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Human-Nature Interactions

Exploring Nature's Values Across Landscapes

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Preface

Understanding the multiple relationships between people and nature across the world is becoming increasingly important in the view of significant socio-ecological challenges such as global biodiversity loss and climate change. The way people conceptualize, assess, and value human-nature interactions, however, largely results from diverse disciplinary, theoretical, socio-cultural, and political contexts. In recognition of these different worldviews and conceptual approaches, this volume aims to be a guiding element to understand better the processes and relationships behind human-nature interactions and to provide practical examples of how these interactions can be assessed across different land systems in Europe and beyond.

The present book is guided by the idea of promoting a comprehensive understanding of socio-ecological systems (SES), including both conceptual contributions and 26 case studies from around the world along a mountain-to-sea gradient, addressing fundamental questions of how to assess and value the environment. Part I aims at setting the theoretical background of how human-nature relationships can be addressed, highlighting similarities and differences between concepts and proposing integrative visions for assessing and valuing SES. Part II is dedicated to mountain landscapes, with a particular focus on the specific challenges of these regions, including processes of land degradation, touristic development, urbanization, and socio-cultural changes. Part III deals with the interactions and interdependencies between people and nature at the rural-urban interface. Suburban areas on the one hand provide the food and energy we need, and on the other hand, urban agglomerations are hotspots of ecosystem service demand and often also the primary source of environmental impacts. Finally, part IV focuses on coastal and marine landscapes where human-marine environment interactions are showcased, and where sensitive ecosystems increasingly get in conflict with human development, leading to ecosystem degradation and biodiversity loss, jeopardizing the provision of multiple nature contributions to people.

Human-Nature Interactions: Exploring Nature's Values Across Landscapes was inspired by a thematic session jointly organized by the editors at the 10th Ecosystem Services Partnership (ESP) World Conference 2019 in Hanover (21–25 October) and developed shortly afterwards in recognition of a lack of literature that systematically addresses the multiple relationships between human and nature along a mountain-to-sea gradient. We sincerely thank all the contributing authors for joining us on this journey and devoting their time for writing the chapters. We are also grateful to the many reviewers for their time and constructive comments which greatly improved the overall quality of the contributions. Finally, we want to express our gratitude to Eurac Research, University of Bergen, University of Bremen, and Lund University for their contributions in making this book open access. We hope this volume can be helpful and insightful for a wide range of readers, including prospective students, lecturers, and young professionals and scientists embarking on a journey to the field of SES research. Lastly, we hope the book can also contribute to widen the discussion on human-nature relationships and valuation and stimulate new perspectives that are needed to build a more sustainable and livable future.

Vilnius, Lithuania — Ieva Misiune
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Bolzano/Bozen, Italy — Lukas Egarter Vigl

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Editors and Contributors

About the Editors

Ieva Misiune is an assistant professor at the Institute of Geoscience, Department of Geography and Land management, Vilnius University, Lithuania. She is a researcher with an expertise in urban ecosystem services and social-ecological systems. Her research interests are related to the demand of ecosystem services, people's perceptions and habits in the use of urban green spaces. Over the course of her studies and work, Ieva conducted a number of internships (Belgium, the Netherlands, and the USA), participated in conferences, and published scientific publications as well as participated in national and international research projects related to the analysis of the social-ecological systems. Currently, she is developing her postdoctoral project on the quality assessment of urban public green spaces and is involved in an international project on citizen engagement in the planning and management of green infrastructure.

Daniel Depellegrin is a former research fellow at the University of Exeter (Renewable Energy Group, UK) and currently a researcher at the Landscape Analysis and Management Laboratory (Department of Geography) at the University of Girona (Spain). His line of research spins around marine socio-ecological studies, decision support science for maritime spatial planning, and ocean multi-use for blue growth. He is author of more than 30 scientific publications in the field of decision support instruments for ocean planning, cumulative effect assessment, maritime conflict-synergy analysis, ecosystem services assessment, and artificial intelligence–based geospatial modelling. Daniel has worked in various international project clusters in the Baltic Sea, Mediterranean Sea, and Atlantic Ocean, among others H2020, NATO – Science for Peace & Security Programme and ERDF-INTERREG. Daniel is currently a research and lecturing grant holder (*sum of intelligences*, UdG2021) at the University of Girona, addressing ocean resource-based sustainability challenges through decision support science in the western Mediterranean.

Lukas Egarter Vigl is a senior researcher at the Institute for Alpine Environment at Eurac Research (Italy) and a lecturer in environmental geomatics at the University of Innsbruck (Austria). In his research, Lukas explores why and how landscapes in mountains change in response to changes in management and climate, and what this means for human well-being and society at large. He answers these questions mainly using tools and concepts from ecology, geography, and agronomy, operating at multiple scales that range from the plot to the landscape level. Over the past 10 years, Lukas has been involved in a variety of international EU-funded projects at the human-nature interface, among them the AlpES project (on Alpine ecosystem services mapping), the LUIGI project (on green infrastructure and ecological connectivity), and the REBECKA project (on climate change and land suitability). Currently, he is leading a research group that aims at better understanding the complex interactions between people and nature and at developing practical solutions to better manage our environment.

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Part I
Conceptualizing Human-Nature Interactions

Chapter 1
Conceptualizing Human–Nature Interactions – An Overview

Lukas Egarter Vigl, Daniel Depellegrin, and Ieva Misiune

Significance Statement The threats posed by climate change and global biodiversity loss are increasingly seen as a major problem for the future of nature and humanity. Significant improvements in the understanding of how human and nature interact are thus required to address both challenges comprehensively. Over the past decade, different nature-based approaches, such as Ecosystem-based Adaptation (EbA), Green Infrastructure (GI), and Nature's Contributions to People (NCP), have enriched the scientific discourse and gained prominence in policy- and decision-making. However, the underlying concepts are vaguely defined, and their systematic uptake is hampered by a lack of clarity over the relationships and overlaps between different nature-based approaches. Here, we discuss recent advances in conceptualizing human–nature interactions with the aim of making these concepts more tangible and applicable for a broader audience.

Keywords Ecosystem-based adaptation · Green infrastructure · Nature's contributions to people · Nature-based solutions · Ecosystem services

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1 Introduction

We live in a time when there is an urgent need to respond to two interrelated global environmental challenges – climate change and biodiversity loss – which are both closely linked to human activities (IPBES, 2019; IPCC, 2021). This requires new ways of thinking about the multiple interdependencies between people and nature, and about how to address them simultaneously (Díaz et al., 2015).

Over the course of the last decade, within the broader field of socio-ecological research, new concepts aimed at addressing environmental challenges, as well as at improving the ecological and socio-economic balance and human well-being, have gained importance (IUCN, 2016). These concepts have been typically framed within socio-ecological systems and often rely on transdisciplinary approaches to bridge differences in perspectives and methodologies for addressing human–nature relationships (Ostrom, 2009). The scientific literature has gradually moved from narrow, reductionist viewpoints towards more comprehensive types of environmental questioning, valuing, and problem-solving (Pascual et al., 2017; Díaz et al., 2018). While such novel paradigms may open new ways to conceptualize human–nature interactions and may be useful to advance scientific ideas in general, they may also easily lead to uncertainties. This may raise questions about their “usefulness” and “representativeness” or about whether they are “complicating things”, especially within broader practitioner and stakeholder groups.

In this chapter we selected three concepts for review, namely Ecosystem-based Adaptation (EbA), Green Infrastructure (GI), and Nature’s Contribution to People (NCP). We believe these concepts have left a lasting mark on socio-ecological research over recent years and, thus, maybe of interest to a broad readership in approaching this field of study (IUCN, 2016; Díaz et al., 2018). They all have emerged relatively recently under the overarching framework of Nature-based Solutions (NbS) and are often closely interrelated and complementary. However, the three notions propose different views and emphasize distinct approaches to conceptualize human–nature interactions. The intent of this chapter is not to exhaustively discuss each concept in detail, but rather to provide a brief overview of recent advances in the field of socio-ecological research and of the different approaches upon which nature-based concepts are based and, thus, to contribute to making the interactions between humans and nature more tangible for a broader audience.

2 Nature-Based Solutions as the Overarching Framework

Nature-based Solutions play a central role in understanding the nexus between the natural environment, society, and human well-being, and they are often considered as an umbrella term for a broader set of ecosystem-based approaches (Welden et al., 2021). Nature-based Solutions were introduced in the early 2000s as an important step towards a paradigm change that saw people move from being beneficiaries of

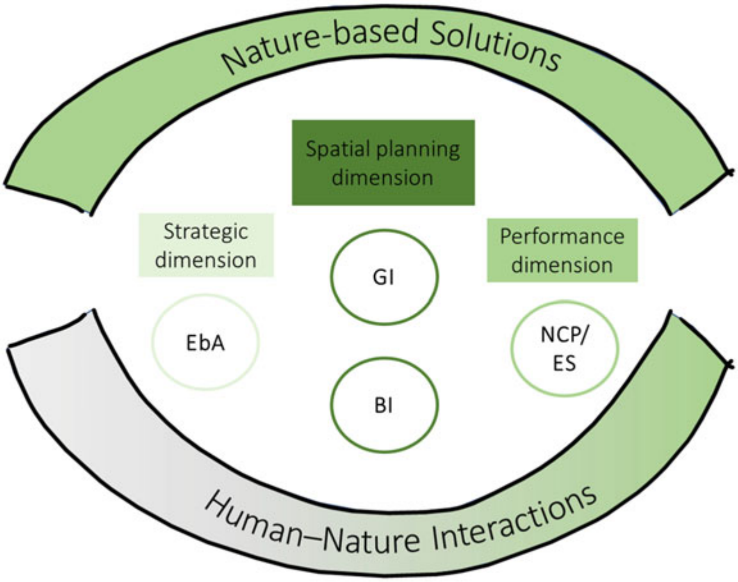

Fig. 1.1 The relationship between Nature-based Solutions and existing key concepts in addressing human–nature interactions. Abbreviations in the figure: *NBS* Nature-based Solutions. *EbA* Ecosystem-based Adaptation, *GI* Green Infrastructure, *BI* Blue Infrastructure, *ES* Ecosystem Services, *NCP* Nature's Contributions to People

nature to having a potentially active role in protecting, managing, and restoring ecosystems (IUCN, 2016). 'Working with nature' is increasingly seen as a promising way to address some important societal challenges, such as climate change and biodiversity loss, while also improving ecosystem resilience and providing multiple environmental benefits (Girardin et al., 2021). Recently, the concept of NbS has also gained a substantial amount of international support, mainly thanks to an active promotion campaign led by the European Union and its Research and Innovation Policy (i.e., through the H2020 program) and to the release of different thematic reports, such as those from the British Ecological Society and the International Union for Conservation of Nature and Natural Resources (IUCN, 2020; Stafford et al., 2021). Moreover, because of their inherently interdisciplinary and complementary nature, NbS also represent a flexible framework for working at the science–practice–policy interface because they cover the strategic, spatial planning, and performance dimensions of human–nature relationships (Fig. 1.1). Indeed, nature-based approaches are key elements for proactive climate change mitigation and adaptation actions that can be applied across scientific fields and innovation sectors. In the following sections we address one exemplar concept from each of these implementation dimensions, namely:

– EbA as a strategic concept.
– GI as a spatial planning concept.
– NCP as a performance concept.

2.1 Ecosystem-Based Adaptation

The first concept that we outline here is EbA. It was first introduced at the fourteenth session of the Conference of the Parties (COP) in 2008 as a new strategic approach for effective climate change adaptation planning. Since then, there have been various interpretations of EbA. Common to all of them is the rationale of helping nature to help people to adapt to the adverse effects of climate change (Pauleit et al., 2017). As such, EbA emphasizes the importance of ecological and natural solutions in strategically addressing societally relevant environmental challenges at the human–nature interface (Lo, 2016).

Since 2008, EbA measures have been implemented in many fields of study, mainly with the aim of reducing disaster risks and the overall vulnerability of communities in the context of a changing climate. For example, healthy ecosystems, such as intact mountain forests, can protect roads and other infrastructure from erosion and landslides, but they can also form physical barriers against extreme weather events such as heatwaves and storm surges, while simultaneously providing a variety of ecological co-benefits that are crucial for human well-being, such as clean water and raw materials (Munang et al., 2013). Hence, EbA are characterized by the proactive use of multiple benefits provided by biodiversity-rich ecosystems as part of a broader strategy that simultaneously addresses crucial sustainable development goals, climate change adaptation, and biodiversity targets (Pauleit et al., 2017).

Although the concept has gained increased international awareness and a significant number of positive examples of its implementation are readily available, many stakeholders still struggle to fully exploit the potential of available EbA options. This is largely due to a lack of transferable and user-friendly strategies as well as methods and instruments for mainstreaming the concept into key planning and decision-making processes. Hence, there is a need for more dialogue, knowledge products and context-specific case studies that provide guidance for advising stakeholders and policy-makers but also provide technical backstops that facilitate and guarantee the practical implementation of EbA measures.

2.2 Green Infrastructure

Since 2013, the European Commission has officially defined GI as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (European Commission, 2013). This definition is based on the idea of consciously integrating the protection and the enhancement of natural processes into spatial planning and territorial development. As a general concept, however, GI dates back to the 1990s when it was introduced to overcome the different rationales and interests in the scientific, policy, and planning communities dealing with urban environments (Hansen et al., 2021).

In fact, GI is particularly relevant for policy because it is action-oriented, tangible, and brings together the efforts of scientists and practitioners in demonstrating how healthy and multi-functional natural areas represent a winning setting for the simultaneous provision of ecological, economic, and social benefits. Moreover, GI provides valid alternatives to the widely used anthropogenic "grey" infrastructure that fulfils only one function at the time, such as drainage or shade. Natural solutions are often multifunctional, meaning that they are "able to perform several functions and provide several benefits on the same spatial area" (EEA, 2017). These functions may be environmental (e.g., conservation of biodiversity or adaptation to climate change), social (e.g., provision of green space or shade in summer), and economic (e.g., supply of jobs and development of business opportunities). For example, while a drainage pipe only transports rainwater, a swale also offers water quality treatment using natural processes, buffers peak flows, provides habitat, and makes the neighborhood more appealing. Likewise, a riverwalk can provide habitat for many species, regulate the speed of the river flow, and create space and opportunities for businesses, social activities, low-emission transport like cycling, and others.

As such, GI networks cover the spatial development dimension of human–nature interactions and can be woven into planning and policy processes at several spatial scales, from the neighborhood to the city and the broader landscape level. Hence, the GI concept can guide a shared understanding about how to manage nature in both urban and peri-urban settings, while still accounting for the complex processes that occur at the science–policy–practice interface.

2.3 Nature's Contributions to People

The concept of NCP was first coined by (Díaz et al., 2018) as part of the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services process to improve the interface between science and policy on issues related to biodiversity and ecosystem services. It is defined as all the contributions, both positive and negative, of living nature (i.e., diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. As such, it covers the performance dimension of working with nature by directly building upon the ecosystem services approach (Daily, 1997). However, it proposes a more inclusive view that also specifically accounts for the diversity of values and perspectives that may arise from indigenous stakeholder groups and local communities (Kadykalo et al., 2019). For example, in studies using the concept of ecosystem services alone there has been often a relatively narrow focus on provisioning (mainly food production) and/or supporting and regulating services (i.e. carbon sequestration or biodiversity-mediated services) and little emphasis on less-readily defined cultural services, such as those arising from a relationship with nature, that go beyond the pure benefits provided (Ellis et al., 2019). Over the last decade, this has led to lively debates within academia on the inclusiveness of the ecosystem services framework, which is mainly criticized for its focus on an instrumental/economic perspective of human–nature relationships (Díaz et al., 2015).

Although both the NCP and ecosystem services concepts are integrated with each other and are not mutually exclusive, the scientific community is still divided about which conceptual approach to use for a better engagement with stakeholders and local decision-makers (Kenter, 2018). From an operational perspective, both concepts have been successfully applied and tested in different contexts, regions, and settings (Chaplin-Kramer et al., 2019; Schirpke et al., 2019). Thus, the prioritization of one over the other should be context- and target-driven rather than purely dependent on a conceptual viewpoint (Peterson et al., 2018). In fact, cohesion in addressing societal challenges, such as climate change and biodiversity loss, will be essential to mobilize support for scientific activities and to secure the commitment of stakeholders, policymakers, and the wider community.

The performance dimension that both concepts cover is crucial in this context, because they provide the measurable indications (i.e., through indicator maps) needed to identify conservation intervention areas and, thus, actively guide implementation measures. Indeed, providing tangible information is essential for a comprehensive assessment, that includes social, economic, and ecological perspectives.

3 Integrating Concepts for More Comprehensive Environmental Problem-Solving

The strengths of the EbA, GI, and NCP concepts presented here lie in their interdisciplinarity and complementarity that facilitates their operationalization into policy- and decision-making processes. Although the terms and definitions are open to different interpretations, their broad thematic and spatial scope guarantees high flexibility and adaptability to the different needs of stakeholders across a variety of fields and sectors (Fig. 1.2).

