could not exercise the American style at all, but could follow the German style.' (Hara 1995: 38–9)

[3] Yawata was established in 1902, controlled by the government until 1934, becoming semi-governmental until 1950. It was the predecessor of the present Nippon Steel & Sumitomo Metal Co. SSW was established in 1918 as a subsidiary of the South Manchurian Railway Co., named Anshan Iron Works until 1933. It was abolished after the Japanese defeat in 1945.

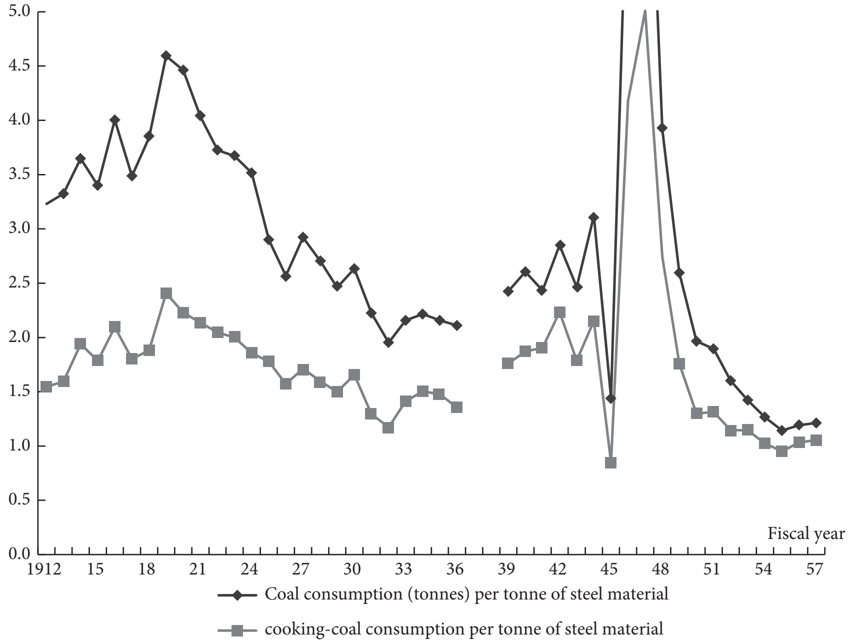

Figure 11.3 Amount of coal consumption per tonne of steel material at Yawata, 1912–57.
Source: Kobori, S. 2010: 107.

programme for the first meeting featured 'real scenes filmed for heat management at blast furnaces, open hearth furnaces and a control room presented by Showa Steel Works' (ISIJ 1941).

Energy-conservation activities during the Second World War

Energy-conservation policy

The Ministry of Commerce and Industry (MCI, the successor of MAC) also started technical guidance on fuel combustion in 1938 as the Sino-Japanese war exacerbated the tight coal supply situation. The engineers who had guided fuel combustion measures in Osaka were used by MCI to spread the principles and practices of guidance.

It is noteworthy that the targets of the guidance, which had been restricted to combustion with the boilers of small firms, also expanded. Because coal supply became tighter and tighter, guidance on fuel conservation became necessary even at large factories, for which such guidance had not been thought necessary during the interwar era. Fuel engineers realized that many points aside from the mode of fuel combustion should be improved to reduce energy consumption further, even in large factories. They explained that it was necessary to improve combustion with a furnace, conserving fuel, controlling steam and keeping insulation as well as combustion with a boiler. They also emphasized that, to accomplish these improvements, it was necessary for any factory, small or large, to install the exact instruments required and to employ full-time workers responsible for energy.

At the same time, the policy name changed from 'guidance for fuel combustion' to 'heat management'. The designation of heat management used by iron and steel engineers, especially in SSW, was broadened to mean energy conservation in general. SSW's heat management became famous not only among the Japanese iron and steel engineers through ISIJ, as described above, but also among the engineers who guided fuel combustion at Osaka Prefecture or MCI. They sometimes visited the heat management centre of SSW and introduced its practices through speeches and articles to engineers who worked at other industries. The government made inspections and held a campaign in every winter of the war to enlighten and improve heat management (Kobori 2010: ch. 2).

After the start of the Sino-Japanese war, several iron and steel factories in Japan also earnestly began to imitate SSW's heat management methods. Yawata established a Heat Management Division in 1944. It tried three ways of reducing fuel consumption per unit of output: a heat-control campaign to cultivate interest in heat management at a job site, the organization of a heat management committee to discuss the subject in each factory and improvement of instrumentation engineering (Kobori 2010: ch.3).

Achievements and issues of heat management during the war

Did these efforts by the government and iron and steel industry bear fruit? Fuel consumption per unit of output worsened greatly during wartime, for four reasons (Figure 11.3). The first was worsening coal quality, which posed a general limitation on the Japanese wartime economy.

The second was a lack of instruments. After 1937, it became much more difficult to import instruments from abroad. The domestic supply of industrial instruments for heat management stagnated because the production priorities were instruments for aircraft and oil refining. Although the steel industry attempted to repair instruments through its own efforts, the results were insufficient because of a lack of spare parts.

Third, the engineering level could not help being worse than during the interwar era because many skilled workers were drafted into the armed forces. To mitigate this, many unskilled workers were employed to increase output. After the start of the Asia Pacific War, the use of 'special workers' such as students, Koreans, prisoners and corps of women volunteer workers increased. They were required to perform tasks not only as assistants but also as regular workers. It is not difficult to imagine that these conditions lowered the standard of engineering at job sites that had relied heavily on the experience and skill of long-term employees.

Fourth, even at factories where there remained numerous skilled workers, they often persisted in using conventional and intuitional practices. Some engineers reported that many skilled workers did not use the instruments for heat management even if they were installed. During the war period, it was too difficult for heat management officers or engineers to re-educate skilled workers patiently (Kobori 2010: chs 2–3).

Under these circumstances, the officers and engineers reported a lack of 'enthusiasm' about heat management among the workers and managers (Nenryo oyobi Nenshosha Co. 1944). It was symbolic that the name of the heat management campaign in 1945 was 'Heat Management Suicide Attack Monthly'. It is noteworthy that 'lack of enthusiasm' was not an empty slogan but accompanied with the indication of concrete problems, for example, leakage of steam or heat, lack of proper fuel storage facilities and insufficient use of instruments. These points, which had not been recognized as problems during the 1930s, became recognized as such during wartime by the Japanese themselves before US technology was installed afterwards. The war fostered interest in energy-conservation technology. After the war, heat management was again embraced by the Japanese officers or engineers who had found many problems related to heat management by themselves during the war (Kobori 2010: ch. 2).

Heat management during reconstruction

Establishing the Heat Management Act

Japan lost its colonies. As a result, Japan lost rich coal mines in Manchuria and many Korean miners disappeared from coal mines in Japan. Therefore, energy restrictions in Japan after the war became tighter than they had been during the war.

When the coal shortage became dire in December 1946, the cabinet adopted a 'Fundamental Policy for Strengthening Heat Management to Break the Coal Crisis'. The aim was to reduce coal consumption while increasing coal production. However, Japan's defeat brought some advantages too. Demobilization meant that skilled workers were not being drafted into the armed forces. This created the fundamental conditions under which post-war Japan was able to improve engineering at the job site. Also, disarmament meant the loss of military demand, which compelled Japanese manufacturers to look for new civilian demand, such as tools for heat management, for example, instruments and steam traps. In the context of these circumstances during reconstruction, the problems that had been acknowledged during wartime by officers and engineers began to be solved gradually.

The actors promoting heat management policies after the war were the Heat Management Division of the government and the heat management associations. The former was established in 1947 by the National Coal Board (integrated into the Agency of Resources in 1949) and moved to the Agency of Industrial Science and Technology (AIST), in 1950 (AIST was an affiliate of Ministry of International Trade and Industry: MITI, the successor of MCI). The heat management associations were private institutions established by heat management engineers. They exchanged research findings and advertised heat management. There were also eight local heat management associations and the Central Association for Heat Management (CAHM), which coordinated them.

A major policy initiative carried out by these actors was industry-specific inspections of heat management. The industry-classified inspection was in operation between 1948 and 1952. This inspection was applied to sixteen industries and 1,204 factories, which were three-quarters of the Designated Heat Management Factories (see the next paragraph). This inspection included many detailed checkpoints which covered not only combustion but the whole field of heat management such as acceptance and inventory of fuel, thermal and heat utilization, and exhaust heat management. The results of the inspection were reported to each factory and good practices were commended at each inspection. Furthermore, some of them were publicized in the bulletin or magazine issued periodically by the heat management associations. The publicized information was not only about the general situation but also about the detailed introduction of good or bad cases. In some industries, the scores of all inspected factories were publicized. The publicity contributed to the advance and advertisement of heat management engineering. Even after the end of the industry-classified inspections, some heat management associations and public research organizations were consultants for heat management. They hired out their services to firms wanting advice related to heat management (Kobori 2010: ch.2).

Another major initiative was the heat manager system, which was started by the Rule of Heat Management in 1947 and consolidated by the Heat Management Act in 1951. The Act was aimed at preserving fuel resources and rationalizing firms through more efficient use of heat energy. It classified factories using more than 1,000 tonnes of coal (6,000 kilocalories per kilogram) annually as Designated Heat Management Factories, which were obliged to select a heat manager, who was obliged to pass the national examination and become a 'Qualified Person for Heat Management'. The manager of the Designated factories was obliged to take the heat manager's opinion seriously (Kobori 2010: ch.2).

A factory manager could reject the heat manager's opinion, so heat managers had to have sufficient skills to be respected by factory managers. Therefore, the government held frequent events to foster their skills: for example, offering training and lessons necessary to become a Qualified Person for Heat Management, regular meetings for Qualified Persons for Heat Management and so on. The Heat Management Act was unique because it was drafted to increase the skill and status of the heat management engineer, in order to improve fuel efficiency; in fact the Agency of Resources, which drafted a bill for heat management, reported that no such law had been passed in any other country, even in Germany (Agency of Resources 1950).

Making and enforcing these policies, government officers requested that iron and steel engineers gave lectures or wrote papers in magazines for engineers of other industries. Tight public–private partnership contributed to the spillover of heat management engineering from advanced industries to others (Kobori 2010: ch. 2).

The iron and steel industry: Developing to the best level in the world

Energy conservation in the post-war iron and steel industry was promoted by oxygen steelmaking as well as heat management. It started after the Second World War throughout the world, especially in the United States, to decrease fuel consumption and shorten working hours. When we discuss these two technologies, it is impossible to ignore the effect of technology imports from the United States. Research findings on the full-scale use of oxygen in open-hearth furnaces (OHF) began to be imported to Japan in 1947, and full-scale technical guidance by American engineers on heat management was given at Japanese iron and steel plants in 1949 (Kikkawa 1949; Kobori 2010: ch. 3).

Nevertheless, the Japanese energy-conservation technology developed after the war was not an exact copy of the US technology. On the contrary, post-war heat management technology in Japan was very different from the US efforts in its objectives and contents. Takami Ota, one of the chief steelmaking engineers of Yawata Iron and Steel Works, made an overseas tour visiting factories in 1954 and reported that the fuel efficiency (calories/tonne) of the US steel industry was inferior to that of Japan. Ota analysed the reasons as follows (Ota 1954: 770).

> I was convinced that the high-level instruments and automatic managers installed by Yawata and the other Japanese steel firms were as good as in the highest-class plants in the US…. in US [factories] OHF operators were not necessarily interested in research or improvements for burning at OHF or in checking the burning scores of daily work… The reason why fuel consumption per unit of output in the US is not always superior to that in Japan was that the US steel factories attach the greatest importance to the efficiency of steelmaking (t/hr)….

Ota recognized that the most important objective of the formation of technology in the United States was maximizing the efficiency of steelmaking in tonnes per hour terms, whereas the most important objective in Japan was fuel efficiency (calories/tonne). He also noted that the difference in the formation of technology influenced the difference in daily work between the United States and Japan. We would fail to grasp the characteristics of the post-war Japanese iron and steel industry if we notice only the introduction of US technology and ignore the history of energy-conservation activities, which bore fruit after the war. Moreover, the introduction of oxygen steelmaking was regarded as negative by the US steel engineers who guided heat management during the reconstruction period because they thought that oxygen steelmaking was not as popular even in the United States as the Japanese steel engineers imagined (Nippon Kokan K.K., Planning Office, Engineering Division 1949). The Japanese introduction of oxygen steelmaking was extremely independent and oxygen use in Japan became much higher than anywhere else in the world during the 1950s (Committee Investigating the Foreign Market in Iron and Steel 1963: 74). As a result of these technical feats, fuel consumption per unit of output at OHF was already better than that of any other country by the early 1950s when old-type furnaces were still widely used (Figure 11. 4).

What was the background to such rapid development of the Japanese energy-conservation technology? We should specifically examine technology exchange and improvement at a worksite.

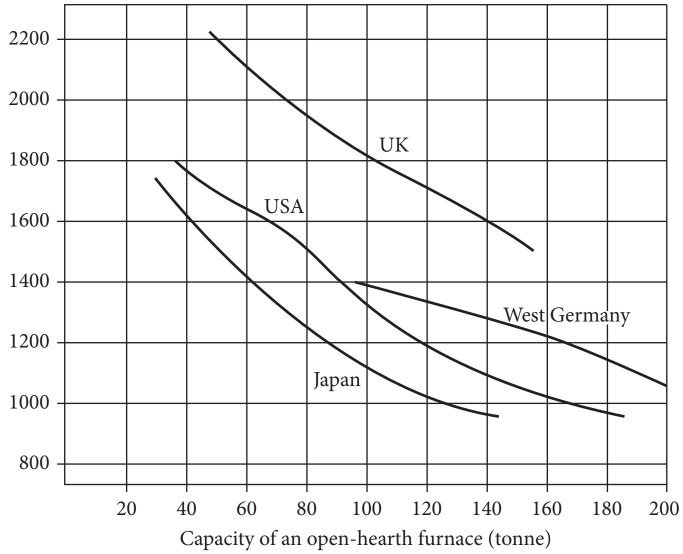

Figure 11.4 Fuel consumption per unit of output (1,000 kcal/tonne) in open-hearth furnaces in four countries in 1953.

Notes: 1. UK and Japan: using the basic OHF; 2. USA: all OHF; 3. West Germany: all using the tilting OHF.
Source: Tabata (1956: 83).

The ISIJ played an important role in technology exchange. It established eight divisions such as pig iron, steelmaking and steel products in 1948, and some divisions researched heat management (Kobori 2010: ch. 3). In the OHF division, each attending company mutually announced and criticized technology (for instance, a burner blueprint) in order to encourage the standardization of technology. The OHF division also researched oil-burning, furnace structure and oxygen steelmaking (Kikkawa 1950; ISIJ 1950). This example illustrates that, by restarting and developing research meetings which had existed between the 1920s and the 1930s, technology exchange preceded the start of full-scale technical guidance from US engineers.

These exchange relations enabled the contents of the US engineers' guidance to be shared closely between the Japanese steel companies. For example, when the US engineers visited Yawata, some heat management engineers belonging to other Japanese steel companies came along and watched them present their advice at Yawata.[4] Their guidance report was later published and sold (ISIJ 1992: 223–47, 287–340). A division responsible for instrumentation and heat management technology, the Heat Economy Division, was established in ISIJ. The Division standardized best-practice designs of furnaces and instrumentation (ISIJ 1953, 1954).

4 Interview with M. Shidara, Yokohama, 24 October 2007.

Each factory's heat management scores were presented to ISIJ every month to be exchanged between the engineers belonging to each factory.[5] Iron and steel factories both cooperated and competed in the development of heat management technology.

We should specially examine the role of Yawata Iron and Steel Works to understand the active exchange of technology and scores. The head office of Yawata was not sensitive about the leakages of technology through ISIJ to its rivals. They wished to develop not only their own company but also the Japanese iron and steel industry as a whole. Such a culture would have been generated before the 1950s, when Yawata had been a governmental or semi-governmental monopolistic company, and probably persisted even after the 1950s.[6]

These exchanged technologies and scores were reported to engineers and workers at worksites through the heat management committee of each factory to stimulate the improvement of energy-conservation technologies. Steel Plant No. 3, Yawata Iron and Steel Works, which was the first steelmaking plant to achieve fuel efficiency of better than 1,000 kilocalorie per tonne in Japan, was a typical case. The engineers of Steel Plant No. 3 tried various methods to interest workers in instrumentation and heat management and thereby improve fuel efficiency, such as the adjustment of the arrangement of staff members to arouse a competitive spirit related to heat management, making workers calculate fuel consumption per unit of output for themselves at every tapping of liquid steel and having them compare the scores with those of other factories or those in foreign countries, trying special programmes to get the president's monthly award for heat management, and instilling the confidence of workers in their heat management. Such steady activities reformed the minds of workers who previously had relied not on instruments but on their own appreciation (Aihara and Sakamoto 1955).

Masao Shidara and Kiyoshi Sugita, famous heat engineers, recalled the chief of Steel Plant No. 3 as very keen on heat management[7] Sugita said the following about heat management in the 1950s: 'Unexpectedly, many men were promoted because they were deeply engaged in heat management. [The man who succeeded in heat management was] remarkable. It was a little different from general improvements of output'.[8] Through the active exchange of technology and scores beyond the factory,

[5] Ibid.

[6] Ibid. Cooperative relations between the Japanese iron and steel firms, which seemed to accelerate the development and diffusion of technology, occurred not only in heat management but also in many other areas. The most typical case is the introduction of the LD (Linz and Donawitz) converter. At first, Yawata and NKK sought to buy the patent of the LD converter from an Austrian company. MITI however coordinated each company to strengthen their bargaining power, and NKK was chosen as the only buyer. Moreover, NKK shared the patent with its domestic rivals, permitting them also to investigate the LD converter factory of NKK, and gave them technological guidance (Lynn 1982; Nakamura 2007). Similar close technology exchange between rivals, which contributed to rapid technological development and diffusion in Japan, was engaged in by shipbuilding firms during the 1950s (Sawai 1995).

[7] Interview with M. Shidara, Yokohama, 6 December 2007; interview with K. Sugita, Tokyo, 27 October 2008.

[8] Interview with K. Sugita, Tokyo, 27 October 2008.

the Japanese iron and steel industry had created a system under which an engineer or worker who was keen on energy conservation was rewarded.

During high-speed growth

Stagnation of energy efficiency improvement

Against a background of severe energy constraints, Japan had tried to improve energy efficiency. The fuel-consumption-per-unit-of-output index of the Designated Heat Management Factories improved rapidly from 100 in 1948 to 89 in 1950, 69.7 in 1955, and 60.4 in 1960 (AIST 1971: 9). Anxiety about energy constraints, however, gradually calmed in the second half of the 1950s because Japanese civil servants and business leaders estimated that crude oil production in the Middle East would continue steadily and that the increase of Japan's exports would facilitate the import of more energy. Furthermore, the energy revolution, the switching of energy resources from domestic coal and water to foreign petroleum, progressed. This revolution was more rapid in Japan than in Western Europe or the United States (Tables 11.1 and 11.2). Japan succeeded in importing oil at a lower price than those countries (Figure 11.5). The government created deeper ports and coastal industrial zones, especially along the Pacific coast, to accommodate the largest tankers in the world (Figure 11.6), which cut crude oil transportation costs. Japan, which has a long coastline, thus had more favourable conditions for importing foreign energy and resources than Western countries, whose industrial zones were generally located inland. During its high-speed growth, Japan did not avoid increasing the import of energy but tried to import energy as economically as possible (Kobori 2010: part III).

Because of these changes, the progress of heat management was weakened in the 1960s. The fuel-consumption-per-unit-of-output index of the Designated Heat Management Factories (100 in 1948) was 60.4 in 1960, 55.8 in 1965, and 55.8 in 1969 (AIST 1971: 9).

In fact, the Heat Management Division at MITI-affiliated AIST was abolished in 1962 because MITI was satisfied that the energy efficiency of energy-intensive industries such as iron and steel, cement, and electricity had reached the highest level in the world (AIST 1964: 366–7). In addition, there were rumours about the abolition of the Heat Management Act in the mid-1960s (Yokoyama 1964: 2; Komatsu 1966: 47). The Heat Economy Division of ISIJ during the high-speed growth era was also regarded as less active than that during the reconstruction period (ISIJ 1982: 25).

The following two points are also noteworthy. First, the energy efficiency of the Japanese energy-intensive industries, for example, iron and steel or thermal-power generation, continued to be the best in the world during the 1960s. How should we evaluate this? Secondly, the system of heat management or technical exchange was not fully abolished. The Heat Management Act was not abolished and the Heat Economy Division and the heat management movement at each factory were also sustained. How did these institutions survive?

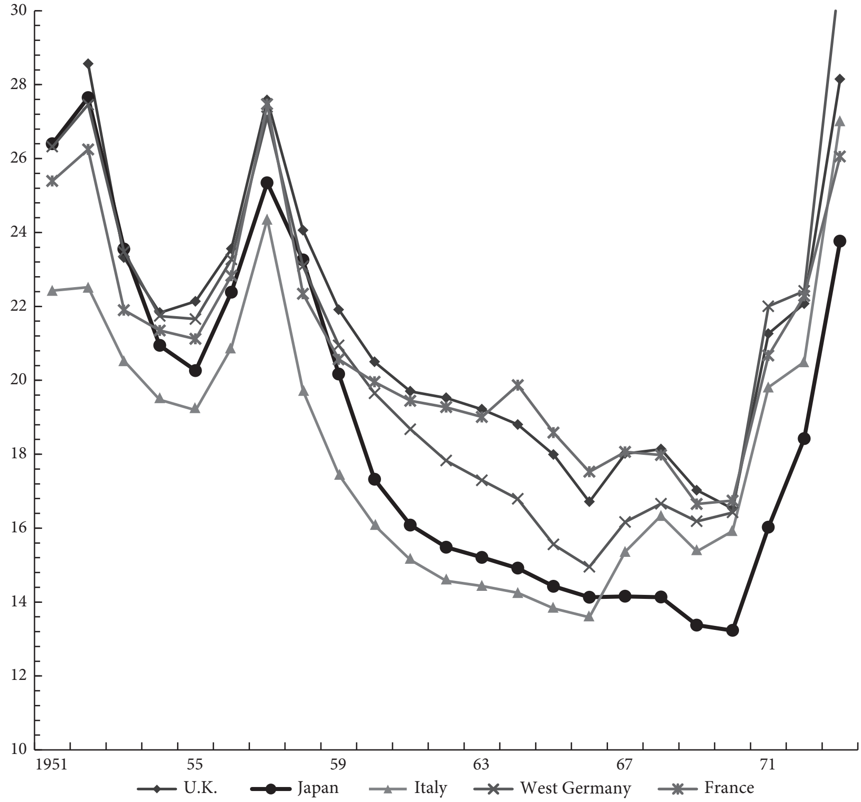

Figure 11.5 Prices ($/tonne) of imported crude oil in five countries, 1951–73.