All three concepts presented here are human-oriented, and the use/role of nature in its broadest sense is considered a valuable option to complement or even replace traditional mono-functional engineering approaches for the protection, management, and restoration of the environment (Pauleit et al., 2017). For example, EbA harnesses the capacity of nature to buffer human communities against disaster risks while also protecting biodiversity at local and regional levels. The approach embraces the concepts of NCP and GI that typically operate at higher spatial levels. In turn, GI is strategically aimed at enhancing the multifunctionality and regional connectivity of ecosystems through focused intervention measures at broader geographic scales, while NCP provides tools for the valuation and measurement of the

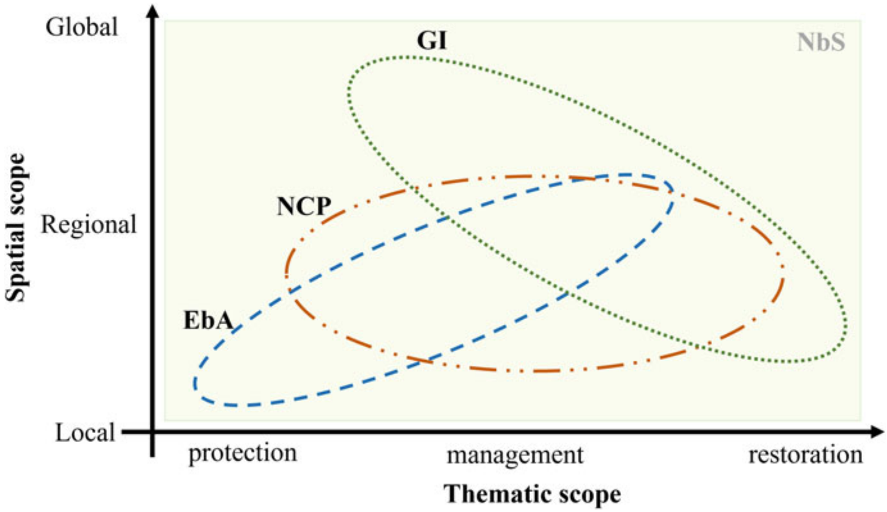

Fig. 1.2 Graphical representation of the thematic fields and scales of the concepts of Ecosystem-based Adaptation (EbA), Green Infrastructure (GI), and Nature's Contribution to People (NCP). Dashed and dotted lines indicate that the delineation of concepts within a particular sphere is not rigid and that there are also other ways to interpret and apply the concepts. The light green box refers to the umbrella concept of Nature-based Solutions (NbS)

direct and indirect benefits provided by healthy socio-ecological systems, contributing to sustainable land management and monitoring (Grêt-Regamey et al., 2021).

The diversity of academic and non-academic theories upon which the concepts presented here are based represent both strengths and weaknesses. Perhaps the main weaknesses, beside their somewhat vague definitions for the same or closely related topics, lie in how they include governance aspects, such as the active participation of public, private, and civil actors; the way in which they handle potential trade-offs between proposed conservation measures and scale of operationalization; and how they strike the balance between being conceptually and operationally sound. The strengths include the possibility to promote a transdisciplinary and comprehensive understanding of the human and nature paradigm that will to be certainly fundamental to face the urgent environmental challenges of our time (Soga & Gaston, 2021). For the future, there will be a need to further encourage the integration of nature-based concepts into environmental problem-solving by stakeholder and decision-makers, providing clear and consistent definitions, demonstrate synergies between concepts and openly communicate important knowledge gaps and limitations.

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Chapter 2
Environmental Values and Nature's Contributions to People: Towards Methodological Pluralism in Evaluation of Sustainable Ecosystem Services

William T. Borrie and Christopher A. Armatas

Significance Statement Given the diverse ways that people value nature and the lack of an all-encompassing methodology able to capture such diversity, we call for the acceptance of plural methodologies for the comprehensive and inclusive evaluation of nature. The chapter provides a primer of five different evaluation approaches of nature: (i) economic/instrumental, (ii) ecological/biophysical, (iii) ethical/intrinsic, (iv) social/shared, and (v) relational. While leveraging the strengths and weaknesses of different evaluation methods is challenging, we suggest that defining the different normative assumptions of each approach (for example, the purposes of evaluation, how values and preferences can be expressed, and the positionality for those who recognise and give voice to different values) will provide a robust foundation for communication and learning across disciplinary and practitioner boundaries.

Keywords Multiple values · Value monism · Ways of knowing · Epistemology

1 Introduction

> Promoting different conceptualizations of value and valuation approaches is more appropriate than a deeper focus on a subset of unidimensional values (e.g. economic, biophysical, social-cultural) (Pascual et al., 2017, p. 14).

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There are as many different values for nature as there are different people who value it. Given these diverse values, we suggest that reliance on a single, all-encompassing methodology is limiting and call for the acceptance of plural methodologies for the comprehensive and inclusive evaluation of nature. Methodological pluralism facilitates a more transparent and participatory approach to natural resource decision-making where definitions are explicit, stakeholders (both human and non-human) are acknowledged, and a shared understanding of nature's value is gained.

There has been an evolution in recent international efforts towards a more expansive assessment of values. The Millennium Ecosystem Assessment (MA), beginning in 2001, adopted an ecosystem services framework and, so, largely embraced a focus on economic or instrumental values (Alcamo & Bennett, 2003). However, criticism for failing to account for the complexities of ecological systems led towards TEEB (The Economics of Ecosystems and Biodiversity) and a goal of better integrating a broader range of environmental values (Carpenter et al., 2009). Most recently, the conceptual framework of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) now acknowledges the central and pervasive role that culture plays in defining environmental values (Díaz et al., 2018). As Rawluk et al. (2018) explain, "rather than attempting to expand ecosystem services to include culture, IPBES have adopted the much broader concept of NCP [Nature's Contributions to People] which incorporates instrumental, intrinsic and relational values and most importantly includes pluralistic valuation methods, including economic, ecological, social and cultural approaches" (p. 1197). That is, the IPBES recognizes that, "in many situations, when dealing with more complex services such as cultural services, . . . [economic assessment] may neither be appropriate nor necessary nor sufficient nor practical" (Díaz et al., 2015, p. 11).

We agree that a comprehensive understanding of how people value nature will require different methods, scientific traditions, and ways of knowing, but we also assert that communication and understanding across such disciplinary silos requires a shared understanding of the different valuation approaches. Even though different approaches to evaluating nature use different definitions, assumptions, and methodologies, we believe the different valuation approaches can work in complementary and mutually enriching ways that lead to more adaptable, responsive, and resilient outcomes.

In this brief chapter, we provide a primer on five approaches to evaluating nature (Table 2.1) that attempt the same fundamental task of identifying, ordering, and prioritizing what is most important in nature:

(i) economic/instrumental, (ii) ecological/biophysical, (iii) ethical/intrinsic, (iv) social/shared, and (v) relational. We then discuss the challenges of utilising all approaches within the context of broadly-defined environmental decision-making.

Table 2.1 Five approaches to evaluating nature

Value type	Definition	Example(s)
Economic/ instrumental	Utility that humans receive from nature, quantifed in discrete units.	Willingness to pay for a marginal improvement in an ecosystem service.
Ecological/ biophysical	Characteristics deemed priorities for the sustainability of natural systems.	Biodiversity, ecological integrity and resilience.
Ethical/ intrinsic	Value independent of perceived human benefits or services (nature for its own sake).	Allowing nature to flourish and exist according to its own interests and ends.
Social/ shared	Collectively shared goals, norms, expectations and traditions, including of means to achieve.	Social Well-being, fairness, equity, frugality, heritage and connection to place.
Relational	Preferences, principles and virtues about relationships between humans and nature.	Domination, care, kinship, sanctity, responsibility or restraint.

2 Economic/Instrumental Values

While the concept of value means different things in different disciplines, economists have spent perhaps as much time as any concerned with value. As Brown (1984) defines it, "a value is an enduring conception of the preferable which influences choice and action" (p. 232). Decisions about what deserves protection and which of nature's contributions to people are most important are reflective of underlying values. The focus of many environmental economist's work (and much of the work on *ecosystem services*) is on instrumental values: the benefits that humans receive from nature. Brown (1984) defines these as assigned values. For instance, a forest may have assigned value for, "specific purposes, such as educational value, recreational value, commercial value, and food value" (p. 234).

Economic approaches use price, or other discrete units such as the marginal rate of substitution between different ecosystem services, as a proxy for the assigned value of the benefits or ecosystem services received from nature. These units may be captured in the market place of buying and selling of goods and services, cost-benefit analyses (CBA), proxy measures such as contingent valuation/willingness to pay surveys, or economic choice modelling studies. However, Brown (1984) concludes, "There are problems with the use of market price, or other economic measures of value, as the sole measure of the value of communal resources" (p. 244). As Williams and Watson (2007) note, "not all values, benefits, goods or services should be ordered by means of market norms" (p. 127). It is said that economic analyses have failed to produced outcomes satisfactory to the public largely because they attempt to reduce all values to a single, monistic measure (Norton, 2017). Technical, all-encompassing economic evaluations are likely to be insufficient and inadequate in their consideration of non-instrumental values. Furthermore, economic evaluations can tend to subsume or colonise all other discussions, foreclosing full consideration of different, hard-to-measure values.

3 Ecological/Biophysical Values

Ecological values reflect a prioritizing of biological and geomorphological features. Ecological science indicates high priority goals such as the maintenance or restoration of:

- biodiversity (defined following the 1993 Covention on Biological Diversity (CBD) as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Mace et al., 2012, p. 19));
- threatened and endangered species;
- population extirpation rates;
- evolutionary distinctiveness;
- ecological structure, functioning, and resilience; and
- an all-encompassing biological integrity (Karr, 1999).

Ecosystem health, as a goal, is defined as "being 'stable and sustainable'; maintaining its organization and autonomy over time and its resilience to stress" (Rapport et al., 1998, p. 397). Similarly, ecological integrity emphasizes a goal of "preservation against nonspecific ecological risks that are general disturbances of the self-organizing capacity of ecological systems" (Burkhard et al., 2012, p. 18). It also calls for the maintenance of geophysical attributes such as water quality and quantity; nutrient cycling; energy flows & capture; metabolic efficiency; climate stability; and erosion control (Burkhard et al., 2012).

However, the basis for these normative visions of ecology is not often addressed (Abson et al., 2014). That is, the why (and by whom) these goals are deemed good, as well as the implications of pursuing these goals, is not commonly considered. There are few direct markets for these ecological values distinct from the ecosystem services they provide, although there are proxies and credits for the existence of biodiversity and individual species (Kontogianni et al., 2012). Additionally, the general public has little ability to assess and rank-order ecological values. Instead, biologists, ecologists, and other scientists have distinct methods of identifying ecological priorities such as biodiversity hotspots, critical or keystone species, or preferred ranges of ecological variability. Ecological scientists rely on increasingly complicated mathematical models, multi-faceted databases, internal criteria of validity and often advanced- and jargon-filled explanations of ecological health and functioning. The public is neither invited into these decision-making processes nor likely to wish to choose between different ecological priorities. While there are threads of phenological approaches (that prioritize location- and time-specific natural history), much ecological science seeks universal and generalizable principles. The intersection with traditional ecological knowledge (TEK) or indigenous and local knowledge (ILK) can be problematic. As Jacobs et al. (2018) suggest, "biological valuation methods are [the] least suitable to capture multiple values" (p. 518).

4 Ethical/Intrinsic Values

Intrinsic and symbolic values exist independent of perceived human benefits or services. That is, nature is valuable and important in, and of, itself. Just as there is a fundamental value or goodness in a child even if they do nothing useful, intrinsic value recognises that nature can be good for its own sake. Within intrinsic value there are different conceptions of value (Batavia & Nelson, 2017) ranging from non-anthropocentric (i.e., all non-human objects have value), biocentric (i.e., all living organisms possess intrinsic value), zoocentric (i.e., animals have intrinsic value), to ecocentric (i.e., ecological collectives such as populations, communities, and ecosystems hold intrinsic value).

The recognition of intrinsic value then suggests an altruistic response of respect, of allowing nature to flourish and exist according to its own interests and ends, and of moral obligations and responsibilities to act with fidelity to protect or actively promote nature's interests (Batavia et al., 2020). With intrinsic value, nature deserves to be admired, revered, and/or celebrated for what it is and to do so independent of how that makes one feel (which can be important and valuable, too). Intrinsic value is not mutually exclusive of instrumental value, as some thing can be valued for both. However, since intrinsic value is for what a thing is, above and beyond what it does, then it cannot be substituted by another object.

As intrinsic value is defined in contrast to utilitarian or instrumental values, it should not be measured with economic methods. While there is economic value recognised in existence, option, and bequest values, there are things (eg. kin, friends) for which asking for a dollar value seems wrong or inappropriate. As Batavia & Nelson (2017) suggest, the "wholesale commodification of non-human nature ... would be incommensurable with the genuine acknowledgement of nonhuman nature's intrinsic value" (p. 372).

While the articulation of environmental values is extensive within the work of environmental philosophy, the measurement of those ethical values is less so. The use of interpretive and qualitative methods can be most suitable and Gould et al. (2015) call for "open-ended, discursive data collection techniques" (p. 577) that may involve person-to-person interviews and/or the use of scenarios, vignettes, and situation-specific questions.

5 Social/Shared Values

Members of the public value *the way* that nature is managed. In addition to wanting particular benefits and services to flow from nature, there is an important value placed on *how* they are achieved. These values (such as fairness, equitable distribution of benefits, efficiency and a lack of wastefulness) are often modes of conduct or standards to which we strive to operate. They are often shared values or our basic ideals as a society. Brown (1984) defined these sorts of environmental values as <u>held</u>

values. He broadly categorizes them as *means values* (such as frugality, generosity, courage, responsibility, and fairness) and *ends values* (such as freedom, equality, beauty, and friendship).

Shared values, such as these, are socially constructed, reflecting collective norms and expectations as well as cultural traditions and practices. Norton (2005) describes these as community-identity values which are "developed and passed from generation to generation, creating cohesiveness within human communities but also binding individuals and communities to their natural habitat" (p. 371). Such values are shared by people in groups or inform the shared identities of particular groups (IPBES, n.d.). Many social values can't be distributed in increments, in that you either protect and value the shared goal or you don't. Thus, there typically isn't an economic market for the buying and selling of shared, social goods. A more community-centric perspective shifts our view of nature beyond the service-provision role or benefits of nature (Turner & Clifton, 2009).

Gould et al. (2015) define some social values as cultural ecosystem services – the cultural heritage, deep connections & attachments to place, sense of belonging and security, and collective well-being - that are seen as essential for human and social well-being. Such social values can be hard to quantify and some respondents resent being asked to take such a reductionist and commoditized approach to these deeply held values. Interestingly, Brown (1984) suggests, "value *arises from* a preference relationship between a subject and an object" (p. 233). That is,

> Value is neither a concept held by the subject nor something attributed to the object . . . value is not an intrinsic quality of anything – rather, it emerges from the interaction between a subject and an object. . . . value in the relational realm is not observable; it is only at the feeling level.

6 Relational Values

Similarly, in contrast to treating nature as an external object that can be valued for the benefits it delivers (instrumental value) or for its own sake (intrinsic value), relational values focus on how nature is to be treated and are defined as, "preferences, principles and virtues about human-nature relationships" (Chan et al., 2018, p. A1). For example, these relations might be ones of harmony, sanctity, or restraint. It is stressed that

> In social contexts of all kinds – including friendships, marriage, partnerships, parenting, extended family, community, and teams – many people naturally think of what is appropriate for that relationship, not only what benefits them, others or nature. . . . it may be treacherously reductionist, if not offensive, to suggest that nature exists to provide (instrumental) utility to humans. (Chan et al., 2016, p. 1463)

Instead, these authors urge consideration of many relational values as *eudaimonic values*, "notions of a good life rooted in relationships" (p. 1463). For example, interacting with nature connects one to the land, strengthens traditions and encourages contemplation, thus sustaining the relationship between human well-being and nature. It can be said that people belong to a place and must behave virtuously – with relational behavior such as reciprocity, care, custodianship, or stewardship of places celebrated as duties and responsibilities. These can be collective histories, perhaps perpetuating a particular culture of kinship and shared journey. Relational values are often locatable, tangible, place-based and both contextually-dependent and situationally-constructed (Rawluk et al., 2018). Their loss can be of great injustice and inequity, perhaps reflective of larger hegemonic or imperial power and status. Tadaki et al. (2017), therefore, emphasise methodologies such as deliberative workshops, public participation GIS, participatory action research (PAR), and other qualitative approaches "as 'technologies of participation' [that] can highlight normative concerns about equity and power in environmental decision-making" (p. 7).

7 Plural Valuation: A Great Challenge But Pressing Need

The challenge of incorporating socio-cultural, relational, intrinsic, ecological and monetary valuation into decision-making has proven quite intractable, for several reasons. As Chan and Satterfield (2020, p. 1030) point out, even with an increase in non-economic assessments of environmental value, from both the broad social sciences and humanities, there is still a general belief that research will be most effective if it can "distil the value of nature into a number" (p. 1030). However, since no single method that can capture all values, the decision as to how to measure values is a normative one (Lliso et al., 2020). By acknowledging and amplifying particular values, different methods not only elicit already-existing values but also bring new values into discussions and deliberations. In effect, the values take on greater standing as a result of their evaluation (Arias-Arévalo et al., 2018). And while some values need to be socially constructed in this way, they resist accumulation and aggregation (Wegner & Pascual, 2011). Indeed, the process of maximizing benefits, given costs, does not necessarily yield collective preferences and well-being.