Note: Including raw oil.
Source: United Nations, Statistical Office (various years).

1960s technological developments and the legacy of 1950s heat management

Regarding technological priorities, the improvement of energy efficiency during the 1960s was secondary. The iron and steel industry regarded mass production or quality control (QC) as more important than heat management. Sugita stated that the turning point occurred in about 1960. Creation of new plants or new processes came to be regarded as 'positive' technology, but heat management came to be regarded as 'rather conservative' (Sugita 2007). The role of energy-conservation technology declined and heat management movements that had continued until and after the Second World War became obsolete. For example, the increasing size of a blast furnace contributed to improved energy efficiency but its first aim was to achieve economies of scale. Despite the progress of the LD converter,[9] continuous

[9] The Linz-Donawitz converter, named after the Austrian towns where it was invented, blows oxygen into the molten metal, reducing smelting time among other advantages.

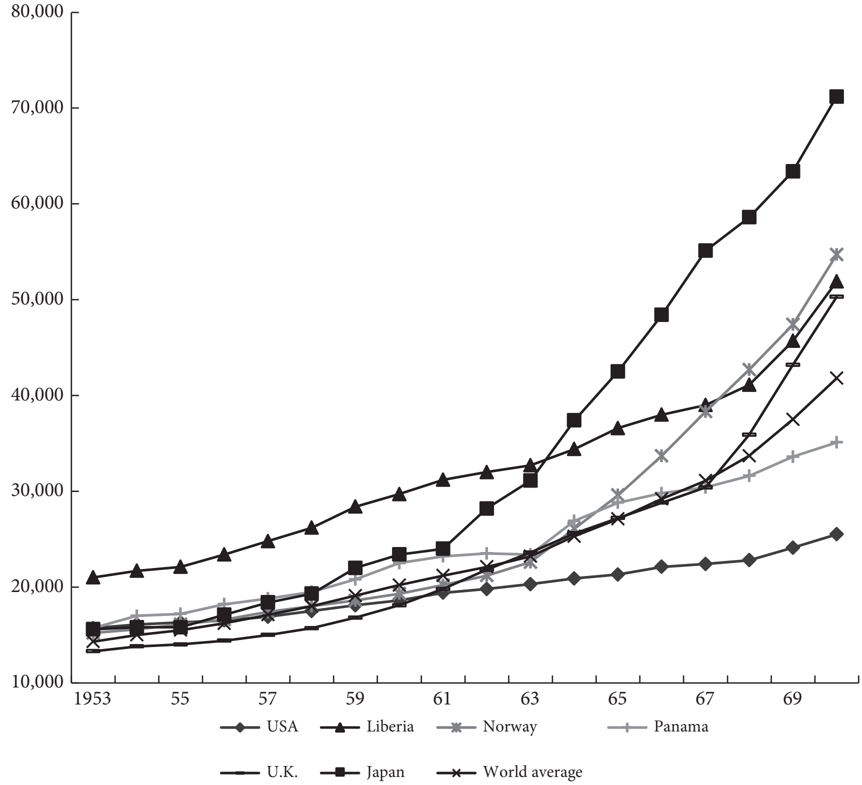

Figure 11.6 Average capacity (deadweight tonnage) of ocean-going tankers in the world and six countries, 1953–70.

Notes: 1. As of 31 December every year; 2. Aggregate data on tankers of not less than 2,000 tonnes gross.
Source: Sun Oil Company (various years).

Table 11.2 Self-Sufficiency Ratio in Total Primary Energy Supply of Six Countries, 1925–73

Year	Japan	France	West Germany	Italy	UK	USA
1925	108.0	64.0	117.4	10.6	135.7	106.7
1938	83.8	62.1	111.3	17.4	117.6	108.4
1950	96.9	67.0	119.9	24.7	98.7	100.4
1953	77.6	63.7	109.7	27.8	94.6	100.6
1955	75.1	62.6	102.1	27.7	86.9	100.2
1957	67.0	54.7	98.2	29.2	86.4	101.4
1960	55.0	57.4	90.7	31.8	77.0	95.1
1966	31.9	42.7	64.9	24.1	59.5	92.7
1973	9.2	20.5	45.0	16.7	49.2	84.0

Source: Darmstadter, Polach and Teitelbaum (1971) and International Energy Agency (IEA) (1991).

casting and QC circles started in the 1960s, and although they contributed greatly to energy conservation after the oil crisis, the aim of these developments during the 1960s was not energy conservation either. The aim of the LD converter was achieving economies of scale and reducing scrap iron consumption; that of continuous casting was the improvement of the yield rate in special steelmaking (Sugita 2007: 113–14; Kajiki 2010: ch. 1).

Nevertheless, it is a mistake to think that such technological progress bore no relation at all to the energy-conservation technology during the reconstruction period. The technology of instrumentation and furnace construction, which had rapidly developed during the 1950s to improve heat management, was utilized to make bigger blast furnaces during the 1960s. The development of oxygen generators for oxygen steelmaking during the 1950s, which was aimed at the improvement of fuel consumption per unit of output at OHF, was one condition that enabled the development of the LD converter during the 1960s. Heat management practices at workshops by engineers and workers during the 1950s was one of the roots of quality control circles (Kobori 2011).

As a result, although the aim of technology development in the high-speed growth era differed from that in the reconstruction period, the technologies which had been developed for heat management in the reconstruction period were inherited for different purposes. These inherited technologies helped sustain the improvement of the energy efficiency of Japanese energy-intensive industries at world-leading levels, as a secondary consequence in the high-speed growth era and as the intended consequences after the oil crisis.

Survival of heat management policy and engineers

It might be thought that, by their success, the heat management engineers had worked themselves out of business: so why did they continue to exist? Environmental pollution in Japan became increasingly severe during the 1960s. In this context, 'Preventing smoke at a firm was often exercised by the person in charge of the heat management' (Saito 1965: 10; see also Shidara et al. 1973: 12). From the first half of the 1960s, some famous heat management engineers insisted, in a magazine published by the Central Association for Heat Management, *Heat Management*, that their profession should devote attention to the prevention of air pollution (Kurokawa 1962: 2; Yokoyama 1964: 2). In fact, in 1963 the prevention of smoke became an aim of the government's heat management policy (AIST 1962: 56; AIST 1963: 49) and from 1968 the subtitle *Energy and Pollution Control* was attached to *Heat Management*. The theme of more articles in this magazine became the technology of air pollution (Tanishita 1969: 8) and in 1971 its title was changed to *Heat Management and Pollution Control*.[10]

[10] In the iron and steel industry, Masao Shidara, the chief of the Heat Management Division at Yawata during the 1950s, became concerned with setting up the national qualification, Pollution Control Manager, in 1971 and wrote a standard textbook for its examination (Shidara 1985).

After the 1973 oil crisis, these surviving institutions were used for energy conservation again. Most articles in *Heat Management and Pollution Control* reverted to the theme of energy conservation. Reflecting this, the title was changed again in 1978 to *Energy Conservation*. The Heat Control Act was amended as the Energy Conservation Act, and the role of heat manager evolved into that of energy manager, which included the conservation of electricity as well as fuel. The Central Association for Heat Management was renamed the Energy Conservation Centre of Japan (ECCJ) in 1978. It has continued to offer technical guidance for energy conservation and to run the national examination for the qualification of energy manager to the present day.

Regarding technical exchange among iron and steel factories, a head of Energy-Management Department of Sumitomo Metal Co. said, 'The reason the iron and steel industry progressed energy conservation promptly after the oil crisis was that… the heat economy engineers attended the Heat Management Division of ISIJ to get information of each firm and discussed this information with their own colleagues' (ISIJ 1982: 24). The institutions developed during the 1940s–50s became less effective during the 1960s but revived in the 1970s.

Conclusion

The eras during which energy consumption per unit of output in Japan improved were the reconstruction period and the oil crisis and thereafter. The common background of both eras was their severe energy deprivation. One must make a sharp distinction, however, between the possibility of the development of energy-conservation technology in the context of limited energy supplies and its realization. Why did the Japanese energy-intensive industries not decline given the background of energy supply limitations during reconstruction? Why did some of them such as iron and steel, cement and thermal power stations sustain the best practices of energy consumption per unit of output in the world, and maintain them even today?

This chapter particularly describes the iron and steel industries, which mutually exchanged energy-conservation technologies, and describes some policies which encouraged energy conservation. After the First World War, Japanese engineers and bureaucrats took a growing interest in coal supply and started to take related measures. The iron and steel industry noted German heat economy technologies, and then emulated them. Some good practices they used, especially imported by SSW, were introduced to other factories through ISIJ. At the same time, Osaka Prefecture started technical guidance for fuel combustion by small firms to reduce smoke and to rationalize their operations; that guidance was imitated by other local authorities.

These activities developed further during the Second World War and bore fruit during the subsequent reconstruction. Heat management of SSW was imitated by other iron and steel factories, which established dedicated heat-management divisions and tried to introduce heat management based on the instrumentation. During the reconstruction period, the scores of each factory as well as good practices were exchanged through ISIJ. Technology exchange among factories was consistent with competition among them. Technical guidance on fuel combustion was given by the Ministry of Commerce and Industry and later broadened to the guidance for heat management, which meant the total fuel-conservation technologies. This was influenced by the heat management of the iron and steel industry, especially SSW. The engineers who exercised technical guidance contributed to the spread of advanced technologies from the iron and steel industry to other industries.

The heat management policy emphasized improvement of managers', engineers' and workers' awareness, information and skills through guidance and licensing systems (introduced by law), rather than installing new and expensive equipment. This policy was suited to the resource-scare and labour-abundant situation in modern Japan, which was especially severe just after the defeat of the Second World War. Reforming workers' thinking on heat management simultaneously improved energy consumption per unit of output in the iron and steel industry. Thus energy conservation in Japanese industry developed along a skill- and labour-intensive path. Although this development stagnated during the high-speed growth era, the innovations of that period had the secondary effect of reinforcing energy conservation. They themselves were underpinned by the improvements in heat management that had been launched in the 1950s. The institutions related to heat management were not abolished during high-speed growth because the heat management engineers emphasized the relation between heat management and the reduction of air pollution. Results show that, after the oil crisis, these technologies developed still further to improve energy efficiency. The institutions which were not fully abolished in the 1960s contributed to their development and diffusion.

We note two research tasks. The first is to examine the spread of Japanese energy-conservation technology to other Asian countries. The export of Japanese heat management technology was plotted in 1959 by engineers in the heat management associations and the first observation team from overseas (India) was invited in 1966 (CAHM 1966: 48–56; Taga 1967: 3). During the oil crisis, in 1973, South Korea passed a Heat Management Act, which closely resembled the Japanese prototype but was more forceful. The government of South Korea gave the guidance for heat management by the Japanese engineers to Korean factories in 1975 (Shiozawa 1974; Hino 1975). Today ECCJ strives to export the Japanese institutions and technology for energy conservation to Asian countries (Taniguchi 2012). The development of the energy conservation in eastern and Southeast Asia presents an interesting theme for future research.

Second, it remains to study the relation between the development of energy-conservation technology and environmental technology as such. Although the development of fuel combustion or heat management contributes directly to the reduction of smoke, it did not contribute directly to the reduction of other air pollutants such as sulpher oxide (Tanaka 1972: 27). Although the fact that perfect combustion was insufficient to reduce the discharge of SOx was already known in the 1920s, the technical guidance for fuel combustion ignored this problem (Kobori 2010: ch. 1). An officer who belonged to the related section of the Regulation for Smoke Control in Osaka clarified it as follows: 'The Regulation aims to develop industrial management.

We should not prevent it by the Regulation' (Osaka City Community Promotion Association 1932: 845–9).

A more severe case was energy conservation through oxygen steelmaking. It actually worsened air pollution. Popularization of smoke dust collectors occurred after 1960. Its speed had been delayed more than the rapid popularization of oxygen steelmaking. The development of energy conservation by the Japanese iron and steel industry during the 1950s was encouraged by loose pollution regulations and by the tacit acknowledgement by neighbours of plants that smoke from the plant was a sign of their prosperity (Sugita 1997; Kobori 2010: 347–8; Miyamoto 2014: 68–73).

In the case of Kitakyushu City, the location of Yawata Iron and Steel Works, it was local women's associations that took the lead in the campaign against pollution. They started in 1963 to research the real damage caused by the pollution, for example, the serial correlation between air pollution concentration and the number of primary school absences, in cooperation with a junior staff member of Kitakyushu City and a university professor. Additionally, they publicized the results of their research, and succeeded in investigating some plants which released pollutants, such as Yawata Iron and Steel Works (Hayashi 1971; Miyamoto 2014: 73–4). Women who participated in the campaign in Kitakyushu were apparently not so dominated by big firms as their husbands were. They contributed to the acceleration of the application of heat management technology to pollution control. When we discuss the relationship between the development of both energy-conservation technology and environmental technology, we should specially examine the role of local residents as well as local and national authorities, private companies and professional engineers.

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12

The Development of South Korea's Nuclear Industry in a Resource- and Capital-Scarce Environment

Se Young Jang

Nuclear energy is regarded as 'clean' in the sense that it does not contribute to global warming, as fossil fuels do. Although there are growing concerns about the environmental effects of radioactive waste on soils and human health, a number of industrialized countries have increased the share of nuclear energy in electricity generation to reduce their dependence on fossil fuels for economic and/or environmental reasons; South Korea (Republic of Korea) is one of them. The share of nuclear energy in Korean electricity generation remained under 10 per cent in the early 1980s, but drastically mounted in the mid-1980s as several nuclear power plants began operation. Nuclear energy actually exceeded fossil fuels in electricity generation in 1989 and 1990. Since then, its share has decreased but still remains above 30 per cent (Appendices 1 and 2).

As Kenneth Pomeranz noted in this volume, South Korea has pursued a 'grow first, clean up later' approach to its economic development in general. Thus, at a glance, Korea's increasing interest in alternative energy sources, including nuclear, which required a huge amount of investment, could be considered as one of the examples of Korea's entry into the 'clean up' phase of economic development. However, the Republic of Korea (ROK) government started its civil nuclear projects much earlier in the 'grow' phase when there was almost no sense of cutting fossil fuel consumption for the sake of the environment. The rapid development of South Korea's nuclear energy industry raises questions about how a country that was relatively short of both natural resources and capital in the 1970s was able to undertake this highly ambitious capital- and technology-intensive project – and whether it made economic sense to do so. To address this issue, this chapter investigates what factors motivated and enabled South Korea to start and invest in the nuclear energy industry in the 1970s. In particular, this chapter attempts to shed light on the role of South Korea's military ambitions to develop nuclear weapons in the 1970s in facilitating its efforts to construct nuclear facilities and invest more in relevant research. This chapter also shows that the competition in the 1970s between nuclear suppliers in the world market created a favourable environment for new customers like South Korea to acquire highly advanced technology and facilities relatively easily.

Deficiency of domestic resources and capital

The Korean War of 1950–53 destroyed almost two-thirds of the country's productive capacity with almost one million civilians killed. Yet the South Korean economy managed to recover in the 1950s, mostly with the help of foreign aid.[1] However, foreign aid diminished drastically in the early 1960s, and was replaced by foreign loans. Throughout the 1960s and 1970s, South Korea showed a remarkable economic performance: the average annual growth rate for 1962–79 was 9.8 per cent (Sakong 1993: 3). Widely regarded as an exemplary case of late industrialization along with Japan and other Asian tigers, South Korea's policy, largely based on state intervention and export-orientation, appeared to facilitate its unprecedented economic growth.[2]

Nevertheless, South Korea's economic capability in the late 1960s and the early 1970s was not sufficient to embark on a highly capital-oriented industry such as producing nuclear energy on its own. For instance, the simple comparisons of gross domestic product (GDP) and GDP per capita between South Korea, Japan and the United States in the period, as shown in Tables 12.1 and 12.2, reveal that South Korea's economic size and capability remained much behind those advanced countries. In particular, the construction of Japan's first commercial nuclear reactor started in 1961, while the construction of South Korea's first commercial nuclear reactor (*Kori-I*) started in 1971. Table 12.3 reveals that, despite this ten-year gap, South Korea's GDP and GDP per capita in 1971 were a lot lower than Japan's in 1961. The comparisons of economic size with other potential nuclear proliferators at that time (Table 12.3) also shows that South Korea would have had more difficulty in launching this capital-oriented industry than other late industrializers.

Table 12.1 Gross Domestic Product 1968–72 (billion 2015 US $)

	1968	1969	1970	1971	1972
South Korea	5.95	7.5	9.4	10.4	11.4
Japan	146.6	172.2	209.1	236.2	312.7
USA	942.5	1,019.9	1,075.9	1,167.8	1,282.4

Source: World Development Indicators, The World Bank.

[1] During 1953–7, foreign aid to South Korea reached its peak. See more details in Krueger (1979: 41–81).

[2] Among many, see Amsden (1989), Westphal (1990: 41–59) and Chang (1993: 131–57).

Table 12.2 Gross Domestic Product Per Capita 1968–72 (2015 US $)

	1968	1969	1970	1971	1972
South Korea	193.11	236.99	291.86	316.83	339.28
Japan	1,450.62	1,669.10	2,003.65	2,234.26	2,917.66
USA	4,695.92	5,032.14	5,246.96	5,623.59	6,109.69

Source: World Development Indicators, The World Bank.

Table 12.3 Comparison of Five Countries When Their First Commercial Nuclear Reactors Began Being Constructed (GDP: billion 2015 US $; GDP per capita: 2015 US $)

	Japan (1961)	Argentina (1968)	Korea (1971)	Taiwan (1972)	Brazil (1972)
GDP	53.51	26.44	10.42	8.59	58.54
GDP per capita	563.59	1,136.13	316.83	560.08	580.67

Note: Taiwan is not a member of the World Bank Group. Thus, Taiwan's GDP (billion 2012 US $s) and GDP per capita (2012 US $s) have been drawn instead from the ECONSTATS website, whose figures are based on the International Monetary Fund's World Economic Outlook data at http://www.econstats.com/weo/CTWN.htm (accessed 10 August 2015).
Source: World Development Indicators, The World Bank

South Korea also started this highly capital-intensive project when the structure of Korea's economy was still based on labour-intensive industries. Although the ROK government began to recognize the need to develop heavy and chemical industry and to put some resources into planning it as early as the late 1950s or early 1960s, its full-scale endeavour to enhance heavy and chemical industry started later, in the early 1970s (Wade 1990: 239–41, 250). In addition, Seoul's industrial priority during the first stage of capital-intensive industrialization was to advance the labour-intensive segments of capital-intensive industries such as machinery, electronics and automobiles. Thus, South Korea's interest in the nuclear energy industry in the late 1960s and early 1970s appeared a little earlier than would have been expected from a 'normal' track of economic development, given that the nuclear energy industry required an enormous scale of investment and a high level of technological achievement.

South Korea was also without abundant natural resources. Hence, from the beginnings of its industrialization, it was not an option to earn huge revenue by exporting primary products. Rather, a variety of primary products were imported to feed people and support incipient industries. In particular, while electricity was indispensable to enable modern manufacturing industries to work, South Korea's natural endowment of energy sources was extremely poor, leaving the country highly dependent on imported primary energy for electricity generation. For instance, South Korea's demand for energy was 'increasing at a rate of 8% per annum on the average during the period of 1961 to 1974', and its 'dependency on imported oil from the

Middle East exceed[ed] 50% of the total energy need since 1971'.[3] This dependency made the Korean electricity industry more vulnerable to price fluctuations in international energy markets as the economy developed (Yang and Xu 2011: 114–15).

The nuclear fuel cycle begins when uranium is mined, enriched and manufactured into nuclear fuel, which is delivered to a nuclear power plant. Hence, an easy access to a sufficient amount of highly concentrated uranium is a necessary condition to launch a nuclear energy project. Although South Korea is generally short of natural resources, one natural resource that South Korea has in relatively large quantity is uranium ore. In 1976, the Ministry of Science and Technology announced that approximately eight million tons of uranium ore had been found in South Chungcheong Province, and the total was estimated to be about 200 million tons.[4] But it turned out to be of poor quality: low in its concentration of uranium. The government has not been successful so far in finding areas where the uranium concentrations are adequate to form an economically viable deposit. The concentrations of uranium mined in the southern part of the Korean peninsula are mostly below 0.03 per cent. Therefore, the ROK government has imported all the uranium needed for domestic use (Korea Hydro and Nuclear Power 2004).

The first OPEC oil crisis in 1973–4, with oil prices quadrupling, shocked oil-dependent South Korea which had been launching a series of projects in its heavy and chemical industry. Despite the deterioration in economic circumstances, though, the ROK government did not retreat from its original policy of promoting outward-oriented developmental strategies and capital-intensive industrialization (Balassa 1990: 5–6). Unlike Japan, South Korea did not implement a policy of increasing efficiency in domestic and industrial use of electricity right after the 1970s oil crisis (Sakong 2009; compare Kobori, in this volume). Instead, the Korean government attempted to mine more coal to offset the deficiency in energy sources, but the domestic coal supply did not match the highly growing demands of the 1970s. Thus, Korea could not help but import coal since 1978.[5] Under these circumstances, some existing literature notes that despite its lack of uranium, South Korea became more interested in nuclear energy in the midst of the oil shock to overcome its dependence on imported energy sources and to further support its incipient heavy and chemical industries which were expected to consume a huge amount of electricity (Lee 2009: 34; Valentine and Sovacool 2010: 7975; Joo 2011: 55).

The argument here does not deny that the ROK government's concerns about energy security and costs, as well as a structural change of industry in the 1970s, would have led Seoul to adopt a more active policy on nuclear energy. However, these economic considerations do not fully explain South Korea's earlier interest in nuclear

[3] Korea Atomic Energy Research Institute (KAERI), 'Need and Justification for Our Institute's Nuclear Fuel Technology Research Program', exact date unknown (presumably in July or August 1975), *Seoul – Service Culturel*, 630PO/1/35, Centre des Archives Diplomatiques de Nantes, France (hereafter the French diplomatic archives).

[4] *The Dong-A Ilbo*, 23 March 1976.

[5] Won Woo Lee, 'Coal Industry' (in Korean, 2007), National Archives of Korea at http://www.archives.go.kr/next/search/listSubjectDescription.do?id=006542. Accessed 10 September 2015.

energy before the 1973–4 oil shock and in what circumstances Seoul, a capital-scarce late industrializer, was able to acquire sufficient foreign support to build nuclear power plants.

'Atoms for Peace' and transfer of nuclear technology

Despite the lack of domestic uranium sources, a change in the external environment enabled South Korea to enter nuclear energy markets. Specifically, a shift in US policy in the 1950s which favoured the transfer of civil nuclear technology and materials to non-nuclear countries paved the way, in the long term, for the rise of South Korea as one of the major nuclear energy producers.