Relational values, and many cultural values, do not sit easily within broad ecosystem services assessments and may not be substitutable nor replaceable. A memorial tree, for instance, represents more than the shade, habitat, and CO_2 capture that it provides and should be evaluated accordingly. Such a tree is not so much a stock of the benefits that flow from it but a unique and complex association of meanings and heritage. Separating the tree into separate benefits and contributions would not fully capture its significance. Maximizing benefits is further complicated by the fact that individuals and communities may hold seemingly conflicting views on the same resource and when values are deeply held and embedded in culture, the repudiation of such values is a denial of those who hold them. Qualitative and humanities approaches are often absent in ecological services assessments, leaving out insights from fields such as ethnography, cultural studies, phenomenology, human ecology, and human-environment geography (Abson et al., 2014; McDonough et al., 2017).

Valuation itself does not automatically lead to greater inclusivity, consensus, nor shared understanding. Just as the choice of evaluation method dictates outcomes of that evaluation (Jacobs et al., 2020), so, too, the expectations of the process of discussion and decision-making can determine outcomes. In particular, some values (and valuers) don't work well with others and may struggle to integrate with singular, perhaps hegemonic, approaches. Some values follow different expectations of epistemology (such as what is considered knowable, by whom, and for what purpose) and it may not be appropriate to measure and express particular values, perhaps because they are sacred or culturally significant. To point to an object may be rude or insulting, just as naming part of nature can change its status and make it more visible, accessible, and vulnerable. In sum, evaluation itself is not value-neutral and a shared, mutually acceptable approach or process that allows full and fair consideration of all values hasn't emerged.

If the purpose of valuation is to give voice to different values and to build collective awareness and acknowledgement, then the gaining of trust and legitimacy can be expected to take time and many resources. Indeed, leveraging the strengths and weaknesses of different evaluation methods is a monumental task, as it requires overcoming disciplinary boundaries (and associated practical components such as competition for funding), navigating inexperience with transdisciplinary research, as well as facilitation, process and leadership abilities well beyond specific disciplinary and bureaucratic expertise. However, some progress has been made with methods such as participatory rural appraisal, deliberative valuation, scenario and futures mapping, and narrative analyses, which all aim for iterative learning, knowledge co-construction, and enagement of the perspectives of different peoples.

In a call for greater transparency and acknowledgment of differences, a comprehensive mapping of the five different approaches to environmental values would, we suggest, define the normative assumptions of:

(a) what can be evaluated (i.e., what can be known and preferred),
(b) the particular purposes of evaluation (i.e., for what end goal or objective),
(c) how values and preferences can be expressed and documented (i.e., how, when, where, and by whom),
(d) the positionality for those who recognise and give voice to different values (i.e., in terms of access to the process, power, and status within society, as well as to available resources and funding), and.
(e) how prioritization of values is to be considered (i.e. choice of criteria such as efficiency, effectiveness, equity, precautionary principles, etc.).

Such a comprehensive mapping would expose commonalities, potential incommensurabilities (inabilities to consider data and outcomes across different methodologies), and identify strengths, weaknesses and specific insights of each approach.

8 Conclusion

Throughout our discussion, environmental values have been defined, examined and documented in different ways within different disciplines. While there may be some overlap between the five approaches discussed, there is not one, universal value foundation. Indeed, any single approach to valuation is too narrow to fully and fairly capture the whole range of worldviews, knowledge systems, and stakeholders (Kadykalo et al., 2019). Instead, there is need of a more pluralistic foundation, one that is less focused on arguments about definitions, conceptual distinctions, and all-encompassing frameworks and methodologies. Constructive consideration and deliberation of the broad diversity of environmental values will require acceptance of each of the five approaches and their tools and methods, as well as communication and learning about the different approaches across disciplinary and practitioner boundaries.

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Chapter 3
Disentangling Trade-Offs Between the State of Coastal Ecosystems with Human Well-Being and Activities as a Strategy Addressing Sustainable Tourism

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Significance Statement Coastal tourism is a major driver for the local and regional economy of many Mediterranean areas. At the same time, this industry generates threats that, added to those produced by other coastal human activities, substantially damage the coastal and marine environment. A damaged environment cannot provide many fundamental benefits for coastal tourism itself, such as for instance clear water, coastal protection and natural beauty. We propose a framework for unravelling the threats and benefits related to coastal tourism, and we present two lists of indicators of coastal tourism sustainability, to monitor the impact of coastal tourism on the natural environment (threat indicators), and to assess which threat mitigation measures can counteract it (enabling factor indicators).

Keywords Coastal tourism sustainability · Coastal tourism indicators · Coastal ecosystem services · Mediterranean coastal ecosystems

1 Introduction

Coastal tourism (CT) has been identified as one of the five priorities of the EU Blue Growth Strategy (EU Commission, 2017). In particular, the Mediterranean area attracts a higher number of tourists than any other destination in the world, as it can fully satisfy sea, sun and fun lovers providing as well a huge choice of cultural, historical and ancient attractions (Apostolopoulos et al., 2001; UNWTO, 2015). The continuous growth of the tourism sector exerts increasing pressures on the environmental resources of coastal zones, as the majority of its activities impacts substantially on the ecological integrity of coastal and marine ecosystems (Drius et al., 2019

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and literature therein), often depleting their functionality and capability of delivering fundamental Ecosystem Services (ES), i.e. the benefits people obtain from ecosystems. In addition, increasing tourism pressure adds to other human impacts (e.g. waste, pollution, water consumption, alien species introduction, habitats and biodiversity loss, overexploitation of marine resources, etc.), causing complex cumulative effects on the Mediterranean marine and coastal environment (Micheli et al., 2013).

The diversity of species, habitats and landscapes lies at the heart of many tourist attractions, therefore the protection of nature is a fundamental prerequisite for the sustainability of the tourism industry on the long term, which aims at maintaining the environmental, economic and socio-cultural spheres in balance. This concept is embedded in the sustainable tourism approach: "*tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities*" (UNEP/UNWTO, 2005). Sustainability indeed can be achieved mainly by: (i) making optimal use, protecting, and conserving environmental resources and biodiversity; (ii) respecting and conserving living cultural heritage and traditional values of host communities; and (iii) ensuring viable, long-term economic operations and fairly distributed socio-economic benefits to all stakeholders. Sustainable tourism aims also at meeting the needs of tourists, which include the beauty and the natural perceptions of recreational sites. In particular, these last are defined as part of ES, which therefore can be explicitly or implicitly used to evaluate the progress towards sustainable tourism (Böhnke-Henrichs et al., 2013; Wu, 2013). In particular, cultural services (the intangible benefits people obtain from their interactions with natural ecosystems including recreation, cognitive development and aesthetic experiences, that contribute to individual and collective human well-being), can help acknowledge the tourism–nature–well-being nexus in planning tourist destinations and their sustainability (Bachi et al., 2020; Willis, 2015). Moreover, as ES are strictly interdependent, the use of one may affect the provision of others, and the optimization of a single service might often negatively affect other services' supply (Böhnke-Henrichs et al., 2013; Rodríguez et al., 2006). However, conceptual frameworks unravelling connections among CT activities, pressures, impacts and ES are still lacking (Arkema et al., 2015; Papageorgiou, 2016).

Because of the increasing demands in the CT sector and consequently the increasing pressures exerted on the natural environment, there is urgent need of action addressing: (i) the definition of the main CT pressures and synergies with other existing human activities (HA); (ii) the characterization of relationships and trade-offs among tourism, other impacts, and benefits deriving from nature, and (iii) the measure of the level of sustainability in every destination together with the assessment of enabling factors (EF, e.g. threats mitigation measures) that can favour sustainable tourism.

In the context of the European INTERREG MED project Co-Evolve "Promoting the co-evolution of human activities and natural systems for the development of sustainable coastal and maritime tourism", we developed a conceptual framework useful for supporting decision makers and planners, which illustrate the complex relationships and trade-offs among CT typologies, their environmental impacts, the ES linked to tourism, and the other HA exerting cumulative effect on the Mediterranean coastal environments (Drius et al., 2019). This framework can be further implemented to better characterize threats and EF related to each type of CT. With the goal to further develop its potential application, in this paper, we (i) shortly examined the framework, further expanding it with the introduction of potential EF; (ii) reviewed the main available indicator systems for sustainable coastal tourism; and (iii) applied the framework approach to guide the development of new candidate environmental and socio-ecological indicators addressing tourism sustainability.

2 The Upgraded Co-Evolve Framework

The Co-Evolve conceptual framework disentangles complex relationships among CT, other HA and coastal ecosystem services (CES), through potential threats and benefit trajectories forming a loop of interconnections (Drius et al., 2019). It was conceived in the form of a cascade model, to connect the benefits arising from CES with their effects on human well-being, and to show how HA may negatively influence the CES capacity to deliver services, which are strictly linked to the development of sustainable CT. It also highlights the dual nature of tourism, both as an industry producing threats to the environment and as an activity that may reconnect human well-being to nature. Following this scheme, CES potentially produce benefits (positive flow) towards both CT and HA (e.g. by ensuring clean bathing water and supplying seafood), but on the contrary CT and HA can threaten CES delivery (e.g. water pollution and waste generated by CT, fish overexploitation produced by intensive fisheries and so on) negatively affecting benefit feedbacks to HA and CT. Moreover, CT and HA can threaten each other, creating a bi-directional threats flow completing the loop (e.g. the industrial production of goods produces different kinds of noise and chemical pollution, which might affect CT, whereas tourist cruises can favour alien species introduction, impairing the development of the aquaculture sector), (see Fig. 1 in Drius et al., 2019). Two important concepts emerge from this framework: (i) CES are set up in the loop as fundamental component, since they provide the essential benefits for both tourism and other HA, posing nature integrity as the base of sustainability of these activities on the long term; and (ii) the threats generated from HA and CT impinging on CES provoke a negative effect on HA and CT.

In order to develop this framework for the Mediterranean, five CT typologies were mainly analysed: (i) beach tourism (i.e. all beach-based activities and nautical sports dependent on beach facilities); (ii) urban tourism (i.e. visiting of coastal villages and towns); (iii) cruise tourism (including associated activities such as embark/disembark facilities and coastal navigation); (iv) recreational boating (including yachting); and (v) ecotourism (i.e. the responsible travel and visitation to relatively undisturbed coastal natural areas, in order to enjoy and appreciate nature). Moreover, threats from CT and to CT were embedded into a new

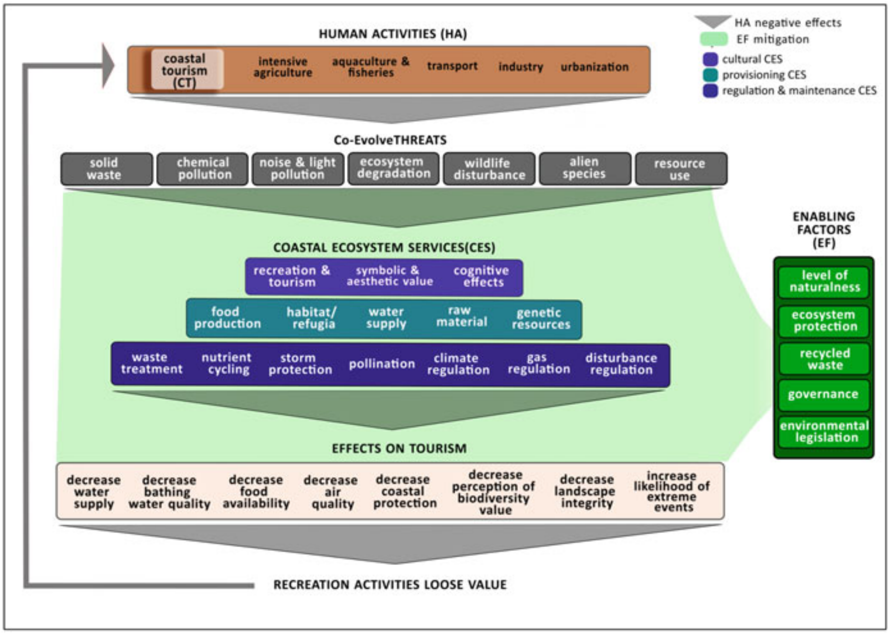

Fig. 3.1 Conceptual framework highlighting the implications of the threats from and to Coastal tourism (CT) for CT development. The negative effects flows generated by CT and by other Human Activities (HA) through their threats to coastal ecosystem services (CES) and thus to recreational activities are indicated by grey triangular arrowheads. CES are colour coded as following: cultural (violet), provisioning (teal) and regulation and maintenance (dark blue). The cream-coloured box contains a set of negative effects produced by a reduced supply of CES, which in turn impair CT assets for the development of CT industry (grey arrow). The light green area represents the mitigation effects produced by Enabling Factors (EF, in the green boxes). Figure modified from Fig. 5 in Drius et al. (2019)

"Co-Evolve threats" classification, which included new emerging threats like for instance "light pollution".

In this paper, building on case studies developed within Co-Evolve, we could expand each component of the loop highlighting the implications of the threats from and to CT for CT development (Fig. 3.1). CT and other HA generate threats, which in turn impinge on CES supply. This is reflected on CT through the loss of quality attributes of natural elements supporting coastal recreational activities (e.g. quality of bathing water, air and food, water supply, landscape integrity, climatic stability, coastal protection, perception of biodiversity etc.). Negative effects generated by the impairment in CT assets are thus directed toward the development of CT industry. The scheme emphasises that, apart from CT, other HA produce threats that can negatively affect tourism recreational activities and cumulate with threats from CT. The key role of CES is highlighted, with a particular emphasis on cultural CES for the survival of CT and for management of conflicts among HA in the long term. We further introduce some potential EF, which might mitigate and counteract

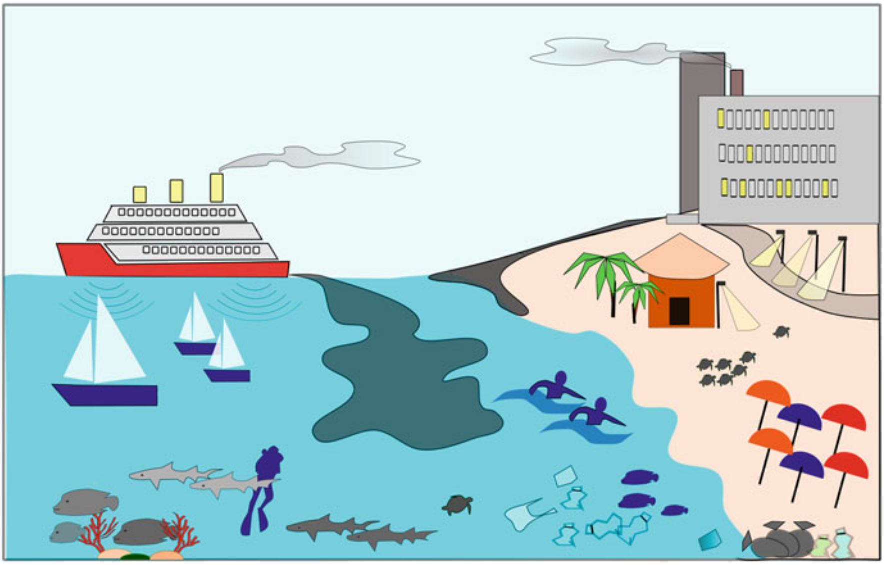

Fig. 3.2 Sketch example on how coastal tourism (CT) and other human activities (HA) affecting CT recreational activities can impinge on coastal ecosystem services (CES) supply. The CT cruise industry, land based industrial and tourism infrastructures pollute the coastal waters of a beach resort; water pollution (Co-Evolve threat) negatively affects coastal water nutrient cycling (regulating CES), fact that, in the long term, provokes a decrease in bathing water quality in the resort, thus affecting most of recreational activities, such as swimming, snorkelling, spearfishing, and nautical sports. Therefore, a coastal resort whose bathing water quality is scarce is likely to lose attractiveness and ultimately to decline (negative effect on CT industry). Other potential threats generated by CT and HA and impinging on CES (e.g. solid waste, light pollution and ship noise) are represented. These threats negatively affect touristic appreciation of natural sites, life cycle and even survivorship of marine organisms, on which various coastal recreational activities depend

negative feedbacks toward CT. Examples of key EF towards tourism sustainability are: governance and environmental legislation (e.g. rigid control on waste production), coupled with the maintenance of a high naturalness level and an effective ecosystem protection. Examples on how CT and HA, by affecting CT recreational activities, can impinge on CES supply are reported in the sketch of Fig. 3.2.