At first, nuclear technology was developed for military purposes as the US atomic bombing of Hiroshima and Nagasaki clearly demonstrated. However, the US-Soviet strategic balance followed by the first Soviet test of a hydrogen bomb in August 1953 ironically created an impetus for international cooperation and control of fissionable material. US president Dwight D. Eisenhower's 'Atoms for Peace' speech at the UN General Assembly on 8 December 1953 opened nuclear research for peaceful purposes to civilians and non-nuclear countries, and led to the establishment of the International Atomic Energy Agency (IAEA) in 1957.[6]

One year after Eisenhower's speech, the US Atomic Energy Act was passed. This promoted international dissemination of atomic energy information under bilateral and multilateral arrangements, which affected a number of countries' decisions to use nuclear technology for peaceful purposes. South Korea was no exception. Seoul and Washington signed the US-ROK Nuclear Cooperation Agreement in 1956. The same year, South Korea's Atomic Energy Law was enacted, and the Korean government accordingly established its Atomic Energy Agency (AEA) in 1959. Thus the legal and other institutional conditions for facilitating the launch of the nuclear energy projects in South Korea started to take shape in the last half of the 1950s under a favourable international environment for acquiring nuclear energy technologies.

On 7 July 1956, President Syngman Rhee met Walter L. Cisler, the CEO of the Detroit Energy Electric Company, who was visiting Seoul as an adviser to the US International Cooperation Agency. In his meeting with Rhee, Cisler strongly recommended that a resource-poor country like South Korea develop nuclear energy technology and start preparatory works, such as establishing administrative bodies and research institutions in charge of nuclear energy, in anticipation of a fruitful future in twenty years. He also stressed the significance of educating young scientists, which led to the decision of the ROK government to send 237 trainees abroad during 1956–64 – to the United States, the United Kingdom, France and West Germany – for training in nuclear science and engineering. One hundred thirty-one out of 237 trainees directly benefited from South Korea's newly established National Scholarship

6 See Eisenhower's 1953 'Atoms for Peace' speech at http://www.iaea.org/About/atomsforpeace_speech.html. Accessed 5 September 2014.

Program for studying abroad, and many of them became principal figures in the South Korean nuclear energy industry in the 1970s and beyond (Korean Nuclear Society 2010: 23–7).

Nuclear energy industry needs highly educated and trained researchers and engineers, but it does not require a large number of employees to be hired at the start-up stage compared to other heavy and chemical industries. In particular, the contracts for the first ten nuclear reactors were based on a so-called turnkey approach, which neither required nor enabled South Korea's participation in some key technological works including architecture engineering.[7] Thus, South Korea's lack of human capital in the beginning did not pose a huge problem in embarking on nuclear energy projects.

Meanwhile, the Eisenhower administration encouraged and supported its allies and some other nations to construct nuclear research reactors under the Atoms for Peace programme. This new policy involved transferring nuclear technology necessary to build and operate those reactors, and granting half of the total cost including nuclear fuel. Welcoming the US initiative, a number of countries embarked on reactor construction projects. For instance, Japan was granted 350,000 US dollars – worth nearly $3 million at 2015 values – by the US government when its second Japan Research Reactor (JRR-2) was built by a US firm in June 1957 (Korean Nuclear Society 2010: 51–2).[8] The Atoms for Peace programme also enabled India to purchase a CIRUS (Canadian-Indian Reactor, United States) reactor from Canada and heavy-water from the United States to use as a moderator.[9] This research reactor later produced some of India's initial weapons-grade plutonium which was used for its first detonation of a 'peaceful' nuclear device in 1974. Despite its original intentions to promote peaceful nuclear uses, Atoms for Peace was inevitably criticized for providing potential proliferators with technical and physical support to develop nuclear weapons because of nuclear technology's dual-use characteristics. Today, some former recipient countries of the programme such as India, Pakistan and Iran are regarded as de-facto and potential nuclear weapons states.[10]

In the era of Atoms for Peace, South Korea also started constructing TRIGA MARK-II, the country's first research reactor. It was provided by US firms General Atomics and General Dynamics under an agreement signed on 3 December 1958. The total reactor cost was $730,000 of which $350,000 was a grant by the US government.

7 'Turnkey' here means 'contracts under which the reactor manufacturer took on all of its responsibility for design, construction and testing of a reactor, including meeting regulatory guidelines, simply turning the key to the reactor over to the utility once the reactor became operational'. See Burness, Mongomery and Quirk (1980: 188).

8 US 1957 dollars are converted to the current value at http://www.saving.org/inflation/. Research reactors, mostly used for research, training and testing, are much smaller and simpler than power reactors and are often located in university campuses or research institutes. Thus research reactors are significantly cheaper to construct than power reactors generating electricity.

9 Fission causes a chain reaction in nuclear reactors, and the moderator is a medium to reduce the speed of this chain reaction. Commonly used moderators are light water, solid graphite, and heavy water.

10 On negative consequences of the Atoms for Peace programme, see Fuhrman (2012).

It was no small amount for South Korea whose GDP per capita in 1960 was only around $155 at 2015 values. Construction for the reactor began in July 1959 and was completed on 5 November 1960. The TRIGA-Mark II reached criticality on 19 March 1962, and began operations eleven days later. In addition, General Atomics provided the 20 per cent-enriched uranium fuel for the reactor (Sung and Hong 1999: 307; Korean Nuclear Society 2010: 53–62).[11]

Long-term nuclear energy planning and South Korea's first commercial nuclear reactor

Although South Korea became interested in nuclear energy in the 1950s, it was in the early 1960s after President Park Chung-hee took power that the idea of using nuclear energy for commercial purposes started to be pursued seriously. The Committee on Developing Nuclear Energy which had been set up by the government produced a long-term nuclear energy plan in 1962, featuring the recommendation that the government start constructing a nuclear power plant with a capacity of 150,000 kilowatts, to be commissioned in 1971. This plan was further endorsed by the IAEA's feasibility review in 1963. The ROK government dispatched two study teams to a number of countries in 1966 and 1967 in order to better understand how other countries had implemented their nuclear energy policies, including their financing. Based on these studies, the government concluded in 1968 that a nuclear power plant with a capacity of 500,000 kilowatts should be built by 1974 in Kori, South Kyungsang Province, and that the type of nuclear reactor at this plant should be selected from three candidates: the Boiling Water Reactor (BWR), the Pressurized Water Reactor (PWR), and the Advanced Gas-Cooled Reactor (AGR) (Korean Nuclear Society 2010: 82–7).

After being given charge of the construction and operation of nuclear plants in 1968, the Korea Electric Power Corporation (KEPCO) invited bids from four Western companies: General Electric, Westinghouse Electric Company, Combustion Engineering and British Nuclear Export Executive. KEPCO also made it clear that the contractor should accept responsibility for securing foreign loans as South Korea was not able to mobilize all the financial sources necessary to build its first commercial nuclear power plant, Kori-I. The four companies submitted their estimated costs in October 1968, and KEPCO chose Westinghouse as the principal contractor after three months of review (Korean Nuclear Society 2010: 88–93).

The subsequent negotiations with Westinghouse did not go smoothly because two parties disagreed about how to structure the cost of construction. The ROK government wanted a fixed annual price of construction until the plant was completed, whereas Westinghouse requested a yearly increase of 5–6 per cent, to allow for inflation. In the end, the two parties compromised on a maximum cap for

[11] GDP per capita data has been drawn from the World Bank's World Development Indicators (1960–69), but other sources show different figures.

a price increase ($6.75 million) which was virtually a yearly increase of 2 per cent. Furthermore, KEPCO secured a loan of $175 million from the US Export-Import Bank. South Korea's Kori-I nuclear power plant was finally opened in July 1978, which made South Korea the twenty-first country in the world to acquire a nuclear power plant (Korean Nuclear Society 2010: 94–100).

Political motivations behind South Korea's nuclear energy projects

Insufficient energy sources, increasing domestic energy consumption and rising oil prices were significant reasons for South Korea to develop a nuclear energy industry in the 1970s. The Korean leadership's decision to acquire relevant technology and facilities to produce nuclear energy reflected its strategy of increasing and diversifying energy supplies. However, South Korea's growing interests in nuclear energy at that time cannot merely be explained by economic conditions. As nuclear technology for a peaceful purpose can be relatively easily converted to military use, the motivation of any government which wants to embark on nuclear energy projects needs to be carefully researched in relation to both economic and geopolitical/security factors. Coincidentally or not, President Park pursued a military option of developing nuclear weapons from the early 1970s (Project 890). Even though the South Korean government's earlier nuclear energy projects in the 1950s and 1960s were mainly motivated by its need for alternative energy sources and facilitated by the US government's favourable terms, South Korea's endeavours to accelerate the development of its nuclear energy sector – particularly since the early 1970s – appeared to have been related to its military intentions to a certain extent.

Despite South Korea's heavy military dependence on the nuclear deterrence offered by the United States, and its apparent sufficiency, President Park tried to develop South Korea's own nuclear weapons against strong opposition from Washington. North Korea's aggression, though, did not appear to be the main driver of Park's nuclear ambitions. First, strengthening its conventional military power would have been less costly and more realistic for the South to catch up with the North, which had the upper hand in defence spending and capability at that time. South Korea's defence spending was 299 million dollars in 1970, while North Korea's spending in the same year has been estimated variously from 576 to 742 million dollars (Moon and Lee 2009). Furthermore, US tactical nuclear weapons had been deployed in South Korea since the 1950s, and thus it was unnecessary for the South to build up its own nuclear arsenals in order to deter military threats from the North. Lastly, the nuclear weapon programme was not launched to counter Pyongyang's military nuclear pursuits. It was likely that Kim Il Sung authorized North Korea's nuclear weapons programme only in the late 1970s, several years later than Park's decision (Mansourov 1995: 25–6).

However, US military commitments to South Korea were significantly on the wane during the late 1960s and the early 1970s when President Park started taking his military nuclear option more seriously (Jang 2016). As Victor Cha points out, 'Washington's ambivalent response to the three North Korean provocations in 1968 and 1969 seriously undermined South Korean confidence in American military commitments' (Cha 2000: 64).[12] In addition, US president Richard Nixon's announcement of the Guam Doctrine in July 1969, expecting Asian allies to take more responsibility for their own defence, followed by the 1971 withdrawal of the US Seventh Infantry Division from Korea – almost one-third of the US forces in the South at that time – undeniably infuriated and disturbed President Park.[13]

Park first started to take the possibility of military nuclear options into consideration in mid-1970 when negotiating with Washington on US troop reduction from South Korea. The then senior secretary for economic affairs at South Korea's Presidential Office (the Blue House), Oh Won-chul, recalled that Park made his decision regarding nuclear weapons when seeking an alternative security measure in the midst of the weakening US security commitment to South Korea.[14] Oh's statement was confirmed by a recent interview with the then prime minister as well as husband of President Park's niece, Kim Jong-phil. According to Kim, the president also mentioned in 1970 that

> we [the ROK government] do not know when the United States will leave, so let's research on nuclear weapons. Even if we cannot develop those weapons [at this moment] because of the [expected] US interference with our project, it would be still beneficial for us to have sufficient technology to make the weapons when necessary.[15]

It is noteworthy that this decision overlaps with the periods when the ROK government established the Agency of Defense Development (ADD) and the Weapons Exploitation Committee (WEC) which soon became deeply involved in the programme.[16] In November 1971, Secretary Oh met the minister of science and technology and the ADD director to discuss a plan for a clandestine programme of nuclear weapons development (Hong 2011: 488). Furthermore, he recalled that at the

[12] These provocations were (1) the failed attempt by a DPRK commando unit to assassinate President Park on 21 January 1968, (2) the seizure of a US intelligence-gathering ship (USS *Pueblo*) with its crew members by DPRK naval vessels on 23 January 1968 and (3) the shooting down of a US Navy reconnaissance flight (EC-121) by North Korean MiG 21 aircraft over the East Sea on 15 April 1969, killing all thirty-one Americans on board.

[13] President Park expressed strong opposition to Washington's unilateral decision to partially withdraw US forces from South Korea. The then-Ambassador William Porter later testified that Park directly told him that the United States 'would not be allowed to take troops out' and 'had no right to do that'. See US House of Representatives 1978: 63.

[14] Interview with Oh Won-chul (in Korean), *Weekly Chosun,* 12 January 2010.

[15] Interview with Kim Jong-phil (in Korean), *JoongAng Ilbo*, 10 July 2015. President Park's statement was translated from Korean to English by the author. Not in refs, added at end.

[16] The ADD was established in August 1970. See the website of the ADD at http://www.add.re.kr Accessed 2 August 2015. It is not obvious exactly when the WEC was established since it was a covert and *ad-hoc* committee directly under the control of the Blue House. However, some literature notes that the WEC was established during a similar period in 1970 to when the ADD started. See Choi and Park (2008: 376) and US House of Representatives (1978: 79–80).

beginning of 1972, Park directly issued the order to him and the then Blue House chief of staff, Kim Jeong-ryeom, to acquire 'necessary technology for nuclear weapons which were inevitable to maintain peace on the peninsula'. The president tightly controlled the programme from the beginning. It was highly compartmentalized among seven defence research institutions.[17] Two of them, ADD and the Korea Atomic Energy Research Institute (KAERI), played major roles. While the latter focussed on an ostensibly civilian side of the project, such as obtaining fissile materials (albeit, weapons-grade), the former worked on manufacturing the weapons and the delivery system. This division of labour enabled Park to hide his military nuclear programme from the United States for as long as possible (Hong 2011: 490–1).

South Korea's nuclear weapons programme in the 1970s proceeded in parallel with, and was covered by, its civilian nuclear projects which had been launched on full scale in the late 1960s and early 1970s.[18] Instead of solely relying on US-supplied light water reactors (LWRs) and low-enriched uranium, which made it more difficult to carry out research on the military uses of nuclear technology, the ROK government approached other nuclear suppliers to find a way to produce plutonium from nuclear fuel reprocessing. Reprocessing is a chemical process to separate plutonium and uranium in the spent fuel from nuclear reactors. Separated plutonium from the reprocessing procedure can be used to make nuclear weapons.

In May 1972, South Korea's minister of science and technology, Choi Hyung-sup, was secretly dispatched to France for consultation on nuclear technical cooperation, particularly in the field of nuclear fuel reprocessing and fabrication.[19] The two governments agreed first on concluding the ROK-France Nuclear Cooperation Agreement to enable South Korea to purchase French nuclear technology and facilities.[20] After a series of negotiations, the agreement finally came into force on 10 October 1974. In the meantime, six months after Minister Choi's visit to Paris in 1972, G. Jeanpierre, representative of the Commissariat à l'Energie Atomique of France (CEA), flew to Seoul and met his counterparts of KAERI and the Ministry of Science and Technology.[21] In this meeting, CEA and KAERI agreed upon technical cooperation, particularly in constructing a nuclear fuel fabrication plant in Korea and training KAERI personnel. This cooperation also included the fields of nuclear fuel development and

17 Interview with Oh (2010).

18 For instance, the budget of KAERI doubled in 1974 (1,664m. KRW) compared to the previous year (810m. KRW). 1,664m. 1974 KRW was worth about $14,168,511 in 2015. See KAERI, 'A Brief Outline of KAERI Activities', May 1974, *Seoul – Service Culturel*, 630PO/1/35, French diplomatic archives.

19 Interview with Kim (2015).

20 Ministry of Science and Technology to Ministry of Foreign Affairs, 'Exchange of the Memorandum of Understanding about Nuclear Cooperation between thé Republic of Korea and France', 11 November 1973, *The ROK-France Nuclear Cooperation Agreement for Peaceful Uses of Nuclear Power*, 741.61FR 1973-74/J-0090, Diplomatic Archives of the Ministry of Foreign Affairs, Republic of Korea (hereafter Korean diplomatic archives).

21 'Program du Sejour en Corée de M. Jeanpierre', date unknown (presumably in November 1972), *Seoul – Service Culturel*, 630PO/1/35, CADN.

irradiation.[22] Attempts at acquiring nuclear fuel reprocessing and fabrication technology were also made through high-level diplomatic exchange. In March 1973, Prime Minister Kim met the French president, Georges Pompidou, and the then minister of economy and finance, Valéry Giscard d'Estaing, who became president in 1974. One of his main negotiation objectives was to acquire nuclear reprocessing technology from France. After that, Kim continuously brought up this issue in 1974 and 1975 when he visited France.[23] At last, KAERI signed two contracts respectively with two French companies: Compagnie pour L'Etude et la Réalisation de Combustibles Atomiques, for fabrication and the procurement of French hardware of various kinds in January 1975, and Saint Gobain Technique Nouvelle (SGN), for the theoretical design of the reprocessing facility in April 1975.[24]

Further, the ROK government contacted Belgium for nuclear technology cooperation in January 1974. Negotiation began in earnest when Minister Choi and the head of KAERI Yun Yong-gu visited the relevant ministries in Belgium and the company Belgonucleaire SA (BN) in May 1974 to consult them about terms and conditions for an experimental plutonium fabrication facilities project.[25] Backed by the Belgian government, in April 1975 BN signed a contract of conceptual study with KAERI to help the latter build a plutonium fuel laboratory in addition to training KAERI personnel in Belgium.[26]

Not only was the Park administration interested in building a nuclear fuel reprocessing and fabrication facility, it also sought to equip itself with other technologies such as uranium enrichment which was also a necessary requirement for accomplishing a nuclear fuel cycle. However, with the US providing only low-enriched uranium, South Korea's research on enriching uranium was significantly restricted from the beginning. If South Korea had adhered to US-supplied light-water reactors, the safeguards applied to enriched uranium fuel provided by the United States would have made it more difficult for South Korea to clandestinely use it for non-peaceful purposes. In order to diversify the sources of nuclear fuel, therefore, South Korea turned to Canadian heavy water reactors. These were more desirable for South Korea because they could run on natural uranium fuel which was comparatively easy to obtain. Canada deuterium uranium (CANDU) reactors could also be refuelled while in operation so that they could be more easily used

22 Letter, KAERI to Jeanpierre (CEA) with attachment entitled 'Agreement for Technical Cooperation in Nuclear Fuel Fabrication between Korea Atomic Research Institute (the Republic of Korea) and Commissariat à l'Energie Atomique (the Republic of France)', 21 December 1972, Ibid.

23 Interview with Kim (2015).

24 Special Investigation Team, 'The Annals of the Park Chung-hee Era no. 31' (in Korean), *JoongAng Ilbo*, 6 November 1997.

25 Ministry of Science and Technology to Ministry of Foreign Affairs, Ministry of Commerce and Industry, and Economic Planning Board, 'Economic Cooperation for a Nuclear Fuel Reprocessing Fabrication Facilities Project', 20 May 1975, Loans for Belgian Nuclear Fuel Fabrication Facility 1974–1976, 761.65/M-06-0040, Korean diplomatic archives.

26 KAERI, 'Plutonium Fuel Laboratory Conceptual Study: Contract between KAERI and BN', 2 April 1975, ibid.

clandestinely to produce weapons-usable plutonium (Hunt 1977: 72–3; Hong 2011: 492). India's detonation of a nuclear device in May 1974 using a Canadian National Research Experimental (NRX) reactor with heavy water offered by the United States reveals this proliferation-friendly characteristic of Canadian heavy-water reactors.

When the ROK government selected a contractor for its first commercial nuclear power plant in 1968, however, a heavy-water reactor was not an option considered. This timing is significant: South Korea's interest in heavy-water reactors followed rather than preceded President Park's launch of Project 890. Park started considering a military nuclear programme in 1970–71, and the ROK government opened negotiations with Canada in 1973 to purchase CANDU and NRX reactors.[27] In particular, South Korea's eagerness to acquire a Canadian NRX from 1973 to 1975 in the midst of growing suspicion of Park's nuclear ambitions shows that South Korea's nuclear programme at that moment was more than a civilian project for commercial and peaceful purposes.

These South Korean efforts to diversify the suppliers of nuclear fuel technology in the 1970s probably contributed to developing its nuclear energy industry in the later periods. Even though the Park administration's attempt to acquire nuclear reprocessing facilities failed mainly due to Washington's strong opposition, the early endeavours to contact various suppliers and some failures to purchase different types of nuclear facilities and equipment would have likely motivated them to develop their own technology and infrastructure. A comparison with Taiwan shows contrasting trajectories between these former potential nuclear proliferators despite their relatively similar geostrategic and economic backgrounds. In contrast to South Korea, Taiwan, which stuck to US-supplied LWRs, was unable to build any of its current three nuclear power plants (with six reactors) with their own technology, let alone export its nuclear technology and equipment abroad.[28]

Competition among nuclear suppliers and opportunities for South Korea

The 1950s and 1960s constituted a remarkable period in the history of the nuclear energy industry internationally. In 1951, the Soviet Union built the world's first 5,000 kilowatts nuclear reactor which supplied electricity to ordinary people in Obninsk. Five years later, the United Kingdom succeeded in operating the Calder Hall nuclear power plant (50,000 kilowatts, Gas Cooled Reactor) followed by the US construction

[27] Memo, R. C. Lee to File CK-151-1 (c.c. Campbell), 7 May 1973; Memo, Kaufmann, 15 August 1973, R13629/8-1, Posting to Korea 1972.07-1974.01, Ross Campbell Fonds, Library and Archives Canada.

[28] Taiwan's three nuclear power plants consist of four General Electronics boiling water reactors and two Westinghouse pressurized water reactors. See more details in 'Nuclear Power in Taiwan', *World Nuclear Association,* at http://www.world-nuclear.org/info/Country-Profiles/Others/Nuclear-Power-in-Taiwan/. Accessed 20 August 2015.

of the 60,000 kilowatts Shippingport nuclear power plant (PWR) in 1957. West Germany started operating its first nuclear power plant (200,000 kilowatts, BWR) in 1959 and Canada joined the group of nuclear energy producers when a 250,000 kilowatts PHWR-type CANDU nuclear power plant came on stream in 1962 (Korean Nuclear Society 2010: 78–9).

The competition in developing new types of nuclear reactor led nuclear suppliers to look for new customers in the overseas market in the 1960s and 1970s. Duane Bratt described this period as the 'golden age' of the nuclear industry since over 80 per cent of all nuclear power plants were ordered in those years. The dominant design of nuclear reactors at the time (and even to date) was the light water reactor of which the largest supplier was the United States. As of the early 2000s, LWRs represented over 75 per cent of all nuclear power plants in operation throughout the world. Under these circumstances, the minor nuclear suppliers made every effort to increase their market share. In particular, the major HWR supplier, Canada, found it more difficult to find new customers because of the dominance of LWRs in the export market (Bratt 2006: 24). Moreover, the competition followed by the generous provision of loans to recipients led to lower financial obstacles which developing countries were not able to overcome with their capability alone. This competition among nuclear suppliers gave opportunities to potential proliferators such as South Korea to become less reliant on one dominant supplier, the United States, and rather seek alternative ways to pursue nuclear technology for both civil and military purposes.

When Seoul was negotiating with Ottawa to purchase Canadian heavy-water reactors from 1973, the Canadian government was eager to sell both CANDU and NRX. Thus, the ROK government attempted to acquire the public loans (aid) of the Canadian International Development Agency (CIDA) for the purchase of an NRX reactor, arguing that KAERI, a would-be operator of the Canadian NRX reactor in Korea, was a non-profit research institute directly reporting to the ROK ministry of science and technology.[29] The CIDA was, however, adamant that South Korea had not been included in the category of underdeveloped countries eligible for Canadian public loans any more.[30] Despite South Korea's repeated requests for public loans, Ottawa did not change its decision that the Canadian Export Development Corporation (CEDC) would be in charge of commercial loans being provided to Seoul for the construction of both Canadian reactors.[31]

The ROK government estimated in February 1974 that this NRX project would require \$15 million from local financing and \$40 million from foreign funds.[32] With regard to the CANDU reactor deal, both governments agreed on the terms of the

[29] Letter, KAERI to Canadian Embassy in Seoul, 17 December 1973, 1974 Negotiations for Loans to Import Canadian Nuclear Reactors, 761-64CN/M-0030, Korean diplomatic archives.

[30] Telegram, ROK Ambassador to Canada to ROK Foreign Minister, 'Loan Negotiations for a NRX', 25 January 1974; Telegram, ROK Ambassador to Canada to ROK Foreign Minister, 'Loans for a NRX reactor', 12 April 1974, ibid.

[31] Telegram, ROK Ambassador to Canada to ROK Foreign Minister, 11 March 1974; Letter, ROK Foreign Ministry to Canadian Embassy in Seoul, 21 March 1974, ibid.

[32] KAERI, 'Application Materials for Canadian Loans to Construct a NRX Reactor', February 1974, ibid.

loan that Canada would offer South Korea: 225 million Canadian dollars (worth nearly 1,150 million CAD in 2015 values) with 8.5 per cent annual interest in addition to a British commercial loan of 10 million GBP.[33] However, the Indian nuclear test in May 1974 changed the whole atmosphere of the ROK-Canada negotiations. Concerned about proliferation risks which NRX reactors had already proved in the Indian case, Ottawa became extremely cautious about further exports of its NRX reactors. This concern directly impacted on South Korea's plans to acquire a NRX reactor from Canada: the latter increasingly hesitated to commit itself to the NRX negotiation with Seoul, and demonstrated their unwillingness to discuss it until Seoul ratified the NPT.[34] Instead, both countries focused on the negotiation for CANDU, and signed a commercial contract supplying a 600-megawatt CANDU unit to South Korea on 27 January 1975 (Atomic Energy Canada Limited 1975: 11). According to the final terms of the contract, the total budget was 566,967,000 CAD which was mostly supposed to be covered by Canadian and British commercial loans.[35]

South Korea's negotiations with France and Belgium also included an issue of the size of loan that these two suppliers would offer. With regard to France, KAERI estimated in 1973 that its fuel fabrication project would require a foreign exchange fund of approximately 8 million French francs (FF) with its reprocessing project needing about 52 million FF. It was also estimated to require a domestic fund of approximately 20 million FF for both projects. Based on these estimates, KAERI accordingly requested the French government to offer government loans to South Korea.[36] Concerning South Korea's conceptual study of a plutonium fuel laboratory with Belgium, KAERI and BN decided to go fifty-fifty on the study's full price. Thus, the Belgian government agreed to provide South Korea with approximately $60,000 from its export promotion fund, and BN promised to cover the remaining part of the cost ($80,000), while Seoul was responsible for the other 50 per cent.[37] South Korea did not succeed in acquiring this critical nuclear technology to produce weapons-grade plutonium from France and Belgium as the United States was increasingly concerned about South Korea's nuclear intentions in 1975. Nevertheless, South Korea was able to make an attempt to embark on this technically complicated project requiring a

33 Telegram, KEPCO CEO to ROK Minister for Trade and Industry, 'Loan Consultation with CEDC Regarding the Nuclear Power Plant III', 10 April 1974, ibid.

34 Summary of Meeting, ROK Foreign Minister Kim with Canadian Ambassador Stiles, 20 January 1975, ROK-Canada Nuclear Cooperation Agreement (2), 741.61CN/J-06-0102/5, Korean diplomatic archives.

35 Telegram, ROK Ambassador to Canada to ROK Foreign Minister, 21 December 1974; Telegram, ROK Ambassador to Canada to ROK Foreign Minister, 31 December 1974, 1974 Negotiations for Loans to Import Canadian Nuclear Reactors, 761.64CN/M-0030, ibid.

36 Letter, KAERI to Pierre Landy, French Ambassador to South Korea, 'Request for Governmental Loans for nuclear fuel fabrication and Fuel Reprocessing Project', 20 November 1973, Seoul - Service Culturel, 630PO/1/35, French diplomatic archives.

37 Letter, BN to KAERI, 4 April 1975; Telegram, ROK Ambassador to Belgium to ROK Foreign Minister, 29 May 1975, *The Introduction of Belgian Loans for Fabrication Facility of Nuclear Fuel Reprocessing 1974–76*, 761.65/M-06-0040/2, Korean diplomatic archives.

significant amount of capital because competition in the nuclear-export market gave newcomers easier access to foreign technology and capital.

Strengthened US nuclear non-proliferation policy and alternative paths for South Korea

After India's nuclear test in May 1974, US and Canadian media began reporting the potential risk of nuclear proliferation in developing countries, including South Korea.[38] The US government also started to look more seriously into South Korea's seemingly civil nuclear programme and concluded in February 1975 that South Korea was in its initial stage of developing nuclear weapons.[39] As a result, Washington strengthened its nuclear non-proliferation policy on South Korea by 'dissuading Canada, France, Belgium from delivering reprocessing-related technologies and equipment to Korea', and also 'threaten[ing] to withhold Export-Import Bank financing of $292 million for the *Kori* 2 nuclear power plant' (Kim 2001: 63–4). More notably, in late 1975, US national security adviser Henry Kissinger sent Assistant Secretary of State Phillip Habib to President Park in order to threaten and appease him. Habib stated that the United States would withdraw its security commitment to South Korea if Park stuck to his original plan. At the same time, however, Habib suggested that the United States would increase its technological and financial support for South Korea's civilian nuclear programme once the clandestine military project was suspended (Kim 2001: 65–6). Under this pressure, Park eventually ordered his officials to suspend the nuclear weapons programme in late December 1976.[40]

This decision in 1976 was not the end of Park's nuclear ambitions, though. Park secretly instructed Senior Secretary Oh to 'acquire the capability, but in a manner not inviting foreign pressure' (Oh 1994: 430). Moreover, in December 1976, the ROK government started a new plan indirectly to acquire nuclear reprocessing technologies. The main role of the newly established Korea Nuclear Fuel Development Institute (KNFDI) was to develop South Korean capabilities for nuclear fuel fabrication, but the institute also pursued acquiring plutonium through reprocessing nuclear spent fuel. It was not easy to develop such nuclear technologies indigenously, but at last the KNFDI managed to construct a nuclear fuel fabrication facility by October 1978 and produced a detailed design of a research reactor in October 1979 (Hong 2011: 508–9).[41] Furthermore, Oh recalled that Korean

[39] Memorandum, Smyser and Elliott to Kissinger, 28 February 1975, Korea (4), Box 9, National Security Advisor Presidential Country Files for East Asia and the Pacific, Gerald R. Ford Presidential Library.

[38] Among many, see the *New York Times*, 5 July 1974; *Washington Post*, 8 July 1974; *Ottawa Journal*, 1 August 1974.

[40] National Foreign Assessment Center, US Central Intelligence Agency (CIA), 'South Korea: National Developments and Strategic Decisionmaking', DOC-0001254259, June 1978, at http://www.foia.cia.gov/docs/DOC_0001254259/DOC_0001254259.pdf. Accessed 5 February 2013.

[41] See also Special Investigation Team, 'The Annals of Park Chung-hee Era no. 32' (in Korean), *JoongAang Ilbo*, 10 November 1997.

researchers succeeded in making yellowcake by refining local uranium right before President Park was assassinated in October 1979.[42] Park's nuclear programme in the late 1970s appears to have been led by his nuclear policy with a dual purpose. One aim was to acquire sufficient nuclear energy for civilian use. The other was to acquire the capability of producing nuclear weapons in case of emergency. In Ariel E. Levite's term, this dual-purpose policy could be called 'nuclear hedging' which means 'a national strategy lying between nuclear pursuit and nuclear rollback' (Levite 2002–3: 59). However, General Chun Doo-hwan, who seized power by a military coup in 1980, eventually removed any remnants of the military programme because he was 'desperate to win recognition and support from the Reagan administration' (Hayes and Moon 2011).

South Korea's rise in the international nuclear energy market

South Korea's aspirations for nuclear energy power never ceased in spite of its decision to take a step backwards on the path to nuclear weapons. Korean researchers' continuous efforts to pursue independent technology bore fruit in later years. From the beginning of its nuclear industrialization, South Korea was not content with the turnkey nuclear reactors offered by the US Westinghouse and Atomic Energy of Canada Limited (AECL). Thus, the ROK government adopted a non-turnkey approach, successfully joining the whole process of architecture engineering in the tenth and eleventh Korean nuclear projects (Sung and Hong 1999: 308–10). Based on a technology transfer agreement with Combustion Engineering (CE), South Korea constructed several KSNPs (Korean Standardized Nuclear Plants, which later changed into OPR-1000) in the 1990s and early 2000s (see Appendix 2). Recently, KEPCO developed the APR-1400 (Advanced Power Reactor) with its own technology.[43]

In December 2009, the United Arab Emirates surprised the world by selecting a South Korean-led consortium to build four commercial nuclear power plants equipped with the APR-1400 at Barakah.[44] This contract was worth $20.4 billion with the expectation to earn another $20 billion by jointly operating the reactors for sixty years. Not only was it surprising that a new exporter had won this bid, but also because South Korea secured the deal in the face of intense competition with other well-established nuclear suppliers: France, the United States, and Japan.[45] The history of South Korea's nuclear energy industry is not long compared to the cases of early nuclear industrializers. However, South Korea succeeded relatively quickly

[42] Interview with Oh (2010).

[43] See more details about APR-1400 at Korea Electricity Power Corporation at http://cyber.kepco.co.kr/kepco_new/nuclear_es/sub2_1_2.html. Accessed 28 July 2015.

[44] See more details of the UAE's nuclear power programme and the UAE-ROK contract on the Barakah plants in *the World Nuclear Association* at http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Arab-Emirates/. Accessed on 23 May 2015.

[45] Other bidders were a French consortium including Areva, GdF Suez SA, Électricité de France and Total SA, and a US-Japanese consortium of General Electric Co. and Hitachi Ltd.

in upgrading its status from a 'learner' to a 'teacher' of nuclear technology (Amsden 1989).[46] Thus for South Korea, the construction of nuclear power plants in the UAE using Korean technology and capital represented a monumental achievement in its civil nuclear history.

South Korea's emergence as a nuclear exporter is an extension of the development of its domestic nuclear industry, which required the acquisition of nuclear power–generating technology. Because of insufficient domestic energy resources, South Korea is a major oil, coal and liquefied natural gas (LNG) importer.[47] Instead of solely depending on imported energy resources, though, South Korea strived to strengthen its energy independence through nuclear energy. The share of nuclear energy in Korea's electricity production in 2014 was about 30 per cent.[48] As of January 2016, South Korea has twenty-four nuclear reactors in commercial operation in four nuclear power plant sites (Appendix 2), the second largest number of reactors among Asian countries after Japan, and the fifth largest in the world. Despite growing anti-nuclear sentiments in Korean society, which emerged in the 1990s and has been further reinforced particularly since Japan's 2011 nuclear disaster in Fukushima, the ROK government continues to push ahead with its pro-nuclear policy by constructing and planning ten more nuclear reactors as of January 2016 (Appendix 3).[49]

Conclusion

In the Anthropocene, environmental challenges been caused by human activities have elicited very different human responses. Unlike some other advanced industrializers, South Korea was a developing country, in the 1970s, which did not have sufficient natural resources to embark on industrialization. In particular, Korea's deficiency in energy sources was a critical constraint upon the development of heavy and chemical industries. Under these circumstances, the 1973–4 oil shock was regarded as a severe blow to South Korea's extreme dependence on imported oil. These challenges, however, did not prevent Korea from acquiring energy sources necessary for its industrialization. South Korea's enthusiasm for nuclear energy to substitute for fossil fuels can be explained in this economic context.

[46] Alice H. Amsden used the terms *learner* and *teacher* to describe the change of roles and status of successful late-industrializers like Korea as a result of their rapid economic development. Although she did not specifically mention South Korea's nuclear industry in her 1989 book, Korea's recent achievement of exporting nuclear technology to UAE demonstrates that the transition of Korea's status from a nuclear consumer/trainee (learner) to a supplier (teacher) has finally been completed.

[47] As of April 2014, South Korea was the second-largest importer of liquefied natural gas after Japan, the fourth-largest importer of coal and the fifth-largest importer of total petroleum and other liquids. US Energy Information Administration at http://www.eia.gov/beta/international/analysis.cfm?iso=KOR. Accessed 28 July 2015.

[48] Power Reactor Information System, International Atomic Energy Agency (IAEA) at http://www.iaea.org/pris/CountryStatistics/CountryDetails.aspx?current=KR. Accessed 25 July 2015.

[49] The 2014 local referendum held in Samcheok is one of the recent examples disclosing the South Koreans' anti-nuclear power sentiments. See more details in Jang (2015).

However, economic analysis cannot explain the full picture of South Korea's development of its nuclear energy industry. Not all countries with scant energy sources have succeeded in producing – or have attempted to produce – electricity using nuclear power. Human responses to a similar environmental or economic challenge are not necessarily similar, and thus the decisions of each actor in the Anthropocene should be analysed in its specific context.

What conditions motivated and enabled South Korea to embark on this highly capital- and technology-intensive industry in the first place? First, the favourable external environment for nuclear technology transfer which had started with the Atoms for Peace project and lasted until India's nuclear test in 1974 helped countries without any nuclear technology gain some basic interests in and knowledge of nuclear energy. As one of the early Atoms for Peace programme recipients, South Korea was provided with a research reactor from the United States in the 1950s, which paved the way for its future development in the nuclear energy industry. Second, President Park's ambitions to develop nuclear weapons in the midst of a weakening US security commitment to Korea also contributed to strengthening Korean researchers' capacity and eagerness for indigenous technology. Due to the dual-use characteristics of nuclear technology, the military and civilian nuclear programmes of South Korea exerted a synergy effect on each other as well.

Lastly, the competition among nuclear suppliers in the 1960s and 1970s led to a favourable external economic environment for new customers like South Korea to access the nuclear market. It also provided a golden opportunity to South Korea which was seeking alternative ways to acquire critical nuclear technology with sufficient funding. Offering loans to foreign countries is indeed not only an economic but also a highly political decision, as Canada's negotiations with Korea showed. Thus, supplier countries' political decisions – which had been facilitated by their economic calculations – eased South Korea's initial political and economic burdens to launch the capital-intensive nuclear industry as well as the military nuclear programme. Conversely, if the United States had consolidated its domination of the market during the period, South Korea would have found it more difficult to consider any military nuclear option under stronger US influences from the beginning and would have more likely remained as a mere importer of US nuclear reactors. Therefore, overcoming energy deficiency is not only in the realm of economic considerations but also of political interaction which makes it necessary and possible.

However, it is not obvious yet whether South Korea's whole investment in nuclear energy has paid off in economic and political terms. Although the achievement of nuclear export to the UAE was the result of South Korea's sustained efforts to acquire an independent nuclear technology, strong competition in the international nuclear market and growing anti-nuclear sentiments appear to increase the potential costs of future nuclear energy projects as well as political division within the Korean population. These costs, accompanied by those of dismantling old nuclear power plants and growing concerns about nuclear safety and environmental effects on local communities, are other factors to consider when it comes to economic and political analysis of the viability of the nuclear energy industry. These questions have not been the main subjects of this chapter, but need to be further researched.

The international transfer of nuclear technology and capital since the 1950s encouraged resource-deficient South Korea to embark on this highly advanced nuclear energy project. As Gareth Austin noted in this volume, the interactions between global and local levels through 'international flows of knowledge, commodities, and capital' in the Anthropocene made it possible to provide resource-poor countries with opportunities to meet their needs. South Korea's recent rise as a nuclear supplier shows that human capacity is not confined to a given physical environment. Further, Korea's choices to develop nuclear energy research and facilities were neither a response to international pressure for fossil fuel reduction nor resulted from a purely economic calculation. Rather, it was a political and economic decision combined with a favourable external environment. Despite some problems, nuclear energy is likely to account for a significant part of South Korea's energy portfolio in the coming years after the 2015 Paris Agreement as Korea's capability to produce renewable energy still remains in the incipient stage.

Appendix 1: South Korea's Electricity Generation by Source in Selected Years (billion kilowatt hours and per cent)

Year	Total	Nuclear	Fossil fuel	Hydro	Non-hydro renewables	Hydroelectric pumped storage
1980	34.472	3.277	29.756	1.539	0.000	−0.100
	100	9.51	86.32	4.46		−0.29
1982	39.670	3.559	34.965	1.560	0.000	−0.414
		8.97	88.14	3.93		−1.04
1984	49.618	11.113	37.097	1.978	0.000	−0.570
	100	22.40	74.77	3.99		−1.15
1986	58.833	26.680	30.306	3.078	0.000	−1.231
	100	45.35	51.51	5.23		−2.09
1988	76.907	37.791	39.288	1.967	0.000	−2.139
	100	49.14	51.09	2.56		−2.78
1989	85.770	44.995	39.996	2.934	0.000	−2.155
	100	52.46	46.63	3.42		−2.51
1990	98.125	50.243	45.516	4.637	0.001	−2.272
	100	51.20	46.39	4.73	0.00	−2.32
1992	121.515	53.703	65.395	3.066	0.002	−0.651
	100	44.19	53.82	2.52	0.00	−0.54
1994	170.768	55.718	113.345	2.323	0.003	−0.621
	100	32.63	66.37	1.36	0.00	−0.36
1996	210.455	63.677	123.178	2.732	0.252	−0.951
	100	30.26	58.53	1.30	0.12	−0.45
1998	225.012	85.205	136.111	4.236	0.065	−0.605
	100	37.87	60.49	1.88	0.03	−0.27
2000	271.993	103.516	164.911	3.970	0.115	−0.518
	100	38.06	60.63	1.46	0.04	−0.19
2002	291.345	106.526	181.161	4.109	0.129	−0.580
	100	36.56	62.18	1.41	0.04	−0.20
2004	345.720	124.179	217.273	4.287	0.425	−0.444
	100	35.92	62.85	1.24	0.12	−0.13

Year	Total	Nuclear	Fossil fuel	Hydro	Non-hydro renewables	Hydroelectric pumped storage
2006	379.065	141.179	234.400	3.433	0.617	−0.564
	100	37.24	61.84	0.91	0.16	−0.15
2008	419.069	144.255	271.137	3.039	1.388	−0.750
	100	34.42	64.70	0.73	0.33	−0.18
2010	468.269	141.890	320.911	3.645	2.696	−0.873
	100	30.30	68.53	0.78	0.58	−0.19
2011	489.729	147.763	335.454	4.552	2.984	−1.024
	100	30.17	68.50	0.93	0.61	−0.21
2012	499.672	143.550	350.105	3.929	3.194	−1.106
	100	28.73	70.07	0.79	0.64	−0.22

Source: International Energy Statistics, US Energy Information Administration (http://www.eia.gov). Accessed 31 January 2016.

* The share of electricity generation by each source is calculated and rounded off by the author, and thus it is an approximate figure.

** US International Energy Statistics are only available for the years between 1980 and 2012 (as of January 2016).

Appendix 2: Nuclear Power Reactors Operating in South Korea (January 2016)

Name	Type of reactor	Capacity (MWe)	Reactor supplier	Commercial operation
Kori 1	PWR	587	Westinghouse (US)	29.04.1978
Wolsong 1	CANDU	679	AECL (CAN)	22.04.1983
Kori 2	PWR	650	Westinghouse (US)	25.07.1983
Kori 3	PWR	950	Westinghouse (US)	30.09.1985
Kori 4	PWR	950	Westinghouse (US)	29.04.1986
Hanbit 1	PWR	950	Westinghouse (US)	25.08.1986
Hanbit 2	PWR	950	Westinghouse (US)	10.06.1987
Hanul 1	PWR	950	Framatome (FR)	10.09.1988
Hanul 2	PWR	950	Framatome (FR)	30.09.1989
Hanbit 3	System 80	1,000	Hanjung/C-E (ROK/US)	31.03.1995
Hanbit 4	System 80	1,000	Hanjung/C-E (ROK/US)	01.01.1996
Wolsong 2	CANDU	700	AECL/Hanjung (CAN/ROK)	01.07.1997
Wolsong 3	CANDU	700	AECL/Hanjung (CAN/ROK)	01.07.1998
Hanul 3	KSNP	1,000	Hanjung/C-E (ROK/US)	11.08.1998
Wolsong 4	CANDU	700	AECL/Hanjung (CAN/ROK)	01.10.1999
Hanul 4	KSNP	1,000	Hanjung/C-E (ROK/US)	31.12.1999
Hanbit 5	KSNP	1,000	Doosan (ROK)	21.05.2002
Hanbit 6	KSNP	1,000	Doosan (ROK)	24.12.2002
Hanul 5	KSNP	1,000	Doosan (ROK)	29.07.2004
Hanul 6	KSNP	1,000	Doosan (ROK)	22.04.2005
Shin Kori 1	OPR1000	1,000	KHNP/Doosan (ROK)	28.02.2011
Shin Kori 2	OPR1000	1,000	KHNP/Doosan (ROK)	20.07.2012
Shin Wolsong 1	OPR1000	1,000	Doosan (ROK)	31.07.2012
Shin Wolsong 2	OPR1000	1,000	Doosan (ROK)	24.07.2015
Total: 24		21,716		

Source: Korea Hydro & Nuclear Power Co., Ltd (http://khnp.co.kr). Accessed 31 January 2016.