3 Existing Indicators for Sustainable Coastal Tourism

Sustainable tourism good practice requires a constant monitoring of the impacts generated by the tourism industry, to determine whether they are acceptable or not, introducing the necessary preventive and/or corrective measures (Asmelash & Kumar, 2019; McCool et al., 2001). At the same time, sustainability should ensure tourist satisfaction, provide meaningful experiences, raise awareness about sustainability issues and promote suitable practices. In this way the provision and maintenance of cultural ES is guaranteed. An efficient monitoring can be performed by means of clear, simple and flexible indicators based on qualitative and quantitative data (Schianetz et al., 2007), which should have the following characteristics: (i) present the current state of sustainability at the destination; (ii) monitor the results of activities and policies carried out at the destination in order to develop and implement sustainability; (iii) warn about the changes that are taking place. Moreover, indicators should be seen as a vehicle to generate community consensus in working towards shared goals (Gahin et al., 2003). Various international organizations so far have put sustainable tourism indicators on their agenda. Two major international initiatives are the Global Sustainable Tourism Council (GSTC) and the United Nations World Tourism Organisation (UNWTO). The GSTC has developed two sets of criteria with the aim of setting tourism sustainability standards among the various stakeholders, by targeting tourism private actors (hotel owners, tour operators etc.) and tourism destinations (e.g. GSTC, 2013). UNWTO has recently put into force the initiative "Towards a Statistical Framework for Measuring Sustainable Tourism" (MST) which aims at developing measures for sustainable tourism taking into account the economic, environmental and social dimensions and the global, national and subnational spatial level (UNWTO/MST, 2016).

Grounded on the initiatives taken by the UNWTO and the GSTC, EU institutions have developed their own frameworks, launching in 2013 the European Tourism Indicator System (ETIS). ETIS intends to provide not only a management tool, but also to help destinations to monitor and measure their sustainable tourism performance, by using an easy to use, shared, and comparable approach for collecting data and information. ETIS is based on 27 core indicators and 40 optional indicators, subdivided into four categories (https://ec.europa.eu/growth/sectors/tourism/offer/sustainable/indicators_en): (i) destination management; (ii) social and cultural impact; (iii) economic value, and (iv) environmental impact. The core indicators capture the baseline information to understand, monitor and manage the performance and impact of tourism activities at a destination, providing possibilities for comparisons over time and a basis for sustainable management. The supplementary indicators address further specialization, covering issues such as cultural routes and accessible tourism (European Union, 2016).

Starting from ETIS, some studies have tried to develop alternative indicators. For example, the INTERREG project Med MITOMED+ tested the ETIS indicators on target Mediterranean destinations and suggested a new set, tuned for coastal areas, providing an online open platform, where local governments can calculate their own indicators (Bršćić et al., 2020). Apart from this, MITOMED+ underlined the importance of involving all tourism stakeholders in the management of the destination and helped them analyse the current impact of tourism on local economies, environments and societies and understand the benefits of using indicators. Whatever the context, all the indicator systems currently available have a prevalent socio-economic nature and they seem to ignore the importance of CES for the long-term sustainability of CT, as well as the primary role of coastal ecosystems and their functions for the existence and prosperity of CT. This induced us to conceive a new approach, in the context of the Co-Evolve framework, for developing sustainability indicators for CT, which focus on coastal ecosystem protection, embracing a holistic perspective.

4 Applying the Co-Evolve Approach for Developing Sustainability Indicators

We started exploring the nexus between CT and CES. On the one hand, CES supply CT with manifold benefits essential for its existence, such as, for instance, the intrinsic value of a natural coastal landscape; on the other hand, unsustainable CT (e.g. water pollution from recreational boating or cruising) negatively impact CES. Then, we investigated the threats from CT to coastal ecosystems and their services and the EF for the protection of coastal ecosystems and their services, always in relation to CT. Finally, we developed our own list of indicators, to be added to the existing ETIS supplementary indicators. The criteria followed to identify the indicators were: data accessibility, data availability and local scale (NUTS3 or Pilot Area) applicability. We proceeded in two steps, first building a provisional list of indicators based on data accessible at the Mediterranean level, and then excluding all those indicators whose data were not available or valid at local scale. Thus, the final list of indicators is the result of a consultation with the partners of Co-Evolve, which provided information on data availability at local scale for some indicators.

Table 3.1 reports the list of indicators, distinguished into Threats and Enabling Factors. Regarding the threats, we identified "Percentage of artificial land cover classes with respect to total surface" as a proxy to express the threat Air pollution, as we could not find a standardized data source valid for all Mediterranean destinations that would report reliable measurement. The indicator is based on the Corine Land Cover spatial database and it can be computed at 10-km wide coastal strip within the NUTS3 region. Air pollution is produced by transportation and industry; in the case of coastal tourism, cruises, airplanes and road vehicles are likely to be the major vectors of this source of pollution. The threat Water Pollution in the Mediterranean Sea is principally the direct result of the discharge of untreated or partially treated sewage into the immediate coastal zone, and it is obviously very relevant for coastal tourism. It can be expressed by the indicator "Percentage of bathing sites with excellent water quality" based on the database WISE, which refers to microbiological pollution only. The indicator "Artificial sky brightness" expressing the threat Light pollution is starting to be considered, albeit marginally, in indicators systems (e.g. GSTC, 2016). Coastal cities and highly developed tourist areas are hotspots of light pollution, representing a relevant new threat element for the monitoring of coastal tourism. It is now recognized that artificial lights impact, even many kilometres away from their sources, on the natural cycles and behaviour of urban and marine fauna that depend on land to complete its life cycles (e.g. sea turtles nesting), (Davies et al., 2014 and literature therein). Ecosystem degradation and

Table 3.1 List of threats indicators for coastal ecosystem protection, developed within the Co-Evolve project

Threats	Co-Evolve indicators	Measure	Scale	Source
Air pollution	Percentage of artificial land cover classes with respect to total surface	Percentage	Value computed at 10-km wide coastal strip within NUTS3	Corine Land Cover 2012 http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view
Water pollution	Percentage of bathing sites with excellent water quality	Percentage	Value computed at NUTS3/PA level	WISE – Bathing Water Quality Reporting under Directive 76/160/EEC http://dd.eionet.europa.eu
Night time light pollution	Artificial sky brightness	mcd/m^2	Value computed at 10-km wide coastal strip within NUTS3	Falchi et al. 2016 supplementary data service http://doi.org/10.5880/GFZ.1.4.2016.001[a]
Ecosystem degradation and fragmentation	Natural land cover classes/artificial land cover classes	Number	Value computed at 10-km wide coastal strip within NUTS3	Corine Land Cover 2012 http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view
Noise pollution	Percentage of people exposed to road noise	Percentage	Value computed at city/PA level	EEA portal https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-2
Waste production	Municipal waste per capita annually produced	Kg/year	Value computed at city/PA level	Data available at municipality /NUT3 level

The measure and the scale of application of the indicators are also reported. *PA* Pilot Area
[a]Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov B, Rybnikova NA, Furgoni R 2016. Supplement to: The New World Atlas of Artificial Night Sky Brightness

fragmentation leading to lower abundances and often to species richness declines is considered the most pervasive threat to diversity, structure, and functioning of marine coastal ecosystems and to the goods and services they provide (Lotze et al., 2006). We identified the indicator "Natural land cover classes/artificial land cover classes", whose data is available through the Corine Land Cover spatial data. For the threat "Noise pollution", standardized data at adequate scale, related to the impact on biota do not currently exist. For this reason, we decided to employ information referred to human health, assuming that it can be valid for wildlife as well, using as indicator the "Percentage of people exposed to road noise" populated through the EEA database. However, anthropogenic underwater noise is now recognized as a relevant world-wide problem, and recent studies have shown a broad range of negative effects in a variety of taxa (e.g. marine mammals, Erbe et al., 2019). The ACCOBAMS Agreement (*The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area*) has undertaken a work aiming at identifying noise hotspots and areas of potential conflicts with cetacean conservation (ACCOBAMS, 2016).

Shifting to the threat “Waste production”, there is a lack of studies quantifying how much solid waste the tourist population produces and how it engages in total and separately collected recyclables. Several studies have used the production of waste by the resident population as a proxy for calculating the seasonal variation of waste production in different towns and regions with high amount of tourists, assuming that residents and tourist produce the same waste amount. However, there is no scientific evidence on whether the proportion of waste generated by the tourist population is the same as that of the resident population, and whether the effect of the tourist population on waste production extends or not over the months following the direct tourist pressure (Mateu-Sbert et al., 2013). Although EU statistical datasets provide valuable information on the trend of waste production, no clear relationship with touristic presence can be done. This considered, the chosen indicator was “Municipal waste per capita annually produced”.

For Enabling Factors (EF) suitable at NUTS3 or local scale, we identified five indicators (Table 3.2). To express the level of ecosystem protection in a coastal destination the indicator “Extent of coastal Natura 2000 sites” proved very adequate. In fact, this information is constantly up-to-date through the dedicated EU Natura 2000 portal following the reporting provisions of the Habitats Directive, 92/43/EEC (Table 3.2). Similarly, the EF Level of naturalness can be expressed by the indicator “Area of natural and semi-natural habitats (based on Natura 2000 sites and EU habitats)”, whose data can be retrieved from the same portal. A very important aspect to consider for the effective protection of coastal ecosystems is the governance of protected areas, for instance that of Natura 2000 sites. Governance issues relate to the existence and implementation of tourism, environmental planning policies, action plans and public expenditure assessment as well as the involvement of and interaction with public and private stakeholders in the planning process. The indicator we chose is a categorical one (yes/no), i.e. the “Implementation of Natura 2000 management plans”. To counteract the threat “Waste production”, we selected the EF indicator “Municipal waste recycled per year”, whose data are available at NUT3 level. However, also in this case, it is not possible to distinguish the proportion of waste recycled by the tourist population in comparison to that of the resident population. Finally, the fifth indicator we proposed is related to environmental legislation, namely “Adequacy of legislation tackling pollution”, which includes the above-mentioned threats (noise, air, water and light pollution). Here the indicator can be categorized into three levels (low; intermediate; high), after an accurate investigation on the existing local measures in each coastal destination.

Table 3.2 List of enabling factors indicators for coastal ecosystem protection, developed within the Co-Evolve project

Enabling Factors	Co-Evolve indicators	Measure	Scale	Source
Ecosystem protection	Extent of Natura 2000 sites	ha	Value computed at PA level	https://natura2000.eea.europa.eu
Level of naturalness	Area of natural and semi-natural habitat (based on Natura 2000 sites and EU habitats)	ha	Value computed at PA level	https://natura2000.eea.europa.eu https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification
Waste recycled	Municipal waste recycled per year	kt/year	Value computed at city/PA level	Data available at municipality/NUT3 level
Governance	Implementation of Natura 2000 management plans	yes/no	Value computed at PA level	https://natura2000.eea.europa.eu
Environmental legislation	Adequacy of legislation tackling pollution	low/intermediate/high	Value computed at PA and wider level	Data available at municipality/NUT3 level

The measure and the scale of application of the indicators are also reported. *PA* Pilot Area

5 Final Remarks

CT is a major driver for the local and regional economy of many Mediterranean areas. On the other hand, it can affect ecosystems through manifold pressures, which can contaminate air and water, cause noise and light pollution, and alter the health of wildlife populations. CT and the HA occurring along the Mediterranean coastline share space and resources, leading to conflicts for often-divergent uses. In addition, the overexploitation of natural resources degrades and depletes coastal habitats, with negative feedbacks for all HA. Hence, both tourism and the other activities have to consider their dependence on CES, and technical and political actions have to be put in practice to reach a compromise that preserves natural resources in the long term. The implementation of indicators to express, on the one hand, the threats from tourism to coastal ecosystems and, on the other hand, the enabling factors which could minimize such threats, represents a precious means to make CT more sustainable and thus to enjoy the Mediterranean coastal ES in the long term. This paper contributed to the advancement of these issues by embracing an ecological view that goes beyond the socio-economic one, which is the one prevalently adopted to assess sustainable tourism development. In particular, starting from the conceptual framework developed by Drius et al. (2019), we proposed some EF, which take into account the protection and the management of the environmental assets. Besides, based on the main existing indicator sets for sustainable tourisms, we suggested and described a new approach for developing sustainability indicators, focussing on coastal ecosystem protection and adopting a holistic perspective.

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Chapter 4
From Human-Nature Dualism Towards More Integration in Socio-ecosystems Studies

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Significance Statement In the management of natural resources and biodiversity, humans and nature have traditionally been considered as two distinct systems, one controlling the other. The concept of socio-ecosystems allows a more integrated approach, in which humans and nature are recognized as interdependent. However, this new perspective does not necessarily eliminate a distinction between humans and nature, or even a hierarchy of humans over nature. This chapter aims to raise awareness of the potential human–nature dualism in socio-ecosystem approaches. Other research fields have adopted different approaches regarding human–nature integration versus dualism, offering a window on the advantages and limitations of various positions. We also discuss how methodological choices are important to translate human–nature integration or dichotomy depending on the study aim.

Keywords Human-nature dualism · Socio-ecosystems · Conservation biology · Natural resource management · Human-nature relationships

1 Introduction

Ways of addressing relationships between humans and nature have significantly evolved in science and policy over the last decades. Historically, Holling and Meffe (1996) blamed the 'command-and-control' mode of ecosystem management for causing self-reinforcing ecological damage rather than solving it. At the same time, the pristine nature highlighted as a model by ecological science (and conservation biology in particular) revealed its limitations in many problematic situations

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in the late twentieth century (Berkes et al., 2003). In both management practices and in conservation biology, the separation between or hierarchy of humans over nature has created a misleading – or even inoperative – understanding of social and ecological dynamics that are in fact coupled. The history of conservation biology has been one of a shift from a perspective that largely treated humans and nature as separate to viewing them as forming interdependent parts of a socio-ecological system (SES) (Mace, 2014). Research in SES focuses on the manifold elements that link social and ecological systems, encompassing practices, governance, knowledge, values, services and functions, and involving an interdisciplinary research effort (Reyers et al., 2010) that provides new perspectives.

SES research is rooted within complex systems science (*e.g.* concepts of resilience and adaptive capacities, see Berkes & Folke, 1998) and has contributed to the development of widely accepted frameworks (*e.g.* ecosystem services), innovative research settings (*e.g.* Long-term Socio-ecological Research zones, Bretagnolle et al., 2019) and international policy recommendations (*e.g.* IPBES, 2016). Albeit heterogeneous, SES research shares the aim of capturing the interplay of social and ecological dynamics in all their complexity – not exclusively social dynamics as mediated by environmental issues or ecological dynamics as affected by human drivers (Folke, 2016). In SES research, treating humans and nature as fundamentally interacting and interdependent systems is not just an analytical choice, but also an ethical principle: humans and nature are recognized as interconnected, reliant on each other to remain sustainable. The approach uses terms such as 'stewardship', 'integrity' and 'reconnection' to describe socio-ecological systems (Folke, 2016).

However, some criticisms of SES have arisen about the attainment of these objectives. The most well-known target of this criticism is the concept of ecosystem services – central in describing the relationships between ecosystems and socio-economic systems – as the notion of 'services' can appear to be strongly anthropocentric (Kolinjivadi, 2019; Muradian & Gómez-Baaggethun, 2021). The very framework of SES is also questioned. Kolinjivadi (2019) suggests that the SES concept has inherited from mainstream natural resource management the principle of human domination over nature, and that this domination manifests itself through managerial and technocratic visions of ecosystem dynamics. Likewise, Cooke et al. (2016) claim that SES frameworks may unintentionally reinforce a mental disconnection and hierarchy between people and the environment, by encouraging people to *act upon* their environment rather than to *act in concert with* other living organisms in order to achieve sustainability. At the same time, SES research is also criticized for its excessive symmetry, in which humans are treated as just another ecological entity and socio-ecological interactions as self-adaptive, thus resulting in an apolitical vision of the ecological crisis (Orach & Schlüter, 2016; Reyers et al., 2010).

In this context, it seems useful to question the conceptions of SES researchers regarding human–nature relationships. Other fields of research, some linked to SES research, have adopted distinct perspectives to overcome the issues posed by the human–nature divide (Table 4.1). This chapter offers some definitions and conceptual clarifications that illustrate the gradient between integration and hierarchy

Table 4.1 List of the different research fields presented and their vision of human-nature relationships

Research field	How are addressed Human-nature relationships	Suggested references
Landscape ecology	Involves an integration of human and ecological drivers of landscape change and sometimes their interactions too; human and nature realms are mostly equivalent	Bastian (2001) and Musacchio (2009)
Territorial approaches	Involves an explicit separation between the human territoriality (similarly or distinctively from animal behaviors) and the resources (from both realms, either independently or interactively) over which it exercises power	Chabot-Hanowell and Smith (2012) and DeScioli and Wilson (2011)
Environmental economics	Involves the optimal management of environment issues (from the nature realm) to maximize benefits and minimize costs in the pursuit of human needs (to the human realm)	Balmford et al. (2011, 2002)
Biodiversity economics	Involves the conservative management of biodiversity by better economically valuing the biodiversity benefits and support for human life	Helm and Hepburn (2014) and Dasgupta (2021)
Coevolutionary current of ecological economics	Considers coevolution mechanisms within and across social and ecological systems, as well as resulting dynamics	Kallis and Norgaard (2010)
Actor network theory	Develops within "collectives" of humans and non-humans. Political work consists in defining the rules by which these collectives are composed and organized.	Latour and Porter (2004)
Environmental humanities	Are about encounters human and non-human beings who "become" together.	Haraway (2008)
Political ecology	Unpacks the relations of power, inequities and the production of 'winners' and 'loosers' related to environmental issues and environmental management (in the case of the paper in relation with the circulation of the notion of ecosystem services).	Kull et al. (2015)
Multispecies ethnography	Investigates the effects of living non-humans on human values, experiences or identities. Humans and non-human livings are considered equals.	Kirksey and Helmreich (2010)
Conservation biology	Must consider the intrinsic value of biotic diversity, irrespective of its instrumental or utilitarian value	Soulé (1985)
Historical materialism (*sensu* Malm)	Interdependent entities (nature and society) with different properties. Acknowledging property dualism is necessary to fight the sources of nature degradation and, in particular, the fossil economy.	Malm (2018)

between humans and nature, and discusses the place and role of human–nature relationships in methodological approaches. It explores some research fields that have proposed various types of integration between humans and nature and/or offered perspectives to address human–nature dualism that may inspire future directions. Interdisciplinary collaboration and exchanges between SES researchers and scholars from other fields interested in human–nature relationships provide a promising avenue to explore.

2 Integration, Dualism, and the Valuation of Nature

SES research is based on the idea that human societies and natural organisms form interdependent and inseparable systems. It focuses on the relationships between these two systems, distinguishing between them while taking into account how they interact. It thus presumes a certain degree of integration of natural and human systems (see Fig. 4.1). Graphical representations of SES (*e.g.* Collins et al., 2011; Bretagnolle et al., 2019) reflect the dichotomous nature of this approach. Such a dichotomy does not necessarily imply the existence of a judgement about the superiority of one system over another, and can be analytically useful. However, it can equally underpin a domination mechanism in which one system is considered superior, turning the dichotomy into dualism: *i.e.* a theoretical structure based on two principles whose duality gives meaning to the whole system, and in which,

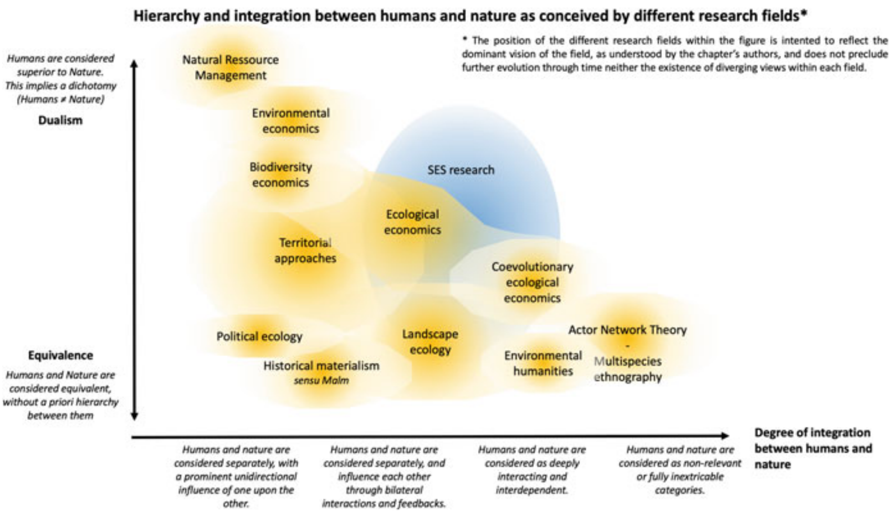

Fig. 4.1 Hierarchy and integration between humans and nature as conceived by different research fields. The position of the different research fields within the figure is intended to reflect the dominant vision of the field, as understood by the chapter's authors, and does not preclude further evolution through time neither the existence of diverging views within each field

according to Plumwood (2003), one element is necessarily superior to the other. This is the case when, for instance, nature is reduced to a mere resource system for humans (Muradian & Gómez-Baaggethun, 2021).

In the current standard social paradigm, such dualism is likely to support the systematic valuation of humans over nature, rather than the other way around. While this might be desired and explicit, it is often unintended and implicit. The latter case calls into question the ethical foundations of SES. Even without intending dualism, the dichotomic distinction between a human subsystem and a natural subsystem may itself result from culturally dualist principles deeply ingrained in Western thought. It is therefore necessary to consider which aspects of the distinction between human and natural subsystems are really necessary to understand SES.

Human–nature dualism may also manifest itself according to the way in which nature is valued. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2016) marked evolution in the way nature is perceived and valued in SES, but the question still raises debate. The IPBES distinguishes three types of values that can be assigned to nature: (1) 'intrinsic values' independent of human experience refer to the inherent value of nature and its components; (2) 'instrumental values' refer to material and nonmaterial contributions of nature to people, e.g. ecosystem services; and (3) 'relational values' refer to the interactions between human and natural entities that contribute to people's identity and quality of life. While instrumental and relational values seem rooted in a dual view of human–nature relationships as they place human interests as the primary consideration in the valuation process, taking into account intrinsic values is often put forward as a moral proposition to enlarge this perspective (Batavia & Nelson, 2017). Although intrinsic values are inevitably assigned by humans to non-humans, they need not be restricted to humans (Vucetich et al., 2015), and allow that at least some components of nature deserve direct moral consideration and care. Nonetheless, assigning values to nature involves a critical political dimension, as this valuation is structured around 'what matters' to people (Jacobs et al., 2018). Choices relating to this valuation should be justified, as they may reinforce human–nature dualism, which can subsequently influence political views and policy.

3 Insights from Other Research Fields

3.1 Observing Human-Nature Dualism Through Its Spatial Expressions

Spatial organization often informs SES views on human–nature relationships (Martin-Lopez et al., 2009), but applying common spatial scales and frameworks to ecosystems and socio-economic systems remains contentious. Certain research fields have an explicit primary focus on the spatiality of human–nature interactions. One example is landscape ecology: it relates spatial patterns (*e.g.* the landscape mosaic) with socio-ecological processes (*e.g.* farming practices and plant dynamics) using geographical principles (Bastian, 2001). This approach strongly permeates SES research.

Territorial approaches focus on territorial behaviour (of humans as any other animal) and resource control strategies (DeScioli & Wilson, 2011; Chabot-Hanowell & Smith, 2012). This approach is adopted in several disciplines such as ethology, anthropology, geography, political philosophy, management or economics. It involves an explicit separation between the society that expresses its territoriality and the resources (be they natural, manufactured or social) over which it exercises power. Whenever a society is considered exterior to nature, and nature is equated to a resource system, the separation reflects human–nature dualism. However, such approaches have the merit of making human dependence on ecosystems explicit. They also pinpoint the transformative power and impact of humans on the natural environment through their efforts to shape and control space.

Territorial approaches have a strong political component. The institutions guaranteeing the sovereignty of a society over its territory, such as nation states, also place humans in a position of responsibility for the development of their living space and the fair and sustainable management of natural resources. In political philosophy in particular, the allocation of territorial rights over natural resources through the sovereignty of nations is controversial (Banai, 2016; Dahbour, 2019): unsustainable governance of natural resources, land grabbing by private foreign investors (Jurkevics, 2021), and the oppression of indigenous peoples (Finley-Brook & Thomas, 2011) are some of the most problematic effects of the national sovereignty principle. In practice, human-centered territorial approaches recurrently adopt a rather dual vision, focusing their analysis on man-made (*e.g.* industrial apparatus) or market resources (*e.g.* tradable raw materials), the adjustment of territorial scales to those of human mobility, or the impact of territoriality on human conflicts, to give some examples. Recently, however, there have been efforts to limit dualism and, for example, reconcile territorial and ecological scales (Barreteau et al., 2016) or even integrate ecological, socio-ecological, and territorial interdependencies in a common framework (Mathevet et al., 2016) with the aim of managing environmental issues more effectively.

3.2 Attempts to Emancipate Economics from Human-Nature Dualism

Different fields of economics have sought to deal with environmental problems. The main field, environmental economics, suggests assigning an exchange value to nature, so that environmental costs and benefits become visible on the market. This contains the implicit assumption that human-made capital can replace natural capital (perfect substitutability) and that the value of nature lies in its utility for humans. It is thus based on a dualistic view of human–nature relationships.

Ecological economics and biodiversity economics have distanced themselves from this perspective, although in most cases they retain a human–nature dichotomy. Biodiversity economics looks for pragmatic solutions to the dramatic decline in biodiversity, using socio-ecological frameworks and methods (Helm & Hepburn, 2014). The valuation of biodiversity is considered critical, since this is expected to increase the effectiveness of conservation regulations and incentives (Helm & Hepburn, 2014; Barthowski, 2017). However, biodiversity economics privileges the monetization of biodiversity and ecosystem services over other valuation methods. In this way, dualism continues to be expressed in this field: a 'first zone' of nature – useful to humans and monetizable – is overemphasized, while a 'second zone' (poorly known or difficult to capture in monetary terms) is left invisible.

Ecological economics also distances itself from environmental economics, but with an explicit rejection of human–nature dualism and the assumption of perfect substitutability. Rather, ecological economists consider the economy as embedded in society, which in turn is embedded in the natural environment. Nature is alternately understood as a physical and energetic boundary to the development of human activities (Georgescu-Roegen, 1971), as a system of resources that is governed by complex bundles of rights (Schlager & Ostrom, 1992), or even as the focal point of conflicts of values and languages of valuation (Martinez-Allier, 2009). Much attention is given to the political character of human–nature relationships, however, the ecological functioning of natural systems as living systems is rarely described. Only a few authors have attempted to open this 'black box', for instance, through the investigation of long-term coevolutionary mechanisms within and across ecological and social systems (Norgaard & Kallis, 2011). This coevolutionary current of ecological economics provides an understanding of human societies – with their values, technologies, organizations and knowledge – as a specific kind of living system, interacting with others and determining (as well as determined by) their evolutionary pathways.

3.3 *Going Beyond Division to Reconcile Human–Nature Relationships*

Other approaches reconsider the dichotomy between humans and nature by studying how people cohabit or 'become' with (Haraway, 2008) other living beings. While humanities have traditionally focused on relationships between humans, actor network theory (ANT) takes the view that human societies are made up not only of humans, but include a multiplicity of diverse and interrelated 'actants', whatever their nature (living and non-living, human and non-human), which constitute complex networks (*e.g.* Latour, 2005). A number of social scientists are exploring these networks and extending them to non-human actants in which agency is not restricted to humans, but distributed among all things that 'compose' the world. By placing relationships at the centre of attention, ANT has profoundly redefined ways of considering and studying human society, fostering the emergence of methods that allow non-humans to be taken into account or even given a voice. For instance, Nabavi and Daniell (2017) have extended the range of relationships connecting actors in a SES by including geographical, financial and political links (*e.g.* institutions, infrastructure, documents, etc.).

Other scholars, inspired by ANT and the environmental humanities, also consider humans and nature in similar, if not equal, terms. Such studies have mostly focused on human–animal relationships, despite communication barriers between species. Examples include a historical investigation of how horses and dogs enrolled in World War I experienced the conflict (Baratay, 2013); innovative sociological and anthropological methods to closely observe how humans and animals interact (Kirksey & Helmreich, 2010); geographical descriptions of how animals shape space (Buller, 2016); and using political ecology to reconsider territorial issues through non-dualistic ontologies, such as those of indigenous peoples (Escobar, 2016).

Multispecies ethnography emerged in the 2010s as an attempt to do justice to the importance of plants and animals in ethnographical accounts of social existence. Beyond ANT, this field develops ethnographical investigations that account for the agency and influence of living non-humans and analyses their capacity to shape and transform human experiences, values and identities. The anthropologists Kirksey and Helmreich (2010) define it as "a new genre of writing and mode of research [in which] creatures previously appearing on the margins of anthropology – as part of the landscape, as food for humans, as symbols – have been pressed into the foreground" (p. 545). Aiming to subvert the emphasis often put on human–nature dualism by Enlightenment philosophers and to do justice to the role and place of non-humans within the social sciences, multispecies ethnography scholarship focuses on the transformative power of mutual encounters and affective dimension between humans and other living beings. For instance, farmers concerned about soil biota can develop an ethical responsibility to care for soil in a way that accounts for the needs of diverse species and possibly leads to management changes at the farm system level (Krzywoszynska, 2019).

4 Methods That Reveal or Attenuate Dualism in SES

The traditional conceptualization of SES relies on a dichotomy that can be reinforced by the different methodologies adopted to study how these systems function: the natural sphere is often examined through biodiversity science methods, while social scientists focus on the social sphere that encompasses human values, institutions and governance (Bretagnolle et al., 2019).

Other methods go beyond the differences between the two systems to focus on their integration. This is the case of causal loop diagrams, composite indicators and narratives (Rissman & Gillon, 2017). Descriptive approaches can also put biophysical and social elements on the same level: for instance, in multivariate analysis, or by applying diversity metrics to both ecological and social systems (*e.g.* Grêt-Regamey et al., 2019). Another alternative might be to imagine different viewpoints that are not based on the usual human–nature dichotomy, in order to better understand SES complexity. For instance, distinguishing between users, whether humans or animals, and attributes of spatial units, including natural and human infrastructure (Boulangeat, 2018). In this approach, drawing a user–space dichotomy has a conscious purpose: it enables humans to contextualize their actions within a network of similar actions. It does not lie in absolute terms a hierarchical structure between two groups of beings.

Methods applied similarly to the various components in a SES could thus provide a new perspective on human–nature dualism. However, when complex SES dynamics are addressed, especially when this complexity relates to power relations, a full equivalence between humans and nature may be neither necessary, desirable nor possible. The crucial point lies in the choice of relevant variables given the objectives. It is therefore important to clarify the need for integration or dichotomy depending on the study aim.

5 Where Do We Go from Here?

SES studies focus on human–nature relationships. However, the question of what is taken for granted due to the researcher's scientific and cultural background in the study of these relationships is rarely asked. Examining how scholars from a diversity of research fields have addressed these relationships suggests that dichotomies are common and sometimes useful tools, but that they should be implemented consciously, that their contextual purpose should be made explicit, and that their relevance as well as political and moral consequences should be considered. Social-ecological research is also confronted with the challenge of integrating Indigenous and non-Western science knowledge, *i.e.* types of knowledge that are not based on peer-review process of validation and do not necessarily rely on notions of neutrality and non-commitment or on a separation between a knowing subject and a known object. The recent work of the IPBES started such an integration, which will further broaden our perspectives on human-nature relationships and dualism.

Human–nature dualism has been held to form the theoretical basis for the plundering of nature and thus to be responsible for the resulting environmental crisis. However, the total rejection of human–nature dualism could endanger some humans and jeopardize nature conservation. The risks for humans could be to cease privileging any human being over non-humans, in particular contexts such as medical experimentation. For nature conservation, a rejection of human–nature dualism poses two kinds of risks. First, it may absolve those most involved in the exploitation of natural resources of their responsibility, as stressed by Malm (2018) in a perspective inspired by historical materialism. Second, the idea that dualism is intimately linked to modernity can lead to the wholesale rejection of the latter's legacy, including its intellectual and conceptual resources (Audier, 2020). Yet some of these resources – for instance, the concept of 'solidarism' (Audier, 2020) – may be valuable in rebuilding a democracy more open to both humans and non-humans and capable of recognizing and respecting their differences.

These risks could be avoided by cultivating our capacity to make distinctions. It is possible to recognize the existence of differences between beings and even to favour humans over non-humans without assuming the universal superiority of humans over nature. Distinguishing between dualism and dichotomy can be useful in this: the notion of 'differentiation' seems more appropriate than that of 'dichotomy', as it allows for distinction without implying division. Approaches from other fields of research concerned with human–nature relationships make sound arguments for avoiding both extremes – excessive continuity or excessive separation – in efforts to further integrate humans and nature in SES (Plumwood, 2003; Maris, 2015). The ability to recognize and respect differences should thus be a fundamental principle in future SES research.

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Chapter 5
A Network Approach to Green Infrastructure: How to Enhance Ecosystem Services Provision?

Andrea Staccione, Sebastian Candiago, and Jaroslav Mysiak

Significance Statement Landscape fragmentation is increasingly undermining the capacity of ecosystems to provide services and benefits to humans. The development of a green infrastructure network can enhance the provision of ecosystem services connecting ecosystem features. We review and explore the concepts, methodologies, and applications that allow to analyse connectivity of green infrastructure networks and the role of spatial connectivity for supporting and maintaining ecosystem services. Together with connectivity, the quality, quantity, diversity, redundancy, and distances of ecosystem elements result to be important characteristics to support the provision of services. We report how spatial and connectivity-based methodologies (for example, network indices and spatial pattern analysis) can support characterisation and prioritization of green infrastructure networks for crucial interventions, both for preserving and restoring connection elements.

Keywords Landscape connectivity · Nature-based solutions · Habitat fragmentation · Network analysis · Spatial planning

1 Introduction

Natural and semi-natural ecosystems are threatened by landscape changes. The fragmentation of contiguous areas of natural ecosystems into smaller elements, driven by urban sprawl and population growth, is one of the main pressures for environmental quality. It is expected that 68% of the global human population will live in cities by 2050, with nearly the 90% of increase occurring in Asia and Africa,

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and the urban population of high-income countries is expected to rise from 81% to 88% by the mid-century (UN, 2018). These trends will contribute to increasing landscape fragmentation and degradation of ecosystems (EC, 2015). At the current trend of soil sealing, Europe, for example, will lose up to 10–15% of the beneficial value produced by ecosystems by 2050 (Maes et al., 2015).