Appendix 3: Nuclear Power Reactors under Construction and Planned in South Korea

Name	**Type of reactor**	**Capacity (MWe)**	**Reactor supplier**	**Start construction (expected)**	**Commercial operation (expected)**
Shin Kori 3	APR1400	1,400	Doosan (ROK)	09.2007	(05.2016)
Shin Kori 4	APR1400	1,400	Doosan (ROK)	09.2007	(03.2017)
Shin Hanul 1	APR1400	1,400	Doosan (ROK)	04.2010	(04.2018)
Shin Hanul 2	APR1400	1,400	Doosan (ROK)	04.2010	(02.2019)
Total under construction: 4		5,600			
Shin Kori 5	APR1400	1,400	Doosan (ROK)	(04.2016)	(03.2021)
Shin Kori 6	APR1400	1,400	Doosan (ROK)	(04.2016)	(03.2022)
Shin Hanul 3	APR1400	1,400	Undecided	(02.2017)	(12.2022)
Shin Hanul 4	APR1400	1,400	Undecided	(02.2017)	(12.2023)
Cheonji 1	APR+	1,500	Undecided	(02.2019)	(12.2026)
Cheonji 2	APR+	1,500	Undecided	(02.2019)	(12.2027)
Total planned: 6		8,600			
Total		14,200			

Source: Korea Hydro & Nuclear Power Co., Ltd (http://khnp.co.kr). Accessed 31 January 2016.

Key to types of nuclear reactors

PWR: Pressurized Water Reactor (light water reactor)
System 80: PWR designed by Combustion Engineering
CANDU: Canada Deuterium Uranium Reactor (pressurized heavy water reactor)
KSNP: (Generation I) Korean Standardized Nuclear Plant
OPR1000: (Generation II) Optimized Power Reactor (a new name of KSNP)
APR1400: (Generation III) Advanced Pressurized Reactor
APR+: (Generation III+) Advanced Reactor Type of APR1400

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13

Water, Energy and Politics: Chinese Industrial Revolutions in Global Environmental Perspective

Kenneth Pomeranz

This chapter is framed by two sets of questions. The first is very much contemporary, the other both contemporary and historical.

The contemporary question is familiar and superficially straightforward: Can China's economic growth be made sustainable? But this means something different for China and for the world. From a global perspective, what it primarily means is, 'How much do Chinese emissions of greenhouse gases need to be reduced to avoid catastrophic climate change? How can that be made compatible with continued economic development in China?' It therefore becomes a question about improving energy efficiency in the short term, and about cleaner energy sources in the medium to long term (since gains in energy efficiency sufficient to offset all the GDP growth China is seeking over the next generation are inconceivable). The problem, of course, is not that one could not mobilize enough fossil fuels to power that growth, even without improving energy efficiency; the problem is that the long-run consequences of doing so would be catastrophic, and felt far beyond China.

From a more narrowly Chinese perspective, however, the question 'Can China's economic growth be made sustainable?' might be rephrased as 'Will some environmental factors seriously constrain Chinese growth before the bulk of its citizens become prosperous?' It is worth remembering here that while both scholarly and popular commentators often talk about China catching up with the West, its per capita GDP is still at roughly half the level of Kazakhstan, Malaysia, Hungary, Poland and Seychelles.[1]

Here the central issues are less about energy, since it is not scarce per se, and more about other necessities; the one most likely to become a binding constraint in the relatively near future is clean water, which is already quite scarce in large parts of the country and harder to move vast distances than is energy. These issues are less familiar to most people than are the energy questions, but probably appear more pressing to

1 Per capita PPP-adjusted GDP figures are available at http://www.imf.org/external/pubs/ft/weo/2015/01/weodata/weoselgr.aspx

Chinese policymakers, since the possibly catastrophic effects of not addressing them successfully will be felt sooner and fall more squarely on China itself. Consequently, they will be the main focus of the second part of this paper. Moreover, we will see here that the energy question and the water question are complexly intertwined, with some measures that might ameliorate one problem likely to exacerbate the other; thus, both questions must be considered, even by people who might be mostly interested in one or the other.

First, though, it is worth placing these contemporary Chinese dilemmas in a broader regional and historical framework. East Asia is the most economically successful part of the non-Western world, and various scholars, including myself, have at times suggested that it has been characterized by a distinct pattern of development. That pattern has historically been significantly less resource-intensive than the kind of economic development that most of the West witnessed, and less energy-intensive in particular. If China in general were to converge towards that path (as the most economically successful parts of the country have already done to a significant extent), that might bode well for at least the global form of sustainability. But this would not be enough by itself, as we will see, and there are also reasons to doubt the applicability of the 'East Asian' model to much of China.

It is also unclear whether this model has any bearing on the more national and water-focused form of the sustainability question. One might even tentatively argue that historic reliance on intensely irrigated agriculture to sustain the high population densities central to the 'East Asian path' suggests, once again, a tension between these two 'sustainability' questions, though here the reasons are somewhat different than in the case of energy: it is quite likely that the easiest way for China to continue growing despite its water problems will be to import ever more primary products while exporting ever more manufactures. In doing so, however, it would be transferring water stress to other parts of the world, and perhaps also inhibiting (through intensified competition for industrial markets) the spread of the 'East Asian path' to other countries. Let us begin, then, by using history to frame the present.

Does the 'East Asian path' have a Chinese future?

Across multiple publications, Kaoru Sugihara has made a vitally important argument to the effect that an East Asian development path, which has been less resource-intensive than those of most North Atlantic countries, offers more hope for sustainable development than any Western model. Data from Japan, Taiwan and South Korea – among the few places on earth that have converged significantly towards Western living standards over the last century (especially since 1945), and among the most energy-efficient economies in the world today – gives that hope plausibility.[2] But most of East Asia's population, GDP, greenhouse gas (GHG)

[2] For the general model, see Sugihara (2003, 2005, 2013). For current energy/GDP ratios, see US Energy Information Agency (2013a). For an earlier example of my own partial embrace and hesitancy about this model, see Pomeranz (2001).

emissions and likely future growth are Chinese, and it is far from clear how 'East Asian' China's economic development path has been or will be.

Sugihara and I agree that East Asian development has been critically shaped by the absence of resource bonanzas like those from which the industrializing West benefited, and that is certainly true of China as well. But China's current situation is very different both from those of contemporary Japan, Taiwan and South Korea and from the way those countries were when they had levels of income, urbanization and so forth comparable to today's China.

Among other things, China's sheer size makes it impossible for it to become as import-dependent as the rest of post-war East Asia when it comes to food; and the need to grow most of its own food greatly complicates its already difficult water problems. As noted above, from a strictly national Chinese perspective, water shortages pose a greater immediate threat to sustainable growth than energy supplies or GHG emissions. And while the kinds of long-term and structural economic and environmental pressures I have written about elsewhere are crucial for both water and energy issues, politics is also vitally important – and does not currently bode well for sustainability in either water or energy supply efforts.

Indeed, if you view the past through today's headlines, the news from China is pretty grim. Energy intensity has been falling in the last several years (after plateauing for 2000–06, which was very alarming); but it is still not falling nearly as fast as output is growing, so total energy use continues to rise. Goals for increasing the share of energy coming from non-fossil fuels sources were not met in the most recent five-year plan, despite heavy investment in renewables and hydropower (Dent 2014: 213). So GHG emissions keep rising, and the country appeared to be behind the pace needed to meet energy efficiency and emissions targets in the Twelfth Five Year Plan (ending in 2015) as well.[3]

Many other environmental trends look equally grim, or worse. The infamous air pollution of Chinese (especially Northern Chinese) cities is probably the best known of these conditions, but it is not the most worrisome; we know, in principle, how to reverse such problems, and have examples of cities that have done so. China's increasing problems with soil contamination and desertification are less obviously reversible in the short to medium term; the same is true of its shortages of clean surface-level water sources. The very rapid depletion and pollution of its underground aquifers, on which it has become extremely dependent, may be the most pressing problem of all in the short run, as there are no obvious substitutes on tap.

It is true, as everyone knows, that China has grown very dramatically over the last thirty-five years, so it has certainly gotten something in return for all this environmental devastation. And in a few parts of China, the ratio of environmental damage to economic gains is better than in much of the world. Coastal China (by which I mean the coast from Jiangsu on south) is now probably a bit below the global average of energy intensity, and improving quite rapidly; Guangdong's energy intensity is, by some measures, comparable to that of South Korea, which places it

[3] See Xinhuanet (2014) for an admission that China faced a 'grim situation' with respect to meeting Plan targets in emissions and energy efficiency.

among the better performers in the world.[4] Not coincidentally, I think, these are also the parts of China that most closely approximate the resource-saving 'East Asian path' that Sugihara has described. But even in these regions many of the environmental conditions directly experienced by residents, such as air and water quality, are far below developed country norms.

Moreover, the rest of China lags far behind – and in fact further behind the 'star' provinces than ever. In 2006, there were a few provinces that were four times as energy intensive as Guangdong, and Ningxia was over five times as energy-intensive; in 1990, there was no place that quite reached four times as energy intensive as the leading provinces. To take another measure, the provinces with the worst energy efficiency in any given year are a steadily rising multiple of the national average (data from Zhang Xin 2009: 64).[5] It seems at least plausible that this spread will keep getting larger. Coastal provinces are having some success at moving more into services – Guangdong has a goal of 50 per cent of GDP coming from services by 2015 and Jiangsu was already at 43 per cent in 2011[6] – which is crucial to reducing the energy intensity of GDP, but the comparable figures for Western provinces are in the 30s. Meanwhile, huge investments in long-range power transmission, oil pipelines, etc., are likely to concentrate energy generation more and more in the West. So even if we confine our immediate worries to energy, long-run sustainable growth seems an elusive target in China, barring some truly dramatic changes in the nature of energy sources; current rates of improvement in the amount of energy consumed for specific tasks are just not fast enough to solve the problem.

Indeed, any long-term projection that could reconcile the kinds of growth Beijing expects with climate sustainability calls for improvements in carbon efficiency many, many times greater than those achieved so far. Imagine, for instance, that Chinese GDP per capita were to rise 6 per cent per year and population 1 per cent per year between now and 2030, the date at which China has recently pledged to cap its emissions. This would bring its per capita GDP to about the current level of Portugal, or slightly above the richest parts of today's China other than Hong Kong.[7] Imagine further that during this period it was able to halve its greenhouse gas (GHG) emissions per dollar of GDP – a much faster rate of improvement than that achieved over the last thirty-five years, during which China moved away from a Cold War obsession with defence industries; imported new and much more efficient technologies which were available off the shelf; gained efficiencies by turning to market-based allocation

[4] Combining data from Zhang Xin (2009: 6) which puts Guangdong at about 60 per cent of the overall Chinese level with country data from The Shift Project Data Portal http://www.tsp-data-portal.org/Energy-Intensity-of-GDP#tspQvChart (using GDP in PPP). There are, however, large differences among results from different data sources.

[5] In 1990 there was one province that was almost 4 times as energy-intensive as Guangdong and a few at 3:1, but nothing close to 5:1.

[6] http://www.china-marketresearch.com/market-review/provincial-overview/jiangsu-demographic-economy.htm

[7] GDP data (PPP-adjusted) from http://www.imf.org/external/pubs/ft/weo/2015/01/weodata/weoselgr.aspx

of many resources; and began paying much more attention to environmental issues than before.

And yet even the optimistic scenario just proposed, in which Chinese energy efficiency improves faster than during the period when all these gains were made, would still imply a 38 per cent increase in annual emissions above today's unsustainable levels. Cutting emissions 80 per cent from that level by 2050 (paralleling California's pledge to cut its emissions 80 per cent from 1990 levels by that date) would imply reaching a GDP/GHG ratio ten times as good as today's, even if China has zero growth in both population and GDP per capita after 2030: in other words that it accepts as its GDP goal remaining forever at the per capita GDP of Portugal in 2013. If one instead allows for twenty more years of 6 per cent growth in GDP (but without further population growth), the improvement would have to be 32-fold by 2050; a more modest 3 per cent per year (about what developed countries expect, and enough to get China's 2050 GDP to roughly the per capita level of Germany or Taiwan in 2013) would require a fifteen-fold improvement. Even if we imagine dramatic sectoral shifts (such as from manufacturing to services) and reductions in waste, such improvements are unimaginable without a rapid shift to carbon-free energy sources: the rates at which previous energy transitions (notably wood to coal and coal to oil) occurred would be nowhere near fast enough. Completely replacing coal with natural gas – the cleanest fossil fuel – would halve GHG emissions per dollar of GDP, and so not be nearly enough. Recent sharp declines in the costs of producing clean power offer some reasons for optimism on purely technological grounds, and one might imagine that an authoritarian state could, if it made this a priority, override entrenched fossil fuel interests more readily than more open polities can. But the Chinese state's limited success with much more modest goals – such as closing especially unsafe and inefficient small coal mines, amidst considerable over-capacity in the industry – is not very encouraging.[8]

One could also put the issue of sustainable growth another way, which has grim implications that are not limited to China. In *Something New Under the Sun,* John McNeill describes what we might call the South Korea/Ghana paradox. South Korea, he argues, was in worse environmental shape than Ghana when it began its period of high-speed growth circa 1960, and it then proceeded to ignore environmental concerns almost totally for at least the next quarter-century. But by growing very fast, it has become rich enough that it can afford to clean up, and today it is far better off than Ghana in environmental, as well as economic, terms (McNeill 2000: 359).

This is not just a generalization from a few notable cases. There is considerable evidence for what is often called the 'Environmental Kuznets Curve': a relationship in which pollution levels rise with a country's per capita income as that country goes from poor to moderately well off, but then begin to fall with further income

[8] On recent, unsuccessful attempts, see Wright (2007). For an on-going effort that reached about half of its target by the time that it was originally supposed to be concluded, see Zhang Yi (2014), compared with Reuters (2014, 2016).

growth beyond that point, so that the overall shape looks like an upside-down *U*.[9] Different studies locate this turning point at different income levels, depending on both the country and the specific pollutant – there is even some evidence that the turning point is coming sooner in China than it did in the first developed countries, which would be grounds for optimism.[10] That this would be true also makes some intuitive sense, given how much more we know about the hazards of pollution than we did several decades ago, and given the possibility for today's developing countries to buy pollution control technologies off the shelf rather than having to invent them.

But 'grow first, clean up later' is not a generalizable strategy, for at least three reasons. The first is the fallacy of composition: it does not follow that having everybody do what made one actor better off will make everybody better off (try standing up to see better at a basketball game). One of the ways that richer countries 'clean up' is by outsourcing the most polluting activities, and that does not solve the global problem. In part because other countries have done just that, about one-third of China's GHG emissions in 2005 were due to exports (Weber et al. 2008). This is about the same as the ratio of exports to GDP, but it is considerably more than the contribution of those exports to GDP – which one study put at more like 9–10 per cent (the difference results from the fact that many exports include imported materials, licensed technology or other foreign inputs).[11] Were China to follow the same strategy of outsourcing its dirtiest activities – and some polluting industries will undoubtedly leave anyway as wages rise – this would help its statistics, but not the world's problems.

Thus it becomes crucial in thinking about East Asia – which Sugihara, Mark Selden (Selden 2015) and various others have stressed is in many ways an integrated economic region within a larger global economy – to ask what the unit is that we are asking about. Japan and Taiwan (and, to a lesser extent, Korea) have attained impressive levels of GDP relative to domestic resource inputs; but do we stop there, or do we need also to consider the far less impressive statistics of China, to which they have offloaded some of the more polluting and lower value-added parts of their production? Or should we be thinking about attributing those emissions to the places that consume these goods, which are mostly in Europe and North America? And if we do that, do we do the same for the embodied energy and other resources imported to East Asia?

The second problem is that not all environmental problems seem equally susceptible to remediation. As noted before, there is substantial evidence for an Environmental Kuznets Curve for various airborne pollutants (see, for instance,

9 For early formulations see Selden and Song (1994) and Grossman and Krueger (1995). The name references the original 'Kuznets curve': Simon Kuznets' famous hypothesis that income distribution became more unequal in the early stages of per capita growth, but then began to become more equal again as growth continued beyond a certain point.

10 Compare, Zheng et al. (2014: 61–71, esp. 71) and Selden and Song (1994) on air, to, for instance, Barua and Hubacek (2008) and Granda, Pérez and Muñoz (2008), and Lewis and Wong (2013) on water, and the summary statement in Ho and Wang (2015).

11 Weber et al. (2008) for pollution estimate; Anderson (2007) for estimates of export to GDP and exports as share of value added.

Selden and Song 1994: 137–62), and some evidence for a similar relationship with respect to gross amounts of wastewater. But so far, most studies have failed to show any such relationship for most forms of water pollution (Barua and Hubacek 2008; Granda, Pérez and Muñoz 2008; Lewis and Wong 2013), or for soil quality/contamination; and in the case of GHG emissions, there is thus far no evidence at all of such a turning point. It may be, then, that the literature on the EKC should ultimately make us more pessimistic about both of our Chinese sustainability questions, even though it offers hope of medium-term relief for the lungs of millions of Chinese citizens.

Climate change in particular poses the problem that greenhouse gases emitted now continue to be in the atmosphere for a long time, and there appear to be more positive feedback loops (ways in which warming promotes further warming) than negative ones. Thus your actions now might be locking in events in a distant future; and even if it seems that by becoming wealthy rapidly you will reach a position where you can ameliorate the harm you are doing, this may be illusory, as there is likely to be a big balloon payment to be made down the road. To put it another way, the 'first get rich, then clean up' strategy requires for its success that there not be increasing negative returns to environmental harm, or at least that the negative returns increase more slowly than your ability to pay for remediation. That is no doubt true for some, perhaps even many, kinds of pollution; but in the case of climate change, we have every reason to believe that it is not true.

Thus there is not much reason to have faith that first getting rich and then getting clean is going to work when it comes to energy and climate. This is quite worrisome because that has been the main path to 'success' in the world so far, both in the West and in East Asia. Japan, Korea and Taiwan may never have had the extremes of resource wastefulness that some Western countries did, but that is not adequate to say that what they have done is sustainable. Even Japan's level of energy use to GDP (in PPP terms), which is about two-thirds of the global average, would not be good enough (if applied worldwide) to save the situation if the whole world, or even just the poorer parts thereof, experiences significant further per capita growth.

Moreover, Japan's energy efficiency no longer stands out relative to the West, because the Western and East Asian paths have converged considerably in recent decades, as Sugihara said they would. Japanese energy efficiency remains considerably better than that of the United States, but it is now slightly worse than Germany (which gets more of its GDP from manufacturing than Japan) or the UK; even a few poor tropical countries actually have similar numbers (though that is partly because they do little heating, and partly perhaps because of quirks of PPP adjustments). It is worth noting, moreover, that East Asia's greatest advantage in energy efficiency may well have been in the pre-industrial or very early industrial era. If Vaclav Smil is right that China had less than half of Europe's average per capita per capita energy consumption in the mid-eighteenth century (and in warm regions still less), while other work suggests that output per capita was still very close to European levels in those days (Smil 2015: 178), that would suggest a very big difference in energy intensity; and if Smil's further guess that China and Japan used only one-sixth as much energy per capita as Britain in 1800 (when the income gap might have grown to 3:1, but probably not more than that, and for Jiangnan was probably no more than 2:1),[12] then that suggests a huge gap in energy intensity during the West's early industrial period. In fact, it would make sense for these differences to have been particularly large during early industrialization. We know that there were enormous differences in energy prices across space in this period, which could not have been arbitraged away, even in theory, because of the enormous costs of shipping energy in pre-industrial times.[13] In addition, as Bob Allen has stressed, early steam engines were so energy-inefficient that for a long time it would only have made sense to use them where energy was exceptionally cheap – Great Britain still had well over half of the world's stationary steam power capacity in 1840 (Allen 2009: 179). Generally, the range of differences among developed countries is smaller today (though one should remember that energy-intensity statistics contain all the problems discussed above). In short, while the diffusion of East Asian–style development has historically been much less damaging to the global environment than diffusion of a stylized Western model would have been, it seems likely to offer only modest relief on the path further forward.

A different sustainability crisis: China's water woes

We will return to energy and climate issues near the end of this chapter. But it is important to look at China's other environmental problems, especially those that might choke off economic growth even if China is willing to disregard the effects of its GHG emissions. Despite the headline-grabbing nastiness of air pollution, soil contamination, etc., most Chinese environmentalists point to water as the single greatest area of concern; and unlike with GHG emissions, China's government does not intend to wait until 2030 before making major efforts to reverse current trends.

Water crises do not have the same inherent physical propensity to strong increasing (negative) returns that plays such a large role in climate change. There could be social or political mechanisms that would create increasing negative returns if, say, water stress leads to various sorts of bad decisions, such as poorly planned and/or competitive water diversions, but those are not the same as having a self-catalysing spiral being built into the chemical processes themselves. So the 'first get rich, then clean up' path is not foreclosed with respect to water for those reasons, and it might seem at first glance that this problem is somewhat less in need of immediate heroic action than climate change. But there are plenty of other reasons to suspect that remediation cannot wait in this case, either, and some of them are reasons that

[12] Broadberry, Guan and Li (2014: 1) suggest a China/UK gap of over 3:1 by 1800, but even their figures, adjusting for Jiangnan's advantage over the rest of China, would be a bit under 2.5:1. For 1750, the figure would be about 1.6:1. All three of these authors (especially Guan and Li) have argued in the past for a much larger and earlier divergence. Even these figures seem to me probably too high, for various reasons, but it is not necessary to pursue that here.

[13] Pomeranz (2000: 64–65, n. 143–4), for various citations on fuel costs and transport; for some early-eighteenth-century energy price differences see Allen (2006: 6). More generally, see Kander, Malanima and Warde (2013: 73–74, 136–38, 192–207).

Chinese policymakers apparently find more compelling than the case for immediate climate action.

The most obvious of these reasons is that China's water problems are already extreme, especially in the North. Surface and near-surface water per capita in China today is roughly one-quarter of the global average; worse yet, it is distributed very unevenly. China's north and northwest, with almost 30 per cent of the national population and over half the country's arable land, have about 7 per cent of its surface water; thus their per capita surface water resources are 20–25 per cent of the average for China as a whole, or 5–6 per cent of the global average. A more narrowly defined North China plain may have only 10–15 per cent of China's per capita supply, or less than 4 per cent of the global average. The North China water table has been dropping by roughly 4–6 feet per year for quite some time now, and by over ten feet per year in many places; some studies estimate that if this rate of extraction is maintained, the aquifers beneath the plain will be completely gone in 30–40 years (Yardley 2007; see also for Hebei, Qu et al. 2005: 41). In Beijing, the retreat of the water table has been even more astonishing: over twenty feet per year since the early 1970s (*Economist* 2013). Daily use for households in the north is considerably lower than that which indicates 'water stress' according to UN standards, while the utilization rates for major northern rivers (though not for China as a whole) are well above levels said to indicate stress: thus the situation is quite serious whether it is measured by per capita consumption or by remaining unexploited supply. Moreover, much of the water is of very low quality. Seventy per cent of the groundwater in North China is unfit for any human contact, even washing, and less still is drinkable; one half cannot even be used for industry (*Economist* 2013). While air pollution is having very measurable negative effects on health – again especially in the north, where it bears much of the blame for life expectancies that are about five years shorter than in the South (Almond et al., 2009) – and soil pollution is also an increasing concern, water problems are the environmental woes most likely to put the brakes on the 'Chinese miracle'. The government wrote ambitious goals for improving access to safe drinking water into the five-year plan that ended in 2015 – but those goals could not be met, and access to safe drinking water continues to worsen in some areas (Liu 2015).

In that local sense, then, water may be the key 'sustainability' issue in China. But if we are more concerned with *global* sustainability, energy and climate are still probably the ball to keep one's eye on. There are links between the two problems: some measures to improve China's water situation are quite energy-intensive, and a well-known paper argues that efforts to improve China's energy efficiency could be impracticable (or at least very painful) because they would increase water stress. If that is true, one imagines that China would probably not implement them, being unlikely to worsen problems that fall completely on its own society in order to ease a global crisis.

But these links are not so strong as to rule out simultaneous improvements in both areas. The energy costs of important water palliatives, though hardly trivial, pale compared to the impact of inefficient practices in other economic sectors, and so could be offset by improvements in those other areas; even desalination, currently the most energy-intensive way of increasing water supplies, need not be completely ruled out on those grounds (it has other environmental risks, however). Meanwhile the conclusion by two scholars that one of the most important ways to improve the energy efficiency of China's economy, concentrating more on services, would increase water strain seems to me to rest at least partly on a conceptual error. For the most part, the dangers of current efforts to expand water supply or move more of it to areas of intense shortage lie elsewhere – including the possibility that water that now flows to other countries would be diverted, effectively externalizing the costs of keeping the Chinese miracle going.[14] And while some steps to lessen GHG emissions would require greater water use (for instance, switching from coal to oil, to some kinds of natural gas use, or especially to biofuels), others would not (switching from coal to conventional natural gas technologies, for example) (Mielke, Anadon and Narayanamruit 2010: 7).[15]

While various projects are underway that would increase North China's water supply, many of them offer only remote relief[16] and/or are quite risky. Some are also quite energy intensive, at least using currently available technologies. Desalinating enough seawater to add 10 per cent to China's current water supply, for instance (using the best currently available technologies), would require raising its electricity consumption by roughly 3.6–4.8 per cent; the increment to GHG emissions would be about half that, assuming that the power was generated at China's average rate of carbon intensity. It is worth noting here that power generation is itself quite water-intensive, especially if the power plant runs on coal, as most in China do – it has been estimated that coal mining, washing and combustion account for about one-sixth of China's annual water withdrawals (Chan 2013). So energy-intensive water palliatives cancel some of their own benefits – but not all.

In the short to medium run, then, strategies for allowing economic growth in China to continue require increasing its water efficiency – either by reducing outright waste (e.g. fixing leaky pipes) or diverting water from less productive to more productive uses. (And it needs to be remembered that much of China is still very poor.) Beijing has set a target of keeping the increase in its water use down to 16 per cent over the next sixteen years (to 2030), and it is not clear where even that much more additional water will come from; the Water Resources Group is projecting a demand increase twice that large, and warning of a chronic, extremely painful gap between supply and demand.[17] But even if 32 per cent more water could be found, China is planning on economic growth far, far in excess of 32 per cent over the next fifteen years. So greatly increased water efficiency must be part of any plan for even semi-sustainability and social stability.

[14] I have discussed some of these efforts and their implications in Pomeranz (2009) and Pomeranz (2015).

[15] One complication here is that extracting natural gas by 'fracking' does not use very much water, but the risk that the water will become polluted if the process is not handled very carefully is especially high.

[16] The most recent potential magic bullet is the discovery of large amounts of fresh water under the seabed off China's coast; but nobody thinks this can be tapped within the next few decades (Post et al. 2013).

[17] 2030 Water Resources Group (2009): 10, for the 32 per cent figure; for the 16 per cent figure, see China Water Risk (2015), citing China's State Council as setting a ceiling of 700 billion cubic metres for 2030, versus slightly over 600 billion per year at the time (2013).

Reducing waste is, by definition, almost pure benefit, and there is general agreement that there is a lot of waste to be reduced – though when we look more closely, some of that 'waste' becomes more ambiguous. Irrigation water that does not get taken up by plants can recharge aquifers; clean river water that is allowed to run to the sea may not meet any immediate human need, but some of it can sustain valuable coastal wetlands. There is, at any rate, little reason to think that there is enough pure waste that can be eliminated to solve China's water crisis; further efficiency gains will have to come from shifting water from some human uses to other, more productive ones. Definitions of 'productive' can vary, of course, and not everything that increases GDP is socially useful; for simplicity, though, I will leave that question aside here. Whatever our priorities might be, China's leaders, and probably the overwhelming majority of its citizens, want a lot more GDP growth.

When it comes to such sectoral reallocation, the big target for a reduction in water use is agriculture. It still accounts for 60–65 per cent of water use, down from over 80 per cent 25–30 years ago; the Water Resources Group suggests that this will decline further, to 50 per cent, by 2030 (the global average is about 70 per cent). However, that would still represent a slight increase in absolute terms over today's levels.[18] From the point of view of decreasing water intensity of GDP (which is to say, increasing efficiency) the logic here is absolutely compelling, as each litre of water produces far less economic output in agriculture than in other sectors. A recent Berkeley study suggested that this disparity could be approaching 100:1, though it mostly gives lower figures; an earlier estimate was 60:1, which is much closer to the figures for various sectors actually found in the Berkeley study.[19] But here is where the fallacy of composition comes in: it is not possible for every country in the world to get out of agriculture, unless we expect to stop eating. While there is clearly some room for eating less in many countries, in China it seems far more likely that consumption of animal protein and fats will continue to rise, pushing up China's food consumption footprint. And though China's recent pattern of buying or leasing vast amounts of land overseas – from Southeast Asia to Africa to Latin America to the Ukraine – suggests that the government is willing to become more dependent on agricultural imports than ever before (as long as they manage the pipeline from beginning to end), they surely know that this kind of outsourcing has limits as a water efficiency strategy. In the United States, agricultural water withdrawals (including livestock and aquaculture) represent about 40 per cent of the total (US Environmental Protection Agency 2004: 9–10), and the United States grows far less of the most irrigation-intensive crops (and does a lot less aquaculture) than China – which needs those irrigation-intensive crops in order to get high yields on scarce land. In South Korea, which has made intensive efforts to conserve water across all sectors (but does grow a lot of irrigated rice), agriculture accounted for 47 per cent of water use in 2012 (UN Department of Economic and

[18] 2030 WRG (2009: 10) projects total demand of 818 billion metres^3, so half is 409; 60–65 per cent of today's 618 billion metres^3 is 371–409.

[19] Kahrl and Roland-Holst 2008: 11–12 (saying 'two orders of magnitude', but providing figures that suggest ranges from 11:1 to 67:1 for direct water use and roughly 30:1 to 50:1 for embodied water use). The 60:1 figure comes from Postel (2008).

Social Affairs 2006: 4–5) and South Korea imports roughly 90 per cent of its food, as against about 5 per cent in net terms for China (Japan and Taiwan are in between, but considerably closer to Korea [Berthelsen 2011]).[20] Moreover, if water were to migrate from agriculture to industrial uses, some of the biggest beneficiaries would be very energy-hungry sectors, including coal mining, other resource extraction (for instance, fracking) and power generation – all sectors which are currently complaining that they are hampered by water shortages, and which would have no trouble selling any increment in their production. Reducing constraints on these sectors thus hurts the environment along another front, which is even more important to the world in general (though perhaps less so to China) (Kahrl and Roland-Holst 2008: 11–12). So the potential for really transformative further change here is limited.

What about a different kind of shift, from industry to services? Here it seems, intuitively, that there should be big gains to be had, but the little bit of existing research we have seems not to confirm that. Despite the large amounts of water used in many industrial processes, a 2008 study estimates that 'services' used 11.2 metres^3 of water for every 1,000 yuan of output, just slightly better than the famously water-intensive chemical industry, and well above the economy-wide average of 8.5. The figure for restaurants was 9.7; for trade it was 8.1, and transport and telecom 8.4. None of these activities appears to be included in 'services' (Kahrl and Roland-Holst 2008: 12). There seem to me to be some significant problems with this study, which make it more alarmist than it should be.[21] But if it is correct, the results would be *very* worrying: they suggest that the general economic movement necessary to continue growth and decrease China's energy intensity will tend to strain its water shortage further rather than relieve them. If, on the other hand, I am right about the problem with the study, then we can be more sanguine about the capacity of a shift to services improving sustainability vis-à-vis both energy and water; but it still suggests that we should not expect too much relief (at least on the water side) to come from a sectoral shift alone. Moreover, the shift to services, even if desirable on all fronts, will not happen automatically. After all, Beijing has been trying to encourage such a shift for some time now, with only partial success; and as China's growth slows down, political authorities seem more far more concerned with preventing that deceleration from being too rapid than with what sectors they stimulate in pursuit of that goal.

Meanwhile, using water 'efficiently' is also partly a matter of moving it to where there is currently the most unmet demand: and there some very ambitious plans are afoot which are themselves worrisome in many ways. By far the most ambitious is the South-North water diversion, which I have written about at length elsewhere (e.g. Pomeranz 2009, 2015). If it is ever fully completed and functions as intended it would move about 48 billion metres^3 per year from the South to the North; this represents

[20] In 2006, Japan imported over 60 per cent of its calories, and 32 per cent of its food by dollar value (Nagata 2008). For Taiwan, it's 69 per cent by calories, and 68 per cent by price: Lee (2014).

[21] It appears that the authors have done their calculation by taking gross output of a given sector and dividing by its water use, rather than value added divided by water use. Presumably value added is much closer to gross output in services than in lots of manufacturing. An attempt to contact the authors was unsuccessful.

about 8 per cent of China's current water use. Enormous amounts of energy would be required to pump such huge amounts of water (roughly the annual volume of the Yellow River, or the Colorado River in the United States) across hundreds of miles, and to treat it so that it arrives in usable form (the first two stages have both been slowed down considerably by the discovery that far more water treatment was needed along the way).

In fact, while China is making significant efforts to improve the efficiency of water use, and to improve the treatment (and thus re-use) of wastewater, the results are thus far not very encouraging, especially when it comes to pollution reduction. Moreover, the regime's biggest investment, at this point, is not in relieving its water crisis in either of these ways, but in increasing water supply in drought-threatened parts of North China – especially the Beijing-Tianjin region – through the South-North water diversion project.

I will not repeat here what I have written elsewhere about this project. In brief, there are many questions about whether this project can work, and massive environmental risks of various kinds; it seems almost certain that the same amount of money could do more to alleviate shortages if used in local efforts to reduce waste or make more water re-usable.[22] (The official cost estimate for the diversion plan is about $65 billion, but the parts completed so far have run far over budget.)[23] But there are also a number of reasons why it is no surprise that the government is nonetheless pushing ahead with this project – the most expensive single construction project in history, so far.

China is, of course, hardly the only country to have pursued mega projects that were probably not the best solution to the problem they were aimed at. Big, dramatic projects stoke national pride and accelerate people's careers in ways that helping to fix a million leaky faucets cannot match. Chinese leaders also view large-scale hydro-engineering as an area in which they can be the world's technological leader, and thereby reap both financial and political benefits. But there are also issues related to China's domestic political economy that are likely to bias central decision-makers towards reliance on big projects involving cutting-edge engineering, even when more local approaches using well-known technologies might seem preferable.

One big factor is probably monitoring issues. It is relatively easy for the central government to assess whether a big construction project is being built, sticking to schedules, and so on; to a significant extent, it can even bypass local officials and arrange to build the project itself. By contrast it is far harder to monitor whether millions of leaks are being fixed, irrigation ditches re-lined, and so on; in places that rely on water for underground aquifers, it is even more difficult to measure the bottom line issue of how fast the aquifers are being depleted or recharged. Changes in the quality of surface water are perhaps slightly easier to assess, but still often quite difficult; and assigning responsibility for changes in water quality can be far harder

22 For a few examples of others – including some people in the Chinese government – making the same point see Leavenworth (2014), Buckley (2014), Yue Wang (2014) and Economist (2013).

23 According to Scott Moore at the (New York) Council of Foreign Relations, the part of the project completed as of 2014 had cost almost 2.5 times its projected cost. See Buckley (2014).

still, especially when a given body of water draws on flows that cross jurisdictional lines.[24] China's political system adds to this a number of issues that make monitoring and enforcing pollution control in particular quite difficult.

Though China has, in some respects, a very centralized political system, Beijing cannot simply pass orders down and expect them all to be obeyed. Instead the common pattern is that the centre can get very high degrees of compliance on a few issues that it deems to be top priorities – even when, as in the case of compulsory birth limitation, these policies are quite unpopular – but must balance this by allowing local officials considerable leeway on other issues; as one scholar puts it, the system 'cannot cope with more than a few state goals simultaneously' (Edin 2003: 51). In the absence of a free press and an independent judiciary (judges answer to the administration at the same level at which they serve), it can be difficult for the centre to even know what is happening in local government, much less force local actors to do what the centre wants; one 2008 survey of over 300 villages found that 81 per cent of officials misreported their village income data, by the very substantial average margin of 44 per cent (Tsai 2008: 805–9). A 2009 MEP report suggested that the discharge of waste pollutants into Chinese water sources was about double previous estimates (cited in Golding 2011: 403).

The Chinese Ministry of Environmental Protection is quite small, with fewer than one-sixth as many employees as the United States' Environmental Protection Agency.[25] Consequently, the monitoring of conditions and assessment of fines are largely left to provincial, municipal and county-level Environmental Protection Bureaus, whose decisions are subject to review by the territorial governments to which they belong (Golding 2011: 404). Given the serious fiscal pressures that many local governments face – and heavy local dependence on sales taxes and revenue from leasing government-owned land to developers[26] – the pressure to ignore pollution by growth-producing local industries is strong. If the problem is not ignored entirely, there is strong pressure to assess fines at a level that represents a tolerable cost of doing business (thus generating revenue) rather than force the illegal activity to cease.

The Chinese central government's major tool for countering these principal-agent problems is the Cadre Evaluation System (CES): an annual performance evaluation required of all officials at all levels, rendered in statistical form, and crucial for promotion or even retention in office. Much has been made by some optimists of the fact that the CES now includes some environmental targets, while in the past it had (heavily weighted) targets for growth but not for environmental protection. But this is, at best, a reason for limited optimism with respect to water issues in particular.

First, the environmental targets that the government has included in the CES so far are not ones that measure environmental results directly: they are targets for energy intensity (which, as we have seen, can fall while total energy use keeps rising, as long

[24] Golding (2011) is an extended treatment of these and other reasons why China's cadre evaluation system is not well suited for providing local officials with incentives to control water pollution.

[25] China Water Risk, http://chinawaterrisk.org/regulations/enforcement/insufficient-resources/ accessed 22 March 2015.

[26] On the importance of land revenues see Hsing (2010) and Rithmire (2015).

as GDP rises), investment in pollution control equipment (which does not always mean it is consistently used), in reporting certain kinds of environmental data (which does not ensure that it is reported accurately) and the like (Zheng et al. 2014: 62).[27] Cadre evaluation is always done by the immediately superior level, and targets are often set by an official who must reach a given quantitative goal parcelling it out to his immediate subordinates; thus, failure to reach a target often affects the careers of all the cadres at a particular level in a given territorial unit and of the next level above. The incentives for collusion are therefore quite strong. Officials who had to reach pollution reduction targets in the past often simply shut down industries for a brief period when they knew monitoring was about to occur, for instance. Moreover, economic growth targets remain quite important, even if a bit less so than before, and social stability targets (which could easily be threatened in rural areas, if officials sharply raised water prices to reduce waste) remain the most important of all. There are, in sum, many reasons for Beijing to doubt that it could rely on the thorough implementation of local water conservation measures, even if it were to allocate the huge sums of money currently allocated to the South-North water diversion to support such local efforts. In that sense, the big project may seem more manageable, even if, in a technological sense, it is far more risky.

Thus far, neither the costs of moving water – whether by pumping it to the surface or across the landscape – nor the costs of 'producing' more of it (by desalination or by treating wastewater to make it usable again) have figured significantly in water pricing, but as China relies more and more on water that is energy intensive, this is placing increasing strains on local actors. More wastewater treatment, for instance, could theoretically make a big difference to the usable water supply while using about as tenth as much power as desalination: a 10 per cent increment with only a 0.4 per cent increment in electricity use.[28] But even that degree of electricity use, priced (as power is in most parts of China) below its true cost, represents a large enough expenditure that it deters many municipalities from operating the water treatment facilities they already have. Budget constraints are local, and some localities with serious water pollution problems face very serious fiscal pressures; more agricultural areas generally face the worst budgetary situations, and also probably use the most water per dollar of GDP. When what appears to be a large Chinese real estate bubble pops (or gradually deflates), these fiscal pressures will get much worse; China's fiscal structure and the very large geographic component of Chinese inequality have made a number of local governments very dependent on revenue from cooperation with high-risk real estate ventures (see, for instance, Hsing 2010).

[27] For more on the cadre evaluation system and its limitations in environmental management more generally, see Wang (2013a: 398–430). For Wang's quick summary of how the targets have not worked, see Wang (2013b).

[28] The average Chinese wastewater treatment plant uses 0.268 kilowatt hour per metres^3 (see Xie and Wang 2012), so treating 60 billion metres^3 (a bit under 10 per cent of current annual water withdrawals) would take 16 billion kilowatt hour. China used over 4,000 billion kilowatt hours in 2013 (US Energy Information Administration, 2013b), so this would only be a 0.4 per cent increment to electricity use.

In sum, then, the amount of energy used to make water available should remain very small relative to China's total energy demand, though it could become non-trivial in the most extravagant scenarios – if, for instance, desalination became important. The much more likely effect is that the money-denominated *costs* of energy used in providing water will become very high relative to the market value of that water, necessitating either a recentralization of these costs (and decreasing incentives to conserve) or price increases that would be very painful to farmers and poor people. And if energy prices rise, as they almost certainly should and will, it is likely to hit hard at wastewater treatment in many poor areas. The cure for that would have to be big water price increases (politically dangerous but economically sustainable in cities, and quite possibly ruinous in some agricultural areas), direct subsidies from Beijing or some combination. Money sent back down from the centre is already a big part of local government budgets, especially in poor areas, so it is certainly possible for Beijing to provide the needed funds; the further increment would be proportionately quite small. The question is rather one of priorities – both in Beijing and in the localities that would have to use earmarked funds as intended.

Conclusion

Rather than try to guess exactly what policies Beijing will follow, and with what results, it may be better to conclude by returning to historical perspectives. China's water and energy stories both suggest the country's ambiguous relationship to an 'East Asian development path'. While the model fits some parts of the country quite well, other regions do not seem to fit at all: China's far west, in particular, may more closely resemble some particularly unhappy development stories, such as Soviet Central Asia and Siberia.[29] Another problem is that China as a whole is simply too big to fully duplicate certain features of the post-war East Asian path (such as importing a high percentage of its food and energy needs). On the other hand, it does seem to be trying to partially duplicate key features of that path, both by increasing its resource efficiency and increasing its imports. The current strategy of buying or leasing lots of overseas land, water, mines, etc., to operate directly, is somewhere in between the colonial strategy followed by pre-1945 Japan, on the one hand, and the post-war Japanese, Taiwanese and Korean strategy of relying on purchasing those commodities on a global market while relying on the United States to ensure open access to that market, on the other.

A big switch towards services in China's sectoral mix would also be one way of making Chinese development more skill intensive, and thus of increasing labour intensity in ways potentially consistent with higher incomes. Skill intensity is, of course, crucial to having *development* along the East Asian path; if you have a resource-

[29] See Pomeranz (2001) for this comparison. In addition to the well-known ecological disasters that resulted from the Soviet development in this region, it resulted in an enormous waste of capital that played a large role in ending the period of rapid per capita growth in the USSR; on this, see Allen (2003).

and capital-saving, labour-intensive economy where the workers are not particularly skilled, you simply have a poor economy. But such a switch is hardly unique to East Asian development, as all the wealthy economies have eventually become less industrial and more service focused; this is part of what has brought their energy intensities down and created increasing convergence among the richer economies. Indeed Japan and Korea (though not Taiwan) are at this point among the most industrial of the rich countries. It is being relatively skill intensive and resource saving *while being heavily industrial* – even during the early industrial phase, which was extremely resource intensive in the United Kingdom, United States, Germany, etc. – that seems to have been the distinctive part of the 'East Asian Path', and one that stands out in the data for many of China's coastal provinces today. But much of the rest of China has not done that. Instead it used few resources during the early industrial era, but only because it remained very poor; became quite profligate with resources during early industrialization (especially in places where that early industrialization was heavily oriented towards military purposes), and remains relatively resource-intensive today: indeed far more so, in terms of both water use and GHG emissions per dollar of GDP, than developed countries in the West. At this point, China's north and west needs to make radical improvements in both these areas if China as a whole is to address either its own sustainability problems or those it poses for the world; a gradual convergence of the rest of the country towards contemporary 'East Asian' patterns, even if it were possible, is likely to be too little too late.

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14

The Present Climate of Economics and History

Julia Adeney Thomas

Lands without history

In the spring of 1915, the *American Historical Review* (*AHR*) focused exclusively on Europe and North America.[1] An extensive report on the annual convention held in Chicago was followed by articles on nineteenth-century Prussian military service, eighteenth-century Anglo-French commercial rivalry, and cotton and capitalism in America's southern states. None of the twenty-two books under review portrayed the non-Western world, nor was there even a category for reviews of such books since 'Ancient History' referred only to the Mediterranean's distant past, 'Medieval and Modern' encompassed only Europe and 'American History' speaks for itself. This narrowness was hardly unusual. As today's *AHR* editors note, this issue 'was typical for that time when areas outside the West and the Northern Hemisphere were considered by many to be lands without history'.[2] In other words, a century ago, a book about the four regions discussed in this volume would hardly have been deemed 'history' at all. Africa, South Asia, Southeast Asia and East Asia may have had a past, but not one that was of apparent interest to the discipline. Sadly, matters are only marginally better today in Anglophone universities as a recent investigation by Luke Clossey and Nicholas Guyatt demonstrates. Their study, 'It's a Small World After All', shows that American history faculties currently muster only enough interest in the rest of the world to

The title of this chapter indicates my deep indebtedness to Dipesh Chakrabarty's path-breaking article 'The Climate of History' (2009).

1 *American Historical Review*, April 1915, vol. 20, no. 3. https://www.historians.org/about-aha-and-membership/aha-history-and-archives/brief-history-of-the-aha (accessed 8 July 2015). This was true for all four issues published in 1915. Volume 20, as a whole, contains one article on the non-West, an essay 'The Origin of the Feudal Land Tenure System in Japan'. Vol. 19 also contains only one article on a non-West topic, the Indian caste system.