Ecosystem services (ES), i.e. the benefits that people obtain from nature, are intensely affected by landscape fragmentation since they depend on ecological functions, landscape spatial pattern distribution, and organisms and material movements (Mitchell et al., 2013). Landscape patterns and ecological functions are strictly related. A change in landscape configuration leads to changes in ecosystem connectivity, defined as the degree to which the landscape influences species movements across ecosystems (Taylor et al., 1993). Fragmentation causes habitat loss and isolation of species, making them more vulnerable and less resilient to changes (Field & Parrott, 2017). Connectivity is fundamental for maintaining species dispersal and sustaining ecological processes. A decrease of connectivity has negative impacts on ES provision, by affecting the rate and pattern of biotic and abiotic flows, the habitats and populations dimension, and, indirectly, altering biodiversity and ecological functions (Mitchell et al., 2013, 2015).

Strategies based on the usage of ecosystem functions to increase environmental, social, and economic benefits, the so-called nature-based solutions, are gaining importance as preferable options when addressing climate and environmental challenges (EC, 2015). These ecosystem-based approaches have a positive effect on the environment, biodiversity and provision of ES. Green infrastructure (GI) is a "strategically planned network" of natural and semi-natural areas with other environmental features designed and managed to simultaneously deliver a wide range of ES and multiple benefits to the society (EC, 2013). GI may mitigate natural hazards by mediating flow and nuisances, or through maintenance of stable physical, chemical, and biological conditions, for example wetlands and floodplains acting as buffers against floods, well-managed forests reducing the risk of landslides, green urban areas mitigating extremely high temperatures.

GI plays an important role for harvesting the effects of spatial configuration and composition on ecological changes and the provision of ES. GI builds upon interconnections, spatial interactions, and distributions of natural elements across a landscape. Therefore, GI can be used to plan and design green spaces, protected areas, and ecosystem restoration from a network perspective. To do this, GI can be described as a set of core areas, hotspots of services and benefits, such as protected areas, forests, urban green spaces or floodplains, and corridors, as vegetated buffer strips, green alleys, or hedgerows that connect core areas to each other and to humans. Core areas and corridors can be respectively translated into nodes and links in a network language. Taking elements from landscape ecology, graph and network analysis make it possible to quantify the effects of landscape fragmentation and to integrate these processes and relationships into GI spatial design and management to address environmental challenges (Babí Almenar et al., 2018). Planning GI as a network, while incorporating ecological, social, and economic aspects, can enhance landscape connectivity and be developed at different spatial scales, from neighbourhood, to cities, to regional, national and international scales (Lafortezza et al., 2013).

Recognising the relevance of GI configuration across the landscape, we explore how to plan and design a GI network for supporting the supply of ES and environmental quality. First, we discuss main concepts and aspects contributing to maintaining and improving ES provision through GI. Second, we review and summarise methodologies to analyse connectivity for GI, spanning from landscape ecology to spatial planning, graph, and network analysis. The chapter highlights elements that can support further developments of frameworks and strategies for territorial planning and decision-making processes.

2 What Matters for Ecosystem Services Enhancement?

The configuration and distribution of GI is fundamental for ensuring and enhancing ES provision. Studies on ES assessment highlight the need of mapping and characterizing ecosystem features. Improving landscape connectivity is important for maintaining ecosystem quality and resilience, meant as the capacity to sustain functions and services in face of disturbances and changes (Table 5.1). It implies the re-creation or restoration of green corridors or natural areas that can facilitate and allow species movements and services or material flows across the landscape. Together with connectivity, diversity and redundancy of ecosystem features have been identified as key characteristics for building resilience for ES against disturbances and changes in the socio-ecological system (Biggs et al., 2012). Diversity refers to the variety, balance, or disparity of elements within the system, leading to spatial and ecological heterogeneity. Diverse elements would respond differently to disturbances, influencing the spread of impacts on connectivity, ensuring that some landscape patches remain undisturbed and provide refuges for the provision of services. Redundancy is the replication of elements or pathways, guaranteeing a compensation in case of losses or failures. These features secure an insurance effect of connectivity, allowing network stability and robustness (Gonzalez et al., 2017). This requires particular attention to the central areas of the ecological networks, that can destabilize the network more rapidly if degraded or lost. Designing and planning a network of GI help to meet these requirements for ES provision and achieving

Table 5.1 Summary and definitions of the key concepts for ecosystem services enhancement

Term	Definition
Connectivity	Degree to which ecosystems features are structurally connected and influence the movements of organisms, material, and energy through the landscape.
Diversity	Presence of different types of ecosystem features across the landscape.
Redundancy	Presence of multiple similar ecosystem features across the landscape.
Proximity to humans	Distances of ecosystems features providing the services (supply sites) from human population using/benefitting from the services (demand sites).
Quality	Level of health of ecosystems that allow good ecological functioning and services provision.

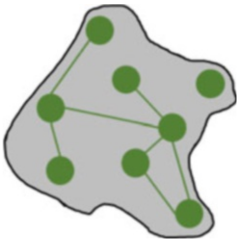
good levels of biodiversity and environmental quality. Indeed, diverse ecosystems distributed across the landscape that are structurally and functionally connected, i.e. both in term of physical landscape structure itself and of organisms and material movements through this structure, demonstrate more stability and resilience compared to systems characterized by isolated components and by low-biodiversity environments (Field & Parrott, 2017).

Proximity to people, distances between habitats and ecosystem quality represent also important features for enhancing ES provision for spatial planning supported by ecological thinking. The definition and interrelationships of landscape character, services and values are essential (Babí Almenar et al., 2018). Vallecillo et al. (2016) demonstrated how urban and peri-urban areas can have equivalent ES potential to more remote and natural ecosystems, identifying however a lower potential per unit area in degraded ecosystems. The proximity to people has a positive influence on the benefits that ecosystems can generate as services, although it is not always necessary for their provision. Analysing the connectivity requirements for ES in spatial planning, Kukkala and Moilanen (2017) found that the ideal spatial configuration for ES may be influenced by the size of local supply areas and the regional network around that support ES provision, the flow between supply and demand sites for services and the access and distribution of ES to multiple stakeholders. For planning green networks, other important aspects are interactions, synergies, and trade-offs between services. Increasing the supply of one ES can either enhance or hamper the delivery of other services. Structure, location, and scope of intervention are therefore vital in planning potential GI network configuration for services and benefits gain.

3 Connectivity and Green Infrastructures: Collection of Methodologies

GI, understood in terms of core areas and corridors, can be represented by graphs and analysed with network measures, that are used to investigate the relationships and influences between GI elements (Fig. 5.1). Graph theory is a well-established mathematical approach dealing with problems of connectivity, network representation, flow and routing in networks applied to many fields. It found applications in landscape ecology studies for habitat and landscape connectivity analysis (Urban & Keitt, 2001). Graphs are used as models of landscapes, constituted by nodes typically representing habitat patches and by links that indicate a functional connection or dispersal potential. Initially applied to population analysis, their potential has been soon recognised for representing and analysing landscape structure through network measures (Galpern et al., 2011). Indeed, due to their flexibility and low data requirements, graphs can be applied to different landscape types and scales.

Graph and network analysis can highlight the favourable geographical configuration that should be maintained, restored, or built by human intervention in order to ensure diverse, redundant and connected ecosystem features of good quality. Using

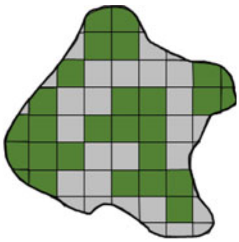


Network centrality measures:

Measures of the importance of the nodes of the network based on diverse connections characteristics such as number of links or distances of nodes, and nodes relationships that influence the network structures, such as position or nodes connected.

Connectivity indices:

Indices assessing the overall connectivity status of the network, that can inform also about role of nodes within the network and their relative importance.



Morphological spatial pattern analysis:

Spatial algorithms that segment a raster image of the landscape into network elements (nodes and links) according to size and distribution of group of pixels.

Fig. 5.1 Summary of main methodologies collected and key concepts visualisations

network centrality measures and connectivity indices enables to characterize the degree of connectivity of the landscape and to identify and rank the importance, role and contribution of nodes, and connections to the overall connectivity (Fenu & Pau, 2018). A main step is the definition of the landscape network structure and the characterization of existing components, i.e. groups of connected nodes or sub-network. It is then possible to identify cut-nodes that stabilize the network. Those nodes are the features that determine the separation of a connected component into two smaller components when removed and could maintain a network connected and stable over time.

To analyse the structure of networks and graphs, different measures or indices are available. These measures are often context dependent and their definition is not always straightforward. Network centrality measures, such as betweenness, degree and closeness centrality, are used to investigate the type and importance of contribution of individual nodes to the system (Field & Parrott, 2017). For spatial analysis, several landscape connectivity indices also exist and can be used for the same scope. The advantage of indices is that of generally taking into consideration the position, quality, and quantity of available areas, including both the effects of landscape composition and structure on species presence and movements (Avon & Bergès, 2016). Two examples of these indices are the Integral Index of Connectivity and the Probability of Connectivity (Saura & Pascual-Hortal, 2007). These indices are more sensitive to the changes affecting landscape configurations and can detect those areas most critical for conservation. Both are graph-based indices applicable to any type and scale of landscape, computing both the overall degree of connectivity and the relative importance of each node and connection. These indices can also be partitioned to assess the type of contributions of each node, in terms of intra-patch connectivity, potential dispersal flux and stepping-stones role (Saura & Rubio, 2010).

Indices can be used to include connectivity consideration when planning new interventions for GI improvement. To do this, connectivity assessment indices and models often consider structural landscape elements as a proxy for functional connectivity, as for example using the presence of a green corridor to measure species movements potential. This bears the risk of oversimplifying the reality. But if included in a wider, scalable and replicable framework assessing connectivity, they can better inform a more integrated landscape management and support practitioners and decision makers for future development plans. For example, Bolliger and Silbernagel (2020) explored the contribution of connectivity assessment methods for a successful spatial design and implementation of GI, stressing the contribution of GI both on structural and functional connectivity to identify critical area of intervention, both for preserving or restoring connection elements. The structural connectivity is usually analysed by addressing the presence and absence of connections, the configuration of corridors and stepping-stones elements, their distances, area and amount of habitat and connections (Kindlmann & Burel, 2008). Functional connectivity analysis is more based on the probability of moving between areas, dispersal rate, search time and the number of areas. In planning perspective, functional and structural corridors are the key for material and species flows, enough to be considered fragile elements and bottlenecks of concerns. The analysis of existing network structure and the identification of critical areas can help to find space and needs of network improvement. Improvement of the network can follow or combine two perspectives: the site-centre and the system-centric perspective (Zetterberg et al., 2010). They respectively aim to identify critical isolated nodes in order to restore connections to them, and to identify the crucial regions for network structure where connectivity should be improved to benefit the overall resilience of the system. For GI design and implementation this is crucial to plan and prioritize where to intervene.

GI studies often apply connectivity concepts, perspectives, and indices using spatial analysis software and techniques such as Geographic Information System or alternative spatial-based approaches. An example is given by the combination of landscape connectivity indices with the morphological spatial pattern analysis (MSPA) (Saura et al., 2011). MSPA allows the characterization of the structure of the landscape network at binary pixel level, based on mathematical analysis of landscape configurations (Soille & Vogt, 2009). Landscape connectivity indices applied together with spatial pattern analysis have been proposed to study ecological networks at different scales, both regional and local, at different ecosystem types, to assess the current situation and to develop or restore connections. Different methods and tools are used jointly for assessing connectivity and simplifying the environmental management. This allows the comprehensive study of landscape structure characteristics through available limited data and generally open and free software. There are various software and tools available for spatial pattern and connectivity analysis (see for example McGarigal et al., 2012; Saura & Tornè, 2010; Vogt & Riitters, 2017; Watts et al., 2009), but not all have ready-to-use and well-integrated outputs and routines to be combined with graph-based connectivity analysis and indices.

The conceptualization of GI as a network and the application of a set of network indicators to analyse its structure is increasing in the research field to foster the understanding of spatial needs for ES delivery. Research can inform policy and decision-making for managing and enhancing biodiversity and ES in a more holistic way. Liquete et al. (2015), for example, integrated the capacity to deliver ES with the identification of core habitats and corridors, based on mapping and connectivity methods, to inform a meaningful development of GI network at EU level. This allows contributions for conservation and/or restoration goals within EU policies. Similarly, Maes et al. (2015) investigated how an expansion of the GI network across the EU would help to maintain ES level, estimating a need of about 20,000 km^2 of additional GI to maintain ES at 2010 levels: an increase of 2.2% in the share of GI area would be needed to face any additional percentage of artificial land. Ala-Hulkko et al. (2019) used combined network and mapping analysis to study the supply and demand of ES across Europe, showing an unbalanced distribution of ES supply and demand sites. Methodologies and results can help to identify where investments, both in terms of natural infrastructure, restoration and eventually transport, are more needed.

4 Conclusion

In this chapter, we reviewed concepts, methodologies, and applications that allow to analyse connectivity of GI networks and the role of spatial connectivity for supporting and maintaining ES. Connectivity is a fundamental condition enabling species dispersal and fostering ES provision. Ecosystems quality, distances, diversity and quantity have also been identified as important design characteristics. An efficient design and planning of GI help to prioritize areas where intervention for restoration and preservation of connectivity are more urgent for ES. Spatial and connectivity-based methodologies resulted to be appropriate to characterise the network structure and inform about overall connectivity status, most important nodes, isolated and poor connected areas. This allows to identify where and how the network can be improved taking into consideration types and quantity of nodes and connections required to ensure ecosystem resilience to environmental and ongoing climatic changes. Easy and replicable graph-based methods can be used to inform landscape managers by developing conceptual frameworks and strategies that can support them through the overall process of GI network analysis and plan: from the identification of network elements to the assessment of current condition of connectivity to the planification of future network configuration. Spatial information and landscape-based contributions can support the realization of nature-based solutions, considering location, societal challenges, alternative intervention, and their impacts to be effective also in future climate change conditions.

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Chapter 6
Transformations of Urban Coastal Nature(s): Meanings and Paradoxes of Nature-Based Solutions for Climate Adaptation in Southeast Asia

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Significance Statement This chapter puts into conversation two distinct yet interrelated planning visions – *Blue Urbanism* as a movement in its own right. driven by the overarching promise of more meaningfully reconnecting coastal cities with their marine ecosystems, and *Nature-based solutions*, with roots in engineering that encompass a broad range of conservationist and infrastructural interventions rooted in Euro-American sensibilities around (urban) nature. Drawing on urban Southeast Asia for inspiration, namely Jakarta, Metro Manila and Singapore, the chapter unpicks dominant understandings of "nature" within its concomitant planning paradigms. Particular attention is placed on divergent meanings and contradictions that underpin how urban coastal nature(s) are materially imagined, reproduced and contested through often technical means, utilitarian value-systems, and modes of governing adaptation in its broadest sense.

Keywords Coastal adaptation · Nature-based solutions · Blue urbanism · More-than-human geographies · Infrastructures

1 Introduction

Cities all around the world face increasing risks from the impacts of global climate change, with larger urban agglomerations in the coastal zone being especially threatened by rising sea levels, heavy rainfall events and a growing occurrence of storm surges. Besides international efforts to mitigate greenhouse gas emissions, political initiatives to foster adaptation are gaining traction, usually with a strong emphasis on urban areas as both being most affected by projected changes, as well as

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being potential change agents that can pro-actively initiate positive transformation and trigger innovation. In recent years, approaches have been developed within the adaptation and wider urban development debates that call for more sensitive approaches to the specific conditions of coastal locations and propose an ecologically inspired planning culture. Of those approaches, Blue Urbanism stands out as a planning philosophy that tries to reconnect coastal cities to their marine environment and overcome the ‘ocean blindness’ of urban development processes over recent decades. Coming more from an engineering background, the debates on nature-based solutions follow on from these considerations in that they call for an orientation towards ecosystems and their services in order to achieve desired goals of adaptation and resilience enhancement. This is to be achieved, for example, through the protection of existing ecosystems, or the mimicking and integration of certain desirable ecosystem functions into more traditional engineering approaches. In this article, we will review some of the recent debates that are led in those emerging trends of urban coastal development, coastal protection and sea level rise adaptation. Drawing from examples and projects in Southeast Asia, we will evaluate those discourses, especially trying to understand the dominant understandings of “nature” in those planning ideas, and which manifestations of “the natural” are envisioned in them.