2 Editors (2015).

devote about 17 per cent of their research to regions outside Europe and North America while the UK still shambles behind with barely 8 per cent (Clossey and Guyatt 2013: 4 of online version).[3]

These observations highlight the importance of our volume's geographical focus, but my point is not to castigate the historical profession for geographical injustice. While it may be gratifying to accuse previous generations of narcissism, racism and lack of curiosity, the frisson of Oedipal righteousness does not help us understand why all places and peoples have had a past but only a few have had 'history'. To understand this widespread historylessness, we need to delve into the question of *why* professional historians in the West systematically excluded (and often continue to ignore) past experiences in places where about 80 per cent of today's human population lives.[4] When we ask why history turned its back on the larger world, it becomes apparent that this exclusion was not incidental. It was instead intrinsic to the modern discipline's intellectual formation in the late nineteenth century when it sought to privilege human liberty and freedom of action. Central to this understanding of freedom was to see it as an escape from nature. According to this reckoning, only those who could rise above natural constraints could be properly historical. Since 'natural constraints' were seen to encompass everything from certain ethnicities, races and bodily conditions to particular ecologies and economic activities, that left most people, most places and an entire gender largely in the dust. All other species besides *Homo sapiens* played roles of minuscule importance or none at all, and were treated as essentially history-less by historians until recently. By the end of the nineteenth century, when the discipline of history was ensconced in universities in the West and in Japan, history was, by and large, the story of the few who had shaken off the shackles of natural constraints.

Wrenching history from nature had not been an easy process. In fact, it took centuries of effort.[5] For instance, in his charming *Methodus ad facilem historiarum cognitionem* (1566), Jean Bodin had to argue for a specifically human history that he distinguished from 'natural history' and 'divine history' because 'it is probable'. 'Probability' as the central characteristic of human history allowed for liberty of choice and moral responsibility unlike natural history which was deterministic according to Bodin and, unlike divine history, where holy interventions surpassed human understanding. Bodin insisted that the historian rightly separated human actions, tracing the wisdom or folly of certain choices, from the inevitable script of natural necessity and from the providential randomness of miraculous intervention

3 With Christian Sidak, I am doing comparative research on the interests of historians in Japan. Our findings show that historians in Japan also consider many lands to be without history although the excluded countries differ from those excluded by historians in the West. There is need for research on those areas considered historical by the faculties in other nations.

4 For world population figures, see Worldometers, http://www.worldometers.info/world-population/#region (Accessed 2 July 2015).

5 Here I focus on this effort in European thought and institutions but an analogous problem of nature, history and statecraft emerged in Japanese thought as well, explored by Masao Maruyama (1974) and Thomas (2001a,b).

(1566, this edition 1945: 15).[6] Well into the nineteenth century, the need to articulate history's unnaturalness persisted. In the 1830s, Georg Wilhelm Friedrich Hegel's *Philosophy of History* furthered the theoretical liberation of history from nature by arguing that only some places have history because only some places witness the working out of the spirit of freedom. Again, history was distanced from nature and from those people weighed down by natural inevitabilities. According to Hegel, certain climates, notably that of Africa, but also to a lesser degree Asia, lock their inhabitants in the morass of absolute injustice called the 'natural condition'. As Hegel put it, Africa 'is the Gold-land compressed within itself – the land of childhood, which lying beyond the day of self-conscious history, is enveloped in the dark mantle of Night. Its isolated character originates, not merely in its tropical nature, but essentially in its geographical condition' (Hegel 1956: 91).[7] Even after Hegel's intervention, it would take another few decades before the definition of history as the story of liberation from nature and other oppressions became an unspoken assumption rather than a point of debate. Indeed, Reinhart Koselleck argues quite strongly that until 1870, 'all histories remained rooted in "nature", directly embedded in biological pregivens' (Koselleck 2002: 8). Only in the 1870s was nature finally vanquished as an element of historical thinking and relegated to prehistory enduring, it could be said, only as history's unconscious.[8]

As the discipline of history became firmly established within Anglophone universities, freedom from nature was secured as a defining characteristic of those lands and people who enjoyed historicity.[9] For most of the next century, concepts and problems connected with 'nature' were not part of history proper. This appears to have been true in European universities as well. Important terms such as 'climate', as Fabien Locher and Jean-Baptiste Fressoz have recently shown, vanished from the lexicon. Locher and Fressoz argue, 'For more than a century, from the mid-eighteenth century to the last thirty years of the nineteenth century, Western societies conceived of their relationship to the environment and their responsibility for the transformation of both nature and their own way of life in terms of climate', but as history and economics achieved the status of disciplinary pursuits in late-nineteenth-century universities, 'the climatic paradigm' for understanding disease, heredity and prosperity collapsed and was replaced by a dematerialized view (Locher and Fressoz 2012: 581). See also Nash 2006). Even worldwide epidemics such as the 1918 Spanish flu which killed more than 20 million people did nothing to attract the interest of historians, even

[6] In 1980, Hayden White made a similar case when he argued that 'in order to qualify as historical an event must be susceptible to at least two narrations of its occurrence. Unless at least two versions of the same set of events can be imagined, there is no reason for the historian to take upon himself the authority of giving the true account of what really happened' (reprinted in White 1987: 20).

[7] Hegel (1956: 91). Originally delivered as lectures in the winter of 1830–31.

[8] I discuss this psychological aspect of the history/nature divide in *Reconfiguring* (2001a: 15–29).

[9] According to the website of the American Historical Association, 'When the American Historical Association (AHA) was founded in 1884, history had only recently emerged as a distinct academic discipline. The first few professors in the field of history had only been appointed at major universities in the 1870s. Up to that point, wealthy men with the leisure time to pursue such endeavors did most of the writing of history and collection of historical manuscripts and archives'.

when it prevented the American Historical Association from holding its 1918 annual convention. As Alfred Crosby notes, historians in general continued to be interested in what 'Bernard Bailyn called *manifest* history …, that is to say, [history] devoted to "the story of events that contemporaries were clearly aware of, that were matters of conscious concern, were consciously struggled over, were, so to speak, headline events in their own time"'. Conscious, deliberate, public actions were the defining objects of historical interest, not average temperatures, water cycles, soil enrichment or germs. Between about 1870 and 1970, 'Professional historians had no interest, certainly no burning interest, in what we today call environmental history, the story of humanity as an often passive or distracted participant in local, regional, and world-wide ecosystems' (Crosby 1995: 1177). The discipline of history had developed a blind spot almost as big as the planet.

Not coincidentally, history's blind spot was shared by modern economics when it was professionalized as a distinct discipline at about the same time.[10] Although classical political economists such as Adam Smith, Thomas Robert Malthus, Thomas Paine and John Stuart Mill had fretted over natural constraints on agricultural and industrial production, neoclassical economics, epitomized by William Stanley Jevons's *Theory of Political Economy* (1871), Carl Menger's *Principles of Economics* (1871) and Léon Walras's *Elements of Pure Economics* (1874–7), abstracted the field from nature's physicality to the realm of mathematics and the market.[11] Karl Polanyi pointed to the strangeness of this manoeuvre in relation to real estate: 'What we call land is an element of nature inextricably linked with man's institutions. To isolate it and form a market out of it was perhaps the weirdest of all undertakings of our ancestors' (1944, quotation from 1957 edition: 178). By the 1930s, 'the economy' had become an autonomous object 'construed as having indefinite growth potential, divorced from natural deterministic factors or physical limits' (Locher and Fressoz 2012: 595). See also Mitchell 1998, 2005). In the 1950s, some economists, particularly those concerned with developing countries such as W. Arthur Lewis, attended to historical agrarian practices rooted in particular geographies, soils and cycles, but this non-mathematical approach lost out in mainstream economics.[12] As economist Jeffrey Sachs points

[10] Although people studied and wrote about political economy and history long before specific faculties and departments were established, these branches of knowledge gained official institutional recognition within universities only in the late nineteenth century. Harvard's Department of Economics was established in 1897. http://economics.harvard.edu/pages/about (Accessed 7 July 2015) Not in refs At Cambridge University in 1903, Alfred Marshall, professor of political economy, succeeded in establishing what was to become the Economics Tripos as an undergraduate degree course and thereby established the Faculty of Economics and Politics. http://www.econ.cam.ac.uk/about/history (accessed 7 July 2015). Not in refs A similar argument about the discipline of sociology might also be made. Adolphe Quetelet, founder of social statistics, linked natural forces, especially climate, to demographics and criminality, but August Comte and Emile Durkheim moved the field away from natural explanations to the closed systems of purely social, denaturalized forces. See Locher and Fressoz (2012: esp. 593–4).

[11] Joel Mokyr has argued that the economy was conceived of as being divorced from culture and ideology as well. See Mokyr (2009, 2015).

[12] I am grateful to Janet Hunter for her illuminating comments on this strand of economic thinking, a strand, as she suggests, that remained central to economic history even as it was extinguished in economics.

out, the 'complete separation of economics and nature was the predominant way of economics thinking and teaching until very recently' (Sachs 2015).[13] Again, as with history, it is vital to understand this separation of economics and nature not as a nefarious plot but as the corollary of the hope, often coded as anti-Malthusianism, that all people might live lives of secure abundance with the resources for self-cultivation and political self-determination. Many, including Marx and Engels, were awed by the majesty of man's 'subjection of nature' (Marx and Engels 1948, quotation from 1998 edition: 40).

Today, economics is beginning to change. In the past few decades, in rough synchrony with developments in history, the discipline of economics has been slowly reopening its eyes to the natural resources and processes upon which production rests. Spanning the spectrum from 'green capitalism' to 'eco-socialism' and even 'environmental anarchism', approaches are coalescing under many rubrics such as Ecological Economics and Steady State Economic Thinking and in several places such as the Institute for New Economic Thinking at Oxford, the Grantham Research Institute on Climate Change and the Environment at the London School of Economics, the Schumacher Center for New Economics in Great Barrington, Massachusetts, and The Earth Institute at Columbia University. However, like history, economics bears the marks of its intellectual formation. Only incrementally are these disciplines reincorporating the materiality of the natural world, though the progress is particularly evident in the sub-fields of environmental history and ecological economics.

In retrospect, it is possible to argue that fossil fuels spiked the eyeballs of both history and economics. The practitioners of these disciplines rightly credited human ingenuity, new political ideals, industrialization, the rise of nations and imperial might with liberating some societies and some human beings from mind-numbing toil, early death and political oppression, but many were blind to the material foundation of this release.[14] That material foundation towards the end of the nineteenth century included nitrogen fixing and, especially, the decisive shift away from biomass and muscle energy to coal and eventually to oil. Instead of drawing on current sunlight alone or the sun's energy stored in plants and animals either living or recently alive, some societies began to exploit what Thom Hartmann (2004) terms 'ancient sunlight', the carbonized energy stored by plants millions of years ago. With the exploitation of this ancient sunlight, energy use grew by leaps and bounds. John McNeill calculates, very roughly, that 'the twentieth century used ten times as much energy as in the

[13] Sachs argues that it is possible to have global prosperity and social justice, and protect the environment by harnessing technologies such as those that can, he says, provide a zero-carbon global energy system.

[14] Nikiforuk argues, 'In insisting that labor, markets, and technology make the world go round, neoclassical economists have ignored the primary source of all wealth: energy. They have disregarded several thermodynamic laws and abused much math. They have also mistaken the creation and exchange of money for the production of real wealth. Oil has powered an unprecedented set of illusions: that exponential growth is normal, that self-interest is always rational; and that capital is disconnected from material resources' (Nikiforuk 2014: 131).

thousand years before 1900' (2000: 15). Andrew Nikiforuk even argues that societies used carbon energy and carbon-fuelled machines to replace human slavery and serfdom (Nikiforuk 2014). But, as we are aware today, that liberation created new dangers and perhaps even what Nikiforuk calls 'a new servitude' (Hartmann 2004; Nikiforuk 2014). The rupture of established planetary geophysical and biological systems summed up in the word 'Anthropocene' is manifesting itself in the loss of species, oceanic dead zones due to nitrogen run-off, erratic weather, a hotter planet, soil erosion, drying aquifers, sinking deltas, species extinction and other woes discussed in this volume. Scientists predict worse to come.

Eco-economic scales: Rethinking the disciplines of history and economics

These manifestations of a changing global environment have spurred some historians and economists to rethink the premises of their disciplines, especially at key points of disciplinary intersection in environmental and economic history, but this reconceptualization is far from universal. It is proving difficult to root out the often unconscious yet fundamental premise that natural resources are infinitely abundant given the right technologies and therefore external to the linear development of humankind. I will return to this difficulty at the end of this chapter when I consider eco-modernism, but the reasons for resistance are understandable. 'Cornucopianism', to use Fredrik Albritton Jonsson's term, is constitutive not only of our modes of representation and the objects of our historical and economic research, but also, in many ways, of our better hopes.[15] Now, as we open our eyes to the consequences of Anthropocenic processes, the landscape before us is both bright and shadowed. On the positive side, as ecological materialism re-enters history and economics, the exclusions upon which those disciplines were founded become evident. Africa and Asia, once submerged from view due to their supposed natural constraints, reappear. On the negative side, this new materialism moderates our highest hopes for universal abundance and liberty. As Gareth Austin remarks in the introduction to the present volume (p. 1), 'there now seems little doubt that, in a vicious dialectic, the worldwide – albeit not universal – spread of industrialization has undermined some of the environmental foundations of continuing economic development'.

What happens once nature is reintegrated into history and economics? Having argued that these disciplines were fundamentally shaped by their divorce from nature around 1870, I now turn to the complex stories that materialize after about 1970 when nature, haltingly, is reintroduced. Put succinctly, the topics that emerge are the ones central to our volume: the 'lands without history', the 'externalities' of neoclassical

[15] Albritton Jonsson (2014). Evidence of historians' continued blind spot when it comes to nature is plentiful. In a recent *AHR* forum discussing where historical practice stands today, none of the five other scholars mentioned the challenge to history presented by anthropogenic climate change, a fact I discuss in Thomas (2012).

economics and the planet's physical properties that once seemed fairly stable and are now rapidly changing.[16] Re-embracing nature redirects our attention. The local, messy, networked, repetitive activities of the vast majority of people most of the time gain prominence. The concern for reproduction as well as production, for conservation as well as expenditure, for well-being as well as wealth feature as crucial to our understanding of past economic developments. History becomes the story of cyclical recurrence as well as 'the story of liberty', a tale of local knowledge and geographical specificity as well as globalization, of passivity and reception as well as activity, of unconscious factors as well as conscious actions, of intransigent materiality as well as fluid, abstract markets, of Africa and Asia as well as the West. In dialectical self-reflection, the histories of the West as well as of other places take on these complexities. Nature fundamentally reshapes the disciplinary concerns of history and economics.

However, as this volume also demonstrates, reincorporating nature does not produce a single, unified, encompassing story. Indeed, the very concept of 'the Anthropocene', in gesturing both to a global condition and to the diverse local processes that produced it, contains a variety of scales, some of them commensurate and some of them in tension with others.[17] When the disciplinary parameters of economics and history expand, stories multiply and analytical methods require retooling. In economics, values uncapturable by markets, need to be calibrated. In history, narrative structures strain to balance the factors of deep time and space with more proximate causes and places. Contending protagonists from human agents and natural actors to physical substances and forces clamour for attention within single texts. As Albritton Jonsson among others points out, agency 'is dispersed both spatially and temporally. Poor countries and distant generations pay the consequences for the consumption pattern of affluent countries in the present' (Albritton Jonsson 2015. See also Gardiner 2013; Nash 2005; Cronon 1992). Concrete examples of the difficulty of mastering such complexity abound. Steven Stoll, for example, recently complained in a review of Gregory Cushman's *Guano and the Opening of the Pacific World: A Global Ecological History* that 'it is about too many things. A book should have great ambition yet remain coherent'.[18] Undeniably, books should have coherence, and coherence is always achieved by leaving things out as Stoll implies. However, as we become more attuned to environmental thinking, the question of what to leave out becomes increasingly hard in both theory and practice.

In this predicament, scale becomes a major issue of concern. Much of the disagreement over the dating of the Anthropocene (whether 8000 BP, 1610, late

[16] Even within environmental histories, the emergence of these topics is slow due to the predilections and disciplinary constraints described above. As Austin points out (above, p. 96), 'Sub-Saharan Africa appears in a peripheral manner in such major late-modern environmental histories as McNeill (2000) and Grataloup (2009)'. Corey Ross (above, p. 199) makes a similar observation on why Southeast Asia has only a faint presence in most global environmental histories. On 'ecosystem services' see Daily and Ellison (2003).

[17] Scale has become a theoretical focus of late. See Thomas (2014a) and Chakrabarty (2009). See also Chakrabarty (2012), Coen (forthcoming) and Shryock and Smail (2011).

[18] Steven Stoll, review of Gregory T. Cushman's *Guano and the Opening of the Pacific World: A Global Ecological History* in *Journal of Modern History* Vol. 87, No 2 (June 2015), 417.

eighteenth century, or the mid-twentieth century), as well as the ascription of responsibility, hinges on scale. The current candidates for culprit range from the entire human species to a few English textile factory owners, from the Ice Age megafauna extinction to the age of nuclear bombs, from the beginnings of agriculture to the European invasion of the Americas. Whether the discussion focuses on overpopulation, overconsumption, capitalism, developmentalism or all economic activity, the questions posed are, at bottom, ones of proper scale. The issues of scale also emerge in the alternative names proposed by historians and others in the humanities and social sciences to replace 'Anthropocene'. Each of these names, in implying different scales of time, place and agency, creates a different way of putting nature and history together. The 'Capitalocene', supported by Andreas Malm, Alf Hornberg and Jason Moore, points the finger of blame at eighteenth-century British industrialists, a move reasserting the primacy of the West; the 'Econocene', suggested by Richard Norgaard, focuses on the incredible twentieth-century expansion of human activity with a '3-fold rise in human population and a 50-fold rise in market activity'; the 'Carbocene' indicates the 'co-starring role played by coal and hydrocarbons like oil and gas in creating our current era'; the 'Thanatocen' highlights species loss; and the 'Manthropocene', proposed because scholars working on the Anthropocene are overwhelmingly male, might also apply to those who consumed and benefited most from growth.[19] Historians Christophe Bonneuil and Jean-Baptiste Fressoz catalogue these terms and add others: 'Thermocene' with its focus on energy, 'Phagocene's' highlighting of overconsumption, 'Phronocene's' metabolic reworking, 'Agnotocene's' focus on the production of 'zones of ignorance', and the contentious history of 'development' captured by 'Polemocene' (Bonneuil and Fressoz 2015). The list could also include 'Plantationocene' and the obscure 'Chthulucene'.[20] Necessarily, each term defines the scales of time and space, and highlights particular agents of the problem; sometimes they reveal new stories and sometimes they reinscribe older histories in new terms.

Scientists have been less inventive in coining new terms, but have argued vigorously about scale, wanting a clear definition of the Anthropocene. Taking the lead in this regard is geologist Jan Zalasiewicz who has argued for the acceptance by geostratigraphers of the 'Anthropocene' as a formally recognized geological epoch beginning in 1945 with the atomic bombs when a measurable global strata of irradiated particles was formed (Zalasiewicz et al., 2010). However, given the complexity of the four-stage approval process of any new geological term, Zalasiewicz and his colleagues have also supported the informal use of the term by scientists and others, arguing again for the 1945 date and pointing to other unofficial, but widely used, geological terms such as 'Precambrian' (Zalasiewicz et al. 2014). In contrast to Zalasiewicz, palaeoclimatologist William F. Ruddiman and his collaborators take

19 For 'capitalocene' see Malm and Hornberg (2014) and Moore (2015); for 'econocene', see Norgaard (2013: 2); for 'Carbocene' and 'Thanatocene' see LeCain (2015: 23); for 'Manthropocene' see Revkin (2014) and Raworth (2014).

20 Harroway (2015).

the long view. Ruddiman has also proposed using the term informally but with a small 'a', although in his view it should designate the transformation of the earth due to the human activities beginning with human-caused extinction of 'about 65% of the genera of large mammals' between 50,000 and 12,500 BP and then with the Neolithic agricultural revolution beginning about 11,600 years ago which started to push up atmospheric carbon 7,000 BP and methane about 5,000 years ago (Ruddiman et al. 2015: 38). Other scientists have suggested that a large-scale concept of the Anthropocene be made official, treating 'the Anthropocene and the Holocene as a single geologic time span' (Certini and Scalenghe 2015: 246).

Historians in general have been reluctant to push the starting date this far into the deep past in part because of the disciplinary commitment to textual sources. But, as Kenneth Pomeranz has suggested, historians might well be comfortable with the idea that the Anthropocene begins earlier in some places than in the others such as China, an approach that has 'a kind of fuzziness that geologists don't like, but historians live by' (Pomeranz 2014). Each concept surveyed above provides not only a description of our predicament and when and how it arose but also an implicit evaluation of the course of action necessary to protect what we cherish. Definitions are about the future as well as the past. The problems of scale, in other words, are not only central to the question of how best to conceptualize the Anthropocene and think about its causes, but also critical to the articulation of what might be done in response to planetary environmental changes.

Three eco-economic scales

Looking at the studies in this volume, it is possible to discern three eco-economic configurations of time, space and agency. Each coordinates different scales in different ways. The purpose of looking at these models is heuristic, useful not only for understanding the past but also for bringing these essays to bear on contemporary issues as I will do in the third and final section of this chapter. My shorthand notation for these three eco-economic configurations is to call them 'double-layered', 'parallel' and 'intersecting'. As I will suggest below, our essays largely overturn the double-layered model; they augment the idea of parallel yet different modes of development, and they give us cause for alarm in portraying the intractable difficulties that arise as multiple scales intersect in today's interconnected and fragile world.

The double-layered world

Of these three eco-economic models, the most familiar is double layered. On top are the planetary-scale processes of modernization obscuring 'traditional' practices beneath. This top layer, long visible in the disciplines of history and economics, is the scale of the powerful: empire builders and capitalists, scientists and engineers, intellectuals and revolutionaries astride the globe. In older histories, this top layer was represented by 'the West' and its crescendo of world domination in the nineteenth century. More recently, modernizers in other parts of the world have embraced global, homogenizing practices. The champions of nuclear power in South Korea, discussed by Se Young Jang, exemplify the type. These people and their actions hold pride of place in historical and economic analyses which privilege ideas and actions purporting to transcend natural constraints. Underneath this scale are 'natural' histories and economies tied to, in Tirthankar Roy's apt phrase, 'geographical specificities'. Although previously overlooked, these local activities have become central to environmental history and ecological economics precisely because they are enmeshed in tighter ecological feedback loops. This localized layer, as Roy and others argue, needs to be rescued from a double dismissal – on the one hand scorn, on the other piety.

First, scorn. The postcolonial turn of the past few decades has largely succeeded in transforming Western scorn for 'backward' cultures, but as this volume demonstrates, there is still much to be learned about the environment from 'undeveloped' places and peoples once mocked as unindustrious and irrational. Although the globalization of Western mega-practices has brought some benefits, it has also brought new problems. Global health initiatives and disease eradication lengthened human life spans, the Green Revolution increased agricultural productivity and more people have access to electricity, but these big initiatives have not been as uniformly successful as their advocates hoped nor as unproblematic. The result of healthier human populations has been an unprecedented rise in rates of population growth and raw numbers: 1.5 billion people inhabited the earth around 1900, 3 billion in the 1960s and more than 7.4 billion today. As Roy notes, human 'population growth was bad for the environment' in northern India.[21] Nor is the attainment of longer life spans assured, given the pressures that having more people puts on the environment. Life expectancy even in the United States now shows signs of declining (Olshansky 2012).[22] The Green Revolution also is not a uniform success. It failed to produce results in Africa where, as Austin points out, it 'is generally considered to have been a non-event' (this book, p. 107). Places such as South Asia where the Green Revolution succeeded for several decades are now discovering that methods of farming using chemical pesticides and fertilizers also make unsustainable demands on water supplies. As farmers pay for deeper and deeper wells, they find themselves ever more in debt. Alan Weisman reports that '270,000 Indian farmers have committed suicide' since 1995, and that 'ingesting pesticide is the symbolic death of choice' (Weisman 2013: 336). According to the United Nations Food and Agriculture Organization, about 805 million people, or one in nine of the world's population, were still suffering from chronic undernourishment in 2012–14. And, sadly, the problems with carbon-based energy production and

[21] Tirthankar Roy, p. 172, this volume referring to the work of Richards, Hagen and Haynes.

[22] Fraser (2015) points to evidence showing that American working-class life expectancy is declining. The Rockefeller Foundation-*Lancet* Commission on Planetary Health, 'Safeguarding Human Health in the Anthropocene Epoch', *The Lancet* published online 16 July 2015. It argues that 'we have been mortgaging the health of future generations to realise economic and development gains in the present. By unsustainably exploiting nature's resources, human civilization has flourished but now risks substantial health effects from the degradation of nature's life support systems in the future' (1).

nuclear power are now too obvious to require description. In short, the mega-level of global markets, big data and technological fixes (as with nitrogen fixing and petroleum-based fertilizers) has brought suffering along with alleviation (Gorman 2013). As the essays in this volume show repeatedly, under many circumstances, local responsiveness to environmental and social factors is more productive and more sustainable than the purportedly 'global' solutions.

That said, it is also important not to fall into the Romantic piety that lauds the premodern, non-Western world as a sustainable Eden. Viewing the non-West as happy 'lands without history' perduring in changeless harmony with nature is as misplaced as scorn. As Roy points out, there was no 'precolonial equilibrium' existing in India before the coming of the West (this book, p. 172).[23] Peter Boomgaard destabilizes a similar Edenic narrative in Southeast Asia. Studies of large-scale deforestation imply that before the 1950s and 1960s people in Myanmar, Malaysia, Thailand, Cambodia, Laos, Vietnam, the Philippines and Indonesia had little impact on the jungles in which they lived. However, as Boomgaard shows, the reason for the survival of forests was not a reluctance of local inhabitants to take advantage of nearby resources. Instead, they exploited their forests but also created techniques for regenerative forestry long before commercial Western interests invaded these areas. While in some ways it may now seem obvious that Asia and Africa had ecological and economic histories, even before imperialism, there is much intellectual labour to be done to overturn the obdurate double-layered view where nationalism, imperialism, capitalism and global projects are visible, while local specificities vanish.

Several of the contributors to this volume are particularly effective in exposing the fallacies of the double-layered world view. For instance, in 'Developing the Rain Forest', Corey Ross provides an elegant exposé of the clash between the modernizers functioning on the global scale visible to old-style history and economics and those small farmers submerged from sight in Southeast Asia. These two groups, as Ross rightly points out, can also be distinguished as those in the 'driving seat' of the Anthropocene and those who until the Great Acceleration sat in the back. Corporate rubber barons and their imperialist allies felt that they bore the burden of history on their shoulders as they marched into Southeast Asia, particularly Malaysia, Indonesia and later Thailand. Planting their rubber trees in orderly lines and rationalizing production seemed to them axiomatically better. To their way of thinking, greater abstraction must surely lead to greater extraction. The 'dynamic export-oriented European sector' would, they assumed, out-perform indigenous village production. Rubber, however, oozes from trees best nurtured in complex ecosystems rather than straight lines. There is nothing particularly abstract about either latex or its natural source. As Ross explains, when smallholders' rubber trees produced more rubber and were less susceptible to disease, the colonial planters were at first disbelieving and then dumbfounded. From their perspective, it was astounding that the people supposed to be without history, incapable as economic actors and aesthetically offensive in not caring for tidy symmetry when planting or tending their crops were able to extract

[23] See also Guha (2006).

more from their natural environment. As Ross shows, 'the proportion of rubber grown on smallholdings steadily over the first half of the twentieth century, and eventually matched or outstripped estate production in the leading export countries of Malaysia, Indonesia, and later Thailand' (above, p. 205). In contrast to doctrinaire modernist thinking, small-scale eco-economies messily embedded in their ecological webs were better suited to the goal of rubber production.

Stories of the often greater success of small-scale, flexible engagements within the immediate environment can be found all over the world. In Africa as in Southeast Asia, Europeans disdained the methods of small farmers. For instance, African farmers were blamed for the poor quality of the soil and, as Austin shows, modern Western methods were assumed to be superior: 'European planters in early-twentieth-century Ghana were confident that their neat, relatively capital- and labour-intensive forms of production were superior to the land-extensive methods of their African rivals' (above, p. 97). The same was true in Kenya in the 1930s. However, the small-scale African farmers triumphed through their ingenious methods such as inter-cropping and controlling capsid infestations in cocoa farms by allowing weeds to grow around the trees for three years. Like their Southeast Asian counterparts, they had learned how to manipulate their environments even though their methods looked inefficient to the newcomers in their midst. As Austin argues, the main source of increased productivity in Africa was not the intensification of labour and capital per unit of land but extensive agriculture and particularly the selective importation of exotic crops such as maize arriving from the Americas.[24] Likewise, Emily Osborn's previous research demonstrates that local agents often have the knowledge and versatility to respond to the resources and needs of their communities in ways invisible to neoclassical economics. Today the handicraft manufacture of aluminium utensils recycles materials and creates useful objects through webs of information, social capital and trade that exist below the global information pathways and manufacturing processes of capitalism (Osborn 2009).

The double-layered eco-economic model which depicts global modernity overwhelming local, traditional practices fails in two ways. First, the division between 'modern' and 'traditional' does not adequately capture developments in the non-West since neither products such as rubber and aluminium utensils nor processes such as rational reforestation fall neatly into these categories. More importantly for the economic and environmental histories of the Anthropocene, the double-layered model fails to direct attention to the fact that some of the most successful inventions arose from below, from those attuned to local environments and social circumstances rather than those attuned to the needs of global markets. Unfortunately, as Austin points out, governments today remain too easily seduced by large-scale investors and big projects while sustainable, sufficient economic production providing decent livelihoods requires investment in small-scale agriculture and in small-scale manufacture as well.

[24] For an enthralling account of the history of corn, see McCann (2005a,b).

Parallel worlds

A second way of thinking of eco-economic scales is to suggest parallel developmental strategies with strongholds in different regions. Instead of one modern planetary scale of development coming into contact with 'backward' micro-scalar activities and overcoming them for better or worse, another way of conceiving of the history of economies and environments is to recognize several viable, co-existing models emerging at the same time. As recent research has indicated, non-Western countries were more vibrant before the overwhelming force of nineteenth-century European conquest than is often assumed, and this vibrancy manifests itself to this day. One of the great contributions of the essays in this volume is showcasing these parallel modernities. The three major distinctions between the modernities of the West and the non-West might be summed up as follows: in contrast to Europe's *capital-intensive* development, there is East Asia's *labour-intensive* development; as opposed to the *land-intensive* regimes in Europe and parts of Asia, there is Africa's *land-extensive* agriculture; against the *high-energy use* regimes of leading capitalist and communist states (especially the United States and USSR) stands the *energy efficiency* of Japan, South Korea and Taiwan. Understanding that there are several pathways to developing healthy, secure human societies provides more options as we consider plausible responses to the Anthropocene. As Kenneth Pomeranz points out (above, p. 272), 'Kaoru Sugihara has made a vitally important argument to the effect that an East Asian development path, which has been less resource-intensive than those of most North Atlantic countries, offers more hope for sustainable development than any Western model. Data from Japan, Taiwan, and South Korea … gives that hope plausibility'.[25] We will learn more if we can thoroughly rid ourselves of the double-layered view that assumes Western industrial modernity – capital intensive, land intensive and high energy use – is the *only* possible pathway to well-being. Alternative models of development consonant with the ever-more stringent constraints of ecological survivability in the post-war 'Great Acceleration' may be discoverable in Africa, East Asia, South Asia and Southeast Asia.[26] While Marx's concept of uneven development as a necessary aspect of capitalism is useful, it is not adequate to capturing these independent, alternative modernities.

Kenneth Pomeranz and Kaoru Sugihara have been among those substantiating the view that the divergence of East Asian from the Western economies was later (as late as the 1830s) and less dramatic than previously thought.[27] Their concern for the environmental components of this divergence sets them apart from those who focus on financial instruments such as Jean-Laurent Rosenthal and R. Bin Wong and those concerned with the size and nature of government such as Peer Vries who argues that Britain did not overwhelm the world due to laissez-faire economics and small government, but in fact had more government intervention in the economy and a larger bureaucracy than China (Rosenthal and Wong 2011; Vries 2015). But even

[25] For the general model, see Sugihara 2003, 2013.
[26] The concept of 'The Great Acceleration' was introduced in Steffen, Crutzen and McNeill (2007).
[27] For the 'great divergence' thesis, see Pomeranz (2000).

given the convergence of Pomeranz and Sugihara's thinking in many respects, the story in East Asia is complicated. Pomeranz, for example, sees 'reasons to doubt the applicability of the "East Asian" model to much of China', especially the vast areas of western China.

The concept of an East Asian pathway also suggests the importance of cultural, political and social continuities. In other words, different modernities arose from different pre-modernities. The predilection for labour- and resource-conserving processes analysed by Satoru Kobori in modern Japan's industrial sector can be traced back to pre-modern Japan. As Kobori argues, beginning in the 1900s after the industrial revolution, local authorities in Japan led the way on issues of energy conservation and smoke abatement. Pitching new energy-saving techniques as cost-saving measures made them especially attractive to industrialists in the 1920s since Japan was no longer self-sufficient in coal and prices had risen. By the time of the 'oil shocks' of the 1970s, Japan was poised to make further improvements in energy efficiency in manufacturing, becoming by 1990 the world leader in this area. These successes were due, as Kobori argues, to local leadership along with market and resource constraints. This type of cooperation between government and industry has a long history in Japan, going back before the armed intrusion of the U.S. in 1853. Samurai leaders in domains such as Satsuma invested in technical expertise and basic natural science.[28] Frugality, too, has a deep history in Japan. Peasants and townspeople in Tokugawa Japan (1600–1868) were attuned to maximizing the efficient use of limited resources even when it entailed greater human labour (see, for instance, Hanley 1999). These historical patterns as well as market dictates and resource constraints combine to produce different developmental pathways in different parts of the world.

The cultural, political and social components of local ecological and economic patterns are revealed by other authors as well. Although ecological factors may have favoured land-extensive exploitation of resources in many areas of Africa (although not in all, as Mats Widgren makes clear), societies could change their agricultural methods if faced with dire circumstances. In Guinea Bissau, as Walter Hawthorne has shown, the desire to escape slavery warranted a heavy investment of labour in land-intensive farming methods such as building dykes for paddy rice, since such efforts meant that communities could move to safer areas (Hawthorne 2003). Similarly, Prasannan Parthasarathi in previous work has shown that in the context of India, precolonial social networks responded more effectively to famine than did the British under whose watch great numbers of people died. Parthasarathi's research overturns the implicit assumption that, for all its faults, the modernization of India created, in the long run, a better life for working people in terms of wages and food security (Parthasarathi 1998, 2011; see also the response by Broadberry and Gupta 2006). Looking at such regional pathways as equally viable modern alternatives undercuts the inevitability of a single global road to well-being and moderates the impulse to adopt single, large-scale projects to combat environmental problems.

[28] See Marcon's work on *honzōgaku* in Tokugawa Japan (2015). There is, I have argued, parallel but different development in Japan and Western Europe that ultimately converges: see Thomas (2014b).

Intersecting scales

The third configuration of eco-economic scales takes seriously the multidimensionality of factors at play in any situation. Especially since the 'Great Acceleration' of growth both of the human population and of its exploitation of natural resources since the Second World War, success by one measure may bring failure by another as many time frames, spatial scales and different kinds of agents collide within narrowing ecological margins of error. For instance, in the 1950s, the process of oxygen steelmaking conserved energy but 'actually worsened air pollution' when it was used by Fuji Iron Works, as Kobori shows. Fixing one problem exacerbated the other. Nuclear power provides an even more dramatic example. Amartya Sen recently noted that 'there are at least five different kinds of externalities that add significantly to the social costs of nuclear power' (Sen 2014: 4). Since these costs cannot be measured by markets or conventional cost-benefit analyses and are spread out across time (e.g. the half-life of uranium) and space (e.g. places halfway across the world where nuclear waste is stored), Sen argues that probability estimates should be used when considering the impact of nuclear energy: 'Even with the tiny probabilities of each of these dangers, the sum of the five, multiplied by the growing number of nuclear enterprises, tends to produce sizable overall probabilities. Estimates of probable harm (from terrible to catastrophic) could be gigantic' (2014: 4). The need to develop a normative framework that accounts for all these dimensions is crucial. As Sen concludes, 'Environmental thinking has to be multi-directional rather than single-focused, even if the focus is something as important as the climatic threats from carbon emissions' (2014: 12).

There is perhaps no better place for demonstrating the difficulty of meeting all the necessary goals including emissions reduction, species protection, human well-being and environmental sustainability than China. China, undoubtedly, looms over all discussions of ecological development; solutions found there are solutions for us all. But, as Kenneth Pomeranz makes vividly clear, solving one enormous problem, limiting energy emissions, may make another enormous problem, the shortage of water, even worse. Already, people in China are thirsty. As Pomeranz points out,

> Surface and near-surface water per capita in China today is roughly one-quarter of the global average ; worse yet, it is distributed very unevenly. China's north and northwest, with almost 30 per cent of the national population and over half the country's arable land, have about 7 per cent of its surface water; thus their per capita surface water resources are 20–25 per cent of the average for China as a whole, or 5–6 per cent of the global average (this book, p. 279)

To solve this problem, some good might be done at the local level by reducing outright waste by fixing leaky pipes. However, even fixing all the leaky pipes, and using water more efficiently would not provide enough water to meet China's growing needs. However, large-scale measures to find and distribute more water would raise energy emissions. Proposed mega-engineering projects include treating waste water, desalinization and the gigantic south-north diversion which would entail pumping water across thousands of miles. These efforts all require vast amounts of energy. In short, knotty and intractable tensions exist between global sustainability that requires China to curb its carbon emissions output and regional sustainability that requires providing water for agriculture, industry and human consumption. Pomeranz highlights these tensions between scales: 'In that local sense, then, water may be the key "sustainability" issue in China. But if we are more concerned with *global* sustainability, energy and climate are still probably the ball to keep one's eye on'. While Amartya Sen argues that 'our scientific priorities as well as our ethical commitments demand more – and multi-dimensional – engagement' (2014: 11) and Parthasarathi suggests that 'the true path forward is new technologies' that are not carbon based, Pomeranz paints a bleaker picture. His research indicates that even the most nuanced probabilistic reasoning may have difficulty producing Sen's 'positive possibilities' and that the time available for introducing alternative technologies is narrowing dramatically as the Anthropocene accelerates.

In other words, the news is not good. Our evidence shows, particularly where the essays focus on contemporary problems, that our room to manoeuvre is narrowing. These natural constraints raise intellectual red flags since, as I argued above, both history and economics were committed by disciplinary imperatives to tracing our ability to overcome such constraints. Once such constraints are reintroduced as absolute and perhaps ultimately intractable, hackles rise. Austin acknowledges this difficulty, pointing out, 'In recent decades there has been a general scepticism about environmental determinism. In African studies, mention of the latter still tends to evoke memories of a semi-racist literature from the colonial era' (above, p. 96). The same is true in Asia. Nevertheless, the biological and geophysical foundations of human well-being are not infinitely available nor infinitely malleable. Fresh water, for instance, though renewable, is finite. As the director of the Global Water Policy Project, Sandra Postel, notes,

> The quantity available today is virtually the same as when civilizations first arose thousands of years ago. As world population grows, the volume of water available per person decreases; thus, between 1950 and 2009, as world population climbed from 2.5 billion to 6.8 billion, the global renewable water supply per person declined by 63 percent. If, as projected, world population climbs to 8 billion by 2025, the water supply per person will drop an additional 15 percent. (Postel 2010: 80)

Pomeranz's picture of China's dilemma applies to the world. We may not be rigidly determined, but we are decidedly constrained. The disciplines of history and economics will be most helpful when they account for this conundrum.

The Anthropocene eco-modernism

'Anthropocene' seems to me a term of just rebuke, naming ourselves as the culprits in transforming the biosphere and geosphere, but some complain that the word appears to proclaim a victor. Environmental historian Timothy LeCain argues that the term implies an 'overestimation of human power and agency' and worries that 'if humans are truly powerful enough to justify naming an entirely new geological period for them, then it is difficult to argue against the proposition that they might, at least in theory, be capable of using that same power to engineer a Good Anthropocene' (LeCain 2015: 1 and 8). Given the planetary havoc, I would suggest that *underestimating* our power to destroy the sources of our own well-being seems a greater danger, but LeCain (and Clive Hamilton as well) is right to warn about the hubris of earth mastery when it comes to groups like the ecomodernists (Hamilton 2014; see also Kintisch 2010). I will end with a brief discussion of them because the essays in this volume speak quite directly to their recently reiterated position.[29]

This group of, primarily, social scientists led by Breakthrough Institute co-founders, Michael Shellenberger and Ted Nordhaus, accept the term 'Anthropocene' and recognize our 'serious toll on natural, non-human environments' but their solution absolves us from having to question our previous approaches. Indeed, they celebrate more of the same. Much as did historians and economists in the late nineteenth century, they seek to 'decouple' humanity from nature through resource-efficient technology and intensification; once human beings and nature are separated from each other, both will flourish. The power of human ingenuity, they claim, can surmount all limits to growth and set us on course for a 'good, or even great, Anthropocene'. More concretely, the *Ecomodernist Manifesto* proposes that 'urbanization, aquaculture, agricultural intensification, nuclear power, and desalination are all processes with a demonstrated potential to reduce human demands on the environment, allowing more room for non-human species' (Asafu-Adjaye et al. 2015: 18). The primary obstacle in the ecomodernists' view is environmentalists, whom they first attacked in 2004, stating, 'We believe that the environmental movement's foundational concepts, its method for framing legislative proposals, and *its very institutions* are outmoded. Today environmentalism is just another special interest' (Shellenberger and Nordhaus 2004: 20). The politics of this approach, say Shellenberger and Nordhaus in *Breakthrough*, is 'postenvironmental, not environmental, and postmaterial, not material' (Shellenberger and Nordhaus 2007: 160). They end their book with the prediction that 'this world, too, [the world of the Anthropocene] we shall overcome' (Shellenberger and Nordhaus 2007: 273).

In light of the essays in this volume, it is difficult to see much evidence that the ecomodernist approach can succeed. Their predilection for large-scale engineering reasserts the double-layered eco-economic model, while the essays here repeatedly demonstrate that projects that ignore geographical specificities and local ecologies fail. The ecomodernist attack on 'low-yield farming' and their claim that 'agricultural intensification' will feed the world's swelling population (Asafu-Adjaye et al. 2015:

[29] Shellenberg and Nordhaus first released 'The Death of Environmentalism: Global Warming Politics in a Post-Environmental World' online at www.thebreakthrough.org in 2004. A second online pronouncement by the group, Asafu-Adjaye et al. 'An Ecomodernist Manifesto' appeared in April 2015 at www.ecomodernism.org. Breakthrough Institute members include Brand (2009, 2010) and Mark Lynas (2011, 2014). For media endorsement of their views, see for instance, Visscher (2015a,b). Others outside the Breakthrough Institute community share their beliefs. See, for instance, Kahn (2010).

18) is undermined by the research here showing that such techniques have not been universally successful and that, even where they were successful, these techniques such as GMO crops make demands on soil nutrients and water tables that are unsustainable. The ecomodernist proposals for dramatic increases in nuclear energy and desalinization do not seem to account for 'externalities' such as nuclear waste and heightened emissions that emerge once such techniques are understood in their full ecological and social contexts. Moreover, regional variations are not only ecological but also cultural, political and social and require historical understanding as well as engineering 'fixes'. Indeed, the ecomodernist vision, rather than being a breakthrough paradigm shift, is best understood as a reversion to old-style approaches in history and economics where human beings were thought capable of transcending nature. It was precisely this decoupling of humanity from nature that enabled us to be so blind for so long to our capacities to undermine the sources of our own well-being; reverting to it is unlikely to produce better results the second time around.

My purposes in this chapter have been threefold. First, I have highlighted the foundational blindness of the modern disciplines of history and economics to nature, a blindness that caused them to devalue activities responding to ecological cycles in favour of activities transcending natural constraints. For a century, between approximately 1870 and 1970, these disciplines staggered on, suffering from self-inflicted sightlessness like King Lear upon the moor. Because of this blindness, these fields of study bear part of the blame for encouraging the anthropogenic forces changing our planet. Second, I have argued that the research in this volume reveals three ways of challenging the modernist paradigm of progress: overturning the double-layered approach that had celebrated large-scale global development; showing parallel yet distinctive modes of development; and, finally, revealing the sometimes intractable difficulties that emerge once we recognize the multiple, intersecting dimensions of our planetary dilemma. These three different eco-economic scales suggest the poverty of our older theories of growth and narratives of progress. My third point is that we are irrepressibly, wonderfully, unalterably physical creatures in a material world. Ecomodernism, just like the original forms of modernism, wants desperately to deny this. But, powerful though we are, we cannot change this basic fact and must govern ourselves accordingly. Part of that reformed self-governance will come through the reconfiguration of the disciplines of history and economics.

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