2 Preparing Coastal Cities for Climate Change – Towards Blue Urbanism?

With the introduction of the term “blue urbanism”, Timothy Beatley (2014) has channeled an increasing attention for the “blueing” of cities (rather like their planned greening), recently picked up in notions such as “conscious coastal cities” (Mega, 2016) and blue-green urbanities (Assmuth et al., 2017). Starting from the observation that many of the world’s metropolises have historically developed in deltaic and other coastal spaces, Beatley notes that those cities and their inhabitants have lost their social connection to the sea and the oceanic realm. For overcoming this “ocean blindness”, he proposes various ways in how to re-establish ‘feelings of connectedness’ that not only impact on how those cities mitigate and adapt to changing sea levels and extreme weather events, but also put into question the current paradigms of urban development and everyday life, together with their concomitant practices of production and consumption. Besides his calls for novel ways of being urban(e) in the form of a transformation of urban citizenry into what he terms as the *homo aqua urbanis* – crosscutting most aspects of everyday life in coastal cities – Beatley postulates the need for tangible economic transformations that embrace benefits that the urban maritime offers, from new recreational parks and tourism facilities, to infrastructures of maritime energy generation (i.e. tidal power, gas extraction), to new forms of urban transport or marine-based food production like aquaponics, and “community-supported” fisheries.

We have argued elsewhere (Siriwardane-de Zoysa & Herbeck, 2020) that despite some legitimate points, the way in how Beatley spells out his call for a more integrative character of urban coastal development processes obstructs the view on the lived realities of coastal dwellers with their own agency of adapting to changing (environmental) conditions. In his strict concentration on city governments as the major actors of coastal transformations, the term is not able to grasp the multitude of perceptions and the contestations towards top-down development processes. Additionally, the treatment of marine ecosystems appears mainly as being unflinchingly utilitarian and resource-centric. Another concept, that promises to entail a more nuanced understanding of "nature" and to give way to integrating ecosystems in their own right into adaptation processes is the idea of nature-based solutions.

3 Nature-Based Solutions – What Nature? Whose Solutions?

Although not in direct conversation with the works on blue urbanism, the relatively new discussion on nature-based solutions (NBS) in climate change adaptation resonates well with some of the assumptions depicted above. Created and made accessible to a wider public at a similar time, NBS have been gaining visibility and are increasingly proposed as alternative to grey infrastructure development in many areas over recent years. With regards to climate adaptation (and often also to the synergies between adaptation and mitigation), NBS are considered to be at least a potential complementary to traditional engineering approaches (Kabisch et al., 2017). For coastal cities, the term suggests a number of more or less established measures, reaching from mangrove and wetland restoration, to sediment management and river re-naturalization, to the protection and development of rainwater retention capacities, to different forms of green urban design (cf. Fig. 6.1).

Facilitated by an expert group under European Union's Horizon 2020 program, the basic guidelines for the debate were published in a report by the European Commission in 2015 (EC, 2015) and have since made wide circles, both in the political-administrative and the engineering sphere. Being a European (and Eurocentric) debate in its very origin (cf. Bridgewater, 2018) NBS quickly found its way to global policy levels and has developed into one of the most influential debates on climate change adaptation in face of unknowns and unknown-unknowns of climate change, with a current focus on small-scale projects and their potential for sustainable and cost-effective risk reduction.

The debate on NBS does not come from nowhere: Ruangpan et al. (2020) show that considerations of alternative approaches to established engineering approaches go back to the late 1970s and the debates on low impact development. Since then, various concepts have been used to call for "greener" and more sustainable solutions to urban problems, with different emphases. For example, in the context of the UNDRR's Sendai Framework for Disaster Risk Reduction 2015–2030, the term

Fig. 6.1 Nature-based solutions for climate adaptation in coastal cities. (Own illustration, based on https://www.nature-basedsolutions.com/)

ecosystem-based disaster risk reduction is used, while the Convention on Biological Diversity uses *ecosystem-based adaptation* to address synergies between biodiversity protection and climate change adaptation (cf. CBD 2009). In a focus on transforming into a more sustainable urban hydrology, terms like *ecohydrology* (Zalewski, 2013) or *green infrastructures* (Wright, 2011) are more common. What unites the different terms is their search for alternative ways of addressing societal and environmental challenges that use elements of "nature" in a broad sense in order to achieve desired outcomes. In its latest twist as NBS, an attempt is being made to use nature-inspired approaches to achieve prosperity gains together with reduced environmental risks and a green-growth agenda – resonating well, of course, with the more recent European New Green Deal as broad, ecologically driven development horizon for the coming decade:

> Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flow, in order to achieve desired outcomes, such as reduced disaster risk, improved human well-being and socially inclusive green growth. (EC, 2015: 5)

The respective documents emphasize cost-efficiency and inclusiveness of such efforts, and envision a European world market leadership as important goals to be achieved through the agenda setting and the active promotion of knowledge and experiences made in European countries – with the Dutch water sector being a prime example of how a growing knowledge base and innovative expertise is actively promoted and, with the support of national governments and international bodies, circulated and sold to other places (cf. Thompson, 2018).

Apart from questions that arise in the context of those specific, postcolonial human-nature relations and the power imbalances that are part of the global assemblage of actors, governments and institutions that constitute the NBS discourse, another question arises at a more fundamental level: what exactly is meant by "nature-based"? What understanding of nature underlies the broader discourse? And how does such an immanent image of nature manifest itself in concrete adaptation projects, especially in the global South? For example, Randrup et al. (2020) characterize NBS as continuation of earlier discourses like sustainable urban development or green infrastructure design, in which the Descartian division between nature and culture is fundamentally sustained; moreover, the anthropocentric and utilitarian orientation of corresponding policies (partly adopted from a similar conceptualization of nature in the ecosystem services approach) is not called into question. This also makes this new discourse fundamentally receptive to the variously expressed criticisms of the commodification of nature, which entails neoliberal practices and policies that focus on the exploitation and valorization of certain aspects of "nature" (cf. Castree, 2003, 2008) to be included in cost-effective environmental policies.

In contrast, debates in human geography have recently opposed these established concepts of human-environment relations and established new ideas of thinking nature and culture together. Here, conceptualizations like the co-production of social nature(s) (Castree & Braun, 2001), nature-cultures (Haraway, 2008; Gesing et al., 2019) or more-than-human geographies (Whatmore, 2006) offer ways to escape the strict division of a "natural" and a "cultural" sphere, instead focusing on the entanglements of human and non-human actors, practices establishing respective relations, as well as the role of representations in related understandings of nature (cf. Gesing, 2019). The impacts of dominant conceptions of nature on the design of NBS in flood control projects has been shown by Dekker and Fantini (2020), who conclude that successful NBS have to "recognize the diversity in relating to nature (...) in order to maintain the local community fabric and the diversity of nature*s* and water*s*" (ibid: 275).

4 Adapting Southeast Asian Mega Cities – Nature-Based Solutions or Climate Gentrification?

With a combination of high urbanization rates over recent decades and a specific susceptibility towards relative sea level rise and other hydrological hazards, coastal megacities in Southeast Asia are hotspots of global attention with regards to adaptation and coastal protection – especially as cities like Manila have been depicted as "disaster capital of the world", with potentially exacerbating risks in the course of global climate change. Regionally, discussions around feasible and cost-effective ways of adapting those cities in the coming decades have been accelerating, and many cities have already witnessed substantial transformations of their coastal settings that are justified with the looming disasters of the coming decades. In all bigger cities, debates are ongoing on how to protect areas threatened by coastal inundation, as well as by flooding resulting from heavy rainfall events - or, even worse, a combination of both.

Jakarta, for example, has been discussing a National Capital Integrated Coastal Development (NCICD) since several years that would include the world's largest dike structure to seal off Jakarta bay at a length of around 35 kilometers. In a blueprint developed in close coordination with a consortium of Dutch engineering companies, the proposal not only includes the construction of a toll road on the so-called superdike, but also the creation of several hectares of reclaimed land in front of the existing coastline potentially used for high end housing developments and a new CBD (CMED, 2014). Similarly, Manila is currently in the process of designing and implementing an integrated development plan for Manila Bay, that is not only coordinated by some of the same companies that closely advised Jakarta's government in the NCICD plans, but evokes similar futuring practices, combining a fundamental transformation of urban hydrology into a more resilient system with the extensive creation of housing and business development facilities, as well as transport and energy infrastructures (NEDA, 2020).

Both examples fit well in the general thrust of coastal transformations and futuring practices that are currently underway in many Southeast Asian coastal cities; proposed adaptation pathways up to now are often characterized by heavy infrastructure solutions that often entail a fundamental transformation of the existing coastal setup, i.e. formal or informal settlements, infrastructure facilities and, if any, remaining ecosystems like mangrove forests. So far, this involves what Colven (2017) has called the "return of big infrastructure" and at first sight runs counter to the described increases in importance for softer, nature-based forms of (coastal) engineering. Supplementing this view, Herbeck and Flitner (2019) have identified three main axes of futuring practices in urban Southeast Asia that often unfold simultaneously: the securitization, the greening, and the valorization of coastal spaces.

And indeed, traces of the "greening" discourse (often not yet in direct reference to NBS discourses) are commonly found in the planning documents and blueprints that are circulated in the region. Indonesia is experimenting with mangrove replanting in coastal Demak to counteract erosion and the elimination of (semi-urban) aquaculture with plans for the upscaling and replication of experiences in other urban areas; the Manila Bay Masterplan includes whole chapters of ecosystem restoration that are depicted as basis for social and economic development including growth, and whose protection will ultimately reduce "the community's exposure to disasters and vulnerability to climate change impacts, [and lead] to safer settlement areas" (NEDA, 2020: 35); and Singapore uses Dutch-inspired poldering technologies in order to stabilize and expand coastlines on Pulau Tekong, one of the outer islands of the city state, while – in a move that is not untypical for Singapore's self-image as a regional development and innovation engine – founding a research centre on nature-based solutions at its national university NUS with the aim of reaching out to countries in the region and diffusing the knowledges and experiences made in such pilot projects.

The common understanding what nature is conceived of in the strategies described above is not easy to be generalized. Not surprisingly, though, a tendency towards a utilitarian conception to nature, strongly aligned to ecosystem services thinking, can be recognized. Nature and "natural" ecosystems are then (and just then) integrated into overall strategies, when they provide services to humans – e.g. in the form of retention capacities, the trapping of sediments to counteract erosion, the provision or reproduction of fish resources, or the potential use for sustainable tourism. The projects show that the question of the specific ecosystem services addressed by the respective NBS are defined by a narrow group of actors and in most cases are still aimed at the engineering of the urban hydrological system - although connections to other objectives (e.g. ensuring shrimp farmers' livelihoods) can be identified in some cases.

It has to be noted, though, that in any of the projects that we found (e.g. mangrove reforestation, land reclamation) we have seen attempts to address diverging perceptions of nature – a fundamental pre-requisite to enable deliberative governance around marine and coastal issues (cf. de Koning et al., 2020), nor the treatment of "nature" beyond an anthropocentric conceptualization. It is not uncommon for supposedly contradictory practices of coastal protection to be combined in one and the same measure. Then it is not surprising when massive land reclamation processes and reforestation with mangroves are mentioned in the same breath, or Dutch-inspired "make room for the river" programs are used as a basis of legitimacy for the eviction of thousands of informal settlers along the riverbanks. Those paradoxes and multiple meanings are not in contrast to the debates on NBS, where *green-grey infrastructures* or *hybrid engineering* are considered to be necessary and legitimate compromises between the two paradigms of coastal engineering. It must be assumed, though, that projects that are obviously only inadequately tied back to potentially contradictory representations of coastal natures – and potential "services" that are deemed important – are not able to achieve a truly sustainable transformation of coastal spaces.

It seems that current lines of urban coastal development in Southeast Asia are caught in the multiple and conflicting demands of global adaptation discourses, path dependencies of existing development paths and postcolonial knowledge networks, as well as new approaches of hybrid and green engineering practices. As a result, paradoxical (strategic) links often emerge between capital-intensive, grey engineering project planning and the at least discursive consideration of ecosystem-based development as a way towards more sustainable and resilient coastal spaces. Unfortunately, the lived experiences with the latest implementations of adaptation projects does not leave much hope for an inclusive governance and transformation of coastal areas; it seems that instead, "the rhetoric of climate adaptation is doublespeak for the displacement of poor, informal communities, and an alibi for unsustainable growth" (Yarina, 2018, s.p.); from what is discussed under the terms Blue Urbanism and NBS so far, there is no reason to believe that this will fundamentally change with the introduction of those approaches.

5 Conclusions

The discourse on Blue Urbanism resonates well with the growing discussions around nature-based solutions in coastal protection. Both approaches portend an ecologically-inspired planning culture, rooted in distinct Euro-American sensibilities around (urban) nature and political practices of decision-making, and an ethic for integrating grey-green-blue infrastructural solutions. Their debates call for integrative urban development processes that take into account the specificities of urban coasts and the perspective of coastal communities. In both cases, there is a demand to overcome the sharp separation between (urban) ecosystems and urban societies to a certain extent, for example in the form of hybrid engineering approaches, “blue” urban development or, more fundamentally, the promotion of a critical awareness of the deep connections between urban societies and coastal and marine ecosystems. We have argued that analyzing different understandings of “nature” or “the natural” in those discourses is crucial for grasping the differentiated agencies for determining the actual shape and potential impacts of such interventions for the protection of coasts in different contexts. By doing so, inequalities on different levels can be analyzed, and structural biases of supposedly more inclusive engineering approaches can be laid open. Here, inequalities can either concern the differentiated capacities for participating in decision-making on coastal adaptation strategies and the privileging of certain forms of knowledge about nature and the benefits of nature-based adaptation strategies in those decision-making processes. Second, inequalities also relate to the differential consideration of human and more-than-human interests in coastal settings when determining concrete adaptation actions. An inclusive social science approach that carefully integrates recent thinking around more-than-human geographies could then “increase justice by looking beyond the human when researching the resocialization of water and nature” (Dekker & Fantini, 2020) and inspire meaningful interventions with mechanisms of reflexive governance (cf. van der Jagt et al., 2021) which could profit both urban residents in coastal locations, as well as ecosystems in their own right. This turn towards “re-imagined communities” (Strang, 2016) of interspecies entanglements could enhance the transformative potential of nature-based solutions in coastal environments.

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Part II
Mountain Systems

Chapter 7
Values of Mountain Landscapes: Insights About the Blue Mountains National Park, Australia from Twitter

Catherine Pickering, Patrick Norman, and Sebastian Rossi

Significance Statement People engage with nature in a range of ways, including sharing their experiences, values and concerns about specific landscapes on social media. For instance, on Twitter, governments, news, conservation, management, tourism and other organizations, as well as individuals share short 280-character microblogs (tweets) about a range of issues. We assessed public debate on Twitter about the Blue Mountains National Park in Australia to illustrate the benefits, but also limitations and concerns with the use of this, still novel, method for public engagement. Using a quantitative analysis of the tweets-content we identified common topics and emotions, including similarities and differences between the tweets posted by Australians and those from other countries regarding this globally important and popular mountain landscapes.

Keywords Social mediapublic engagement · Sentiment analysis · Values

1 Introduction

Natural landscapes are important globally including those conserved in national parks and other types of protected areas (Worboys et al., 2015). They provide ecosystem services that are worth billions of dollars to communities, underpinning and supporting life on earth (Watson et al., 2014; Worboys et al., 2015). They also inspire people with cultural, spiritual and historical values, reflected in strong

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emotional connections to these landscapes including through a range of cultural ecosystem services (Worboys et al., 2015). Some of the ways that nature is valued are conceptualised in other frameworks such as natures contributions to people including non-material contributions such as learning and inspiration, physical and phycological experiences (Diaz et al., 2018). Reflecting the increased interest in the social aspects of landscapes there is increasing interest in listening to people when they talk about different landscapes, including who talks, what they say and what they feel about them including for nature based tourism (Newsome et al., 2012; Veal, 2017), park management (Dovers et al., 2015), cultural ecosystem services (Calcagni et al., 2019), nature contributions to people (Diaz et al., 2018), as well as social ecological system (Jahn et al., 2009) among other frameworks and contexts. Researchers, governments, land managers and others often create the opportunity for such discussions with people expressing their views in community forums, focus groups, advisory boards, surveys and interviews among others (Dovers et al., 2015, Veal, 2017, Reed et al., 2018).

Increasingly people use social media to talk about topics that matter to them, with billions of people posting text and images each day on platforms such as Facebook, WhatsApp, WeChat and Instagram (Statista, 2020). One of the dominant platforms for publicly debate is Twitter, which is used by leaders, governments, news agencies, conservation, land managers, tourism and community organisations along with millions of individuals to discuss everything from world events to their daily lives (Orellana-Rodriguez & Keane, 2018; Leetaru, 2019; Wojcik & Hughes, 2019). Although communication on Twitter is limited to tweets of 280 characters, the content, timing and emotions expressed in tweets are used to monitor wars, elections, economies, natural disasters and pandemics (Pickering & Norman, 2020; Mangachena & Pickering, 2021). Twitter is starting to be used to assess how people relate to natural landscapes including in national parks (Teles da Mota & Pickering, 2020; Wilkins et al., 2020). It can be used to monitor visitation to national parks (Hamstead et al., 2018; Tenkanen et al., 2017) and to assess how people and organisations respond to events in parks and their management (Brown et al., 2020; Fink et al., 2020; Pickering & Norman, 2020). This includes comparing how people feel about parks, including those living close by, as well as those based further away (Pickering & Norman, 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). Twitter is also used by news organisations, government management agencies, tourism operators and others to inform people about specific parks, with some of these accounts with millions of followers (Halpenny & Blye, 2017; Orellana-Rodriguez & Keane, 2018; Leetaru, 2019; Norman, 2020; Pickering & Norman, 2020).

Here we illustrate how Twitter can be harnessed to assess the ways that people value and relate to natural landscapes by assessing public discussions about a prominent national park in Australia: The Blue Mountains National Park in New South Wales. This large Park (2679 km^2) is part of the Greater Blue Mountains World Heritage Area, close to the largest city in Australia, Sydney (Fig. 7.1). The Park is very popular with Australian and international visitors, with over five million visits per year (New South Wales Government, 2020). Specifically, we looked at the

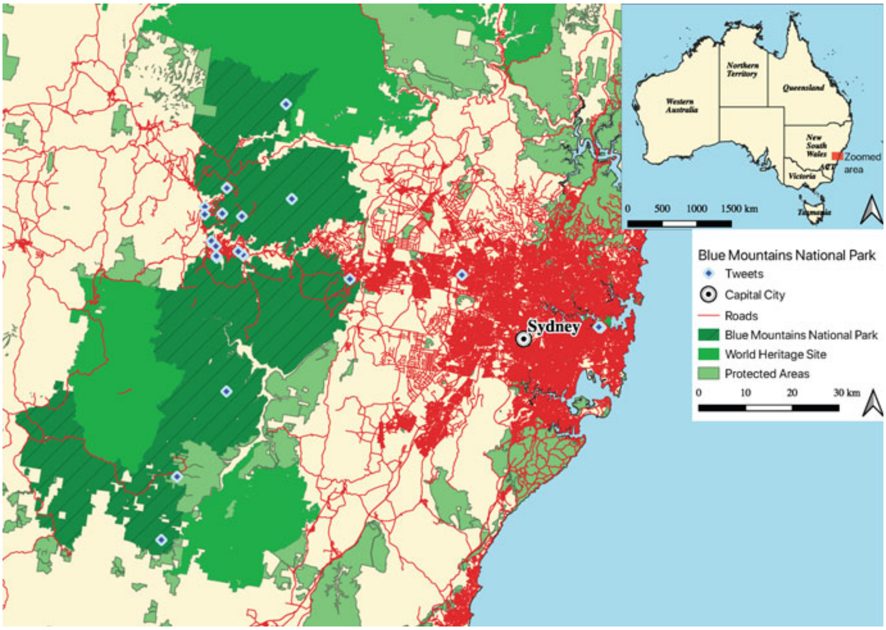

Fig. 7.1 Location of Blue Mountain National Park, including those tweets that contained geolocation information. See text for details

scale and nature of the discourse including who talked, about what, when and what emotions were expressed. This included comparing what Australians (nationals) talked about in relation to the Park compared to those living elsewhere in the world (internationals). The results illustrate some of the benefits, limitations and concerns with using Twitter to understand how people relate to natural landscapes.

2 Methods

Twitter allows people to register with the platform and then using an Automated Programming Interface, obtain metadata about a sample of tweets. A range of metadata associated with each tweet can be obtained including the text of the tweet, the user (Tweeter) identification number, the user location (text if provided), time and date of the post (given in GMT), and information on the platform used to post the tweet. To obtain this free data, a person must be registered with Twitter and abide by their policies on the use of the data. Using interactive code in the archiving Google sheet, TAGS for Twitter, it is then possible to automatically retrieve from Twitter a sample of tweets for each day the TAG is setup to run, with returns of up to 18,000 tweets per hour possible. The TAGS for Twitter can be used over long periods of time to monitor discourse as issues arise. Here it was used over several

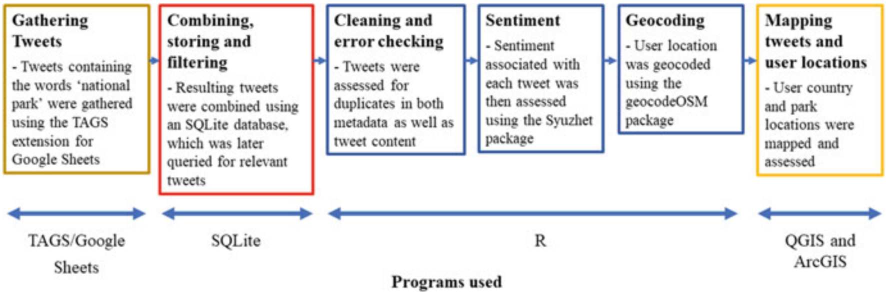

Fig. 7.2 Details of the steps and programs used to collect and analysis tweets from Twitter relating to the Blue Mountains National Park, Australia

months to accumulate a massive SQLite database of millions of tweets that used the term 'national park' in the text of a tweet (Norman, 2020) (Fig. 7.2).

To illustrate how Twitter could be used at the scale of a single landscape/national park we subsampled our global database to extract just those tweets using the term 'Blue Mountains' for tweets sent from the second July 2018 till first August 2019, using a SQLite database query (Fig. 7.2). Similar approaches have been used to assess a specific issue (horses) in a specific park (Kosciuszko National Park) during a period of intense public debate (Pickering & Norman, 2020), to compare public discourse among different types of national parks in South Africa (Mangachena & Pickering, 2021) and to assess at a country level the scale and nature of public debate about national parks in Nepal (Bhatt & Pickering, 2021). It is possible to directly use TAGS for Twitter to search for a given park, location or topic relevance by entering specific search term(s), and then monitor it over time to examine changes in responses to specific events, with the resulting metadata about the tweets available to export as csv file(s) for further analysis. To determine what people feel about a landscape its possible to code the sentiments and emotions expressed in the text of the tweets using the National Research Council of Canada's lexicon database of sentiment and emotions associated with specific words (National Research Council Canada, 2019). For the Blue Mountains tweets we did this using the 'nrc' emotion lexicon in the 'Syuzhet' package in R (Jockers, 2017; R Core Team, 2019), but as the word 'blue' is itself associated with sadness in the lexicon, we removed this word from the text of the tweets prior to coding to avoid bias. Where people who sent tweet (tweeters) were from can also be coded to country-level using the R function geocodeOSM from the tmaptools package based on text location information they provided (R Core Team, 2019), and this was also done for the Blue Mountain Tweets, although for smaller datasets it is also possible to manually code tweeters to country (Pickering & Norman, 2020). To quantify the content of the tweets, the text of all the tweets can be pasted into online programs such as 'wordcloud.com' to generate a list of common words, to then, group common terms into categories. For the Blue Mountains tweets words were grouped if they related to tourism/visiting, the location of the Park, features within the Park, activities, management issues, conservation, safety and others, and tweets with such terms/categories using a similar approach to other studies of tweets about Parks (Pickering & Norman, 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). For the Blue Mountains Park the most common terms related to geographical locations and visiting the Park and individual tweets were coded if they therefore contained terms such as visit or trip, wentworth or falls, Sydney, Katoomba, three or sisters, nsw or new south wales, world heritage, or "aust" for variants on Australia (Table 7.1). Chi-square Tests were then used to compare if there were significant differences in sentiments, emotions and the content of tweets sent by accounts based in Australia (nationals) and those sent by people in other countries (internationals). The number of tweets sent by accounts based in different countries was also mapped in QGIS. Finally, for the few tweets that included geolocation data, ArcGIS was used to map where tweets were sent from in relation to the Park, road networks and the city of Sydney.

3 Results

There were 1176 original tweets that used the name of the Park sent by 723 tweeters representing at least 44 countries (Table 7.1, Fig. 7.3). Many were sent by people based in Australia (40%, nationals), while 36% of the tweets were sent by internationals and for the remaining 24% of the tweets either the tweeter did not provide location data, or the data they did provide could not be assigned to a country. The potential audience reading tweets about Parks was massive, with a theoretically reach of 2.5 million tweeters, but as there is likely to be overlaps in followers among accounts, the real reach would be considerably smaller.

Although 37% of the tweets contained geolocation data (Fig. 7.1), this only represented 21 different locations, as nearly all were reposted images from Instagram (96%). Instagram relies on people manually coding their images by place names using text, and so many images often have the same general geolocation data. In this case, nearly all these tweets were associated with Instagram images from a few places in the Park, and 237 of them had the same geolocation in Katoomba, a popular tourism town in the middle of the Park.

There were clear themes in what people talked about in relation to the Park based on the most common words used in the tweets. This included talking about the geographical location of the Park (Australia, Sydney, New South Wales), its status (World Heritage Area), prominent places in the Park (Three Sisters, Katoomba, Wentworth Falls), visits to the Park (trip, visit etc), and what the Park meant to people (stunning, inspiring, awe, amazing and adventure). Many of the Park tweets were positive, with more positive (38%) than negative sentiments (7%) expressed, although most (55%) were neutral in tone.

Although there were some common themes and emotions in the tweets, there were also differences depending on where people were from (Table 7.1). Australians were far more likely to talk about how the Park is a World Heritage Area (10% Australians vs 1% internationals), about their visit (10% vs 7%), and about one of the prominent destinations in the Park: Wentworth Falls (8.2% vs 1%). In contrast

Table 7.1 Details of tweets about the Blue Mountains National Parks including the number of tweets and tweeters, and the percentage expressing specific sentiments, emotions and topics, sent by accounts based in Australia (national) or other countries (international)

Counts		All	National	International	
	Tweets	1176	475	421	
	Tweeters	723	227	292	
	Geolocation	439	142	187	
	Instagram	606	207	241	
	Facebook	110	67	26	
	Reach (thousands)	2,521.6	366.9	1,281.6	
Percentage of tweets		**All**	**National**	**International**	**Tests**
Sentiments and emotions	Positive	38.3	47.4	30.6	**<0.001**
	Neutral	55	42.5	65.1	
	Negative	6.7	10.1	4.3	
	Anger	8.2	11.4	4.5	**<0.001**
	Anticipation	44.1	50.5	40.9	**0.020**
	Disgust	5.3	6.7	2.6	**0.006**
	Fear	15.6	23.2	9.7	**<0.001**
	Joy	32.7	38.3	28.3	**0.008**
	Sadness	9.7	13.1	6.4	**0.001**
	Surprise	13.7	19.4	9.7	**<0.001**
	Trust	33.2	50.9	16.9	**<0.001**
Topics	Visit/trip	7.1	9.7	9.0	**0.012**
	New South Wales	19.6	20.4	17.8	0.361
	Falls	6.5	10.9	3.6	**<0.001**
	Wentworth (Falls)	3.7	8.2	1	**<0.001**
	Sydney	20.2	23.6	19.7	0.102
	Katoomba	6.7	4.8	8.3	**0.043**
	Three Sisters	7.5	5.3	9.0	**0.035**
	World Heritage Area	5.7	9.9	1.4	<0.001
	Australia	30.5	24.4	34.7	**0.004**

Values are colour coded by size, with higher values in red. P values for Chi-square tests comparing national and international tweets are provided, with those in Bold significant. Reach = sum of the number of followers for all tweeters

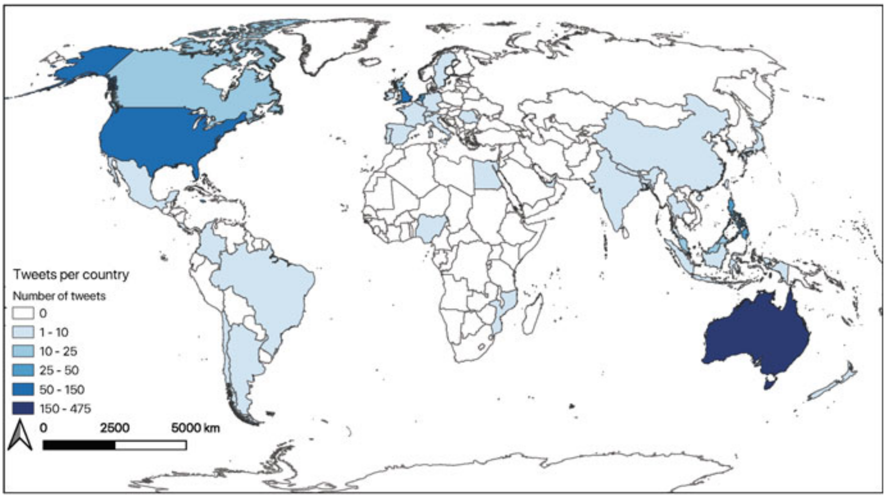

Fig. 7.3 Number of tweets per country about the Blue Mountain National Park. Data based on information provided by some tweeters about where they are from and does not indicate geolocation where the tweet was sent from

internationals were more likely to talk about the Park in reference to Australia (35% internationals vs 24% Australians), about two other prominent tourism destinations that are easy to access and close to each other: the town of Katoomba (8% vs 5%), and the nearby Three Sisters lookout (9% vs 5%). They also differed in overall sentiment and the specific emotions expressed, with Australians far more likely to express positive and negative sentiments when tweeting about the Park as well as emotions such as anger, anticipation, disgust, fear, joy, sadness, surprise and trust, while internationals tended more often to be neutral when tweeting about the Park (65%).

4 Discussion

There are benefits in using Twitter to listen to public debate(s) about nature (Table 7.2), including, as illustrated here, for the Blue Mountains. Twitter is popular with millions of people posting about diverse issues relating to natural landscapes, including national parks with more than a million tweets sent about more than 140 parks over a few months globally (Norman, 2020). This includes people from a range of countries that are interested in, and engaged with specific landscape. Here people from 44 countries talked about the Blue Mountains during the sampling period while globally tweets about parks were sent by accounts from more than 180 countries (Norman, 2020). The size and nature of the discourse varies dramatically among continents, regions, parks and people (Brown et al., 2020; Norman,

Table 7.2 Benefits, limitations, and challenges of using Twitter as a source of data for research into how people value landscapes

Benefits
Scale: Large numbers of tweets are sent daily Large numbers of people are tweeting about diverse topics. Large number of people reading tweets with some accounts with millions of followers. Provides insights into the views of people locals, visitors as well as those from other regions and countries.
Relevance: For parks and other natural landscapes people tweet about their visit, activities, access, safety, natural features, biodiversity and conservation and other topics.
Timing: Tweets are a rapid form of communication and hence can be used to communicate with people and see how people respond to specific decisions/events.
Emotions: People often express emotions and sentiments in tweets and so they can be used to monitor how people feel about specific places, events, and issues.
Access and analysis of data: Its relatively easy to access data using the Twitter API and Google TAGS and its usually free. Data can be analysed and visualised using a range of programs and levels of complexity as required.
Who: Some information is available about who sends tweets but see limitations and concerns
People who use social media platforms such as twitter include those who can be hard to access via more traditional methods of engagement such as surveys, focus groups and stakeholder workshops.
Limitations and challenges
Peoples interest in issues on Twitter can be strong and rapid, but also ephemeral and not all issues and places are talked about.
There are important ethical and privacy issues with the use of data from social media including from Twitter.
The amount of information in tweets is limited, and the meaning of tweets can be ambiguous including identifying satire and irony, it can be hard to identify relevant tweets based on search words with different meaning, and responses are often ephemeral.
Access to social media data including Twitter changes including in response to privacy concerns but also for commercial reasons. As a result, detailed geolocation data is no longer available about where tweets were sent from.
Twitter is more likely to reflect the views of English speakers, people from countries such as the USA, men, those who are wealthier and better educated.

2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). For the Blue Mountains, lots of the people tweeting about the Park were Australians, and this appears to be common, with nationals often tweeting about parks in their own country (Hamstead et al., 2018; Norman, 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). Tweets about national parks cover a range of issues including geographical location (such as country, region, nearest city), visitation, landscape features and/or biodiversity within the Park, access and facilities, as well as safety and conservation (Norman, 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). For the Blue Mountains the tweets were mostly about visiting, features within the Park and where the Park is located.

It's possible to use Twitter to not only assess what people talk about, but how they feel about landscapes. For the Blue Mountains most of the discourse was positive, and similar often positive emotional responses can be seen in tweets about other parks (Pickering & Norman, 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). This may reflect the positive way in which parks are seen by many local communities, although specific issues relating to national parks can trigger strong and rapid negative reactions including animal welfare issues or restricting access (Fink et al., 2020; Bhatt & Pickering, 2021; Mangachena & Pickering, 2021).

Twitter data can be obtained rapidly, with some websites and organizations continuously monitoring Twitter (Healey, 2019). The use of the Twitter API and options such as the Google TAGS and others is making it easier to access the data and analysis of the metadata can be fairly straight forward. Also, common database packages such as Excel and R, as done for the Blue Mountain tweets, can then be used to process the tweets. Therefore Twitter can provide an additional avenue of information that can complement others, such as surveys and hence additional insights into who, what and how people feel about landscapes (Ilieva & McPhearson, 2018; Calcagni et al., 2019; Ghermandi & Sinclair, 2019; Teles Da Mota & Pickering, 2020).

There are important limitations and challenges in using Twitter for assessing public discourse including about specific landscapes and land uses (Ilieva & McPhearson, 2018; Ghermandi & Sinclair, 2019; Teles Da Mota & Pickering, 2020; Pickering & Norman, 2020). First, only some issues are discussed on Twitter, and topics and responses can be fleeting. As a result, there may not be much discourse about some issues, and/or it may pass rapidly and hence be hard to obtain for past events and issues (Bhatt & Pickering, 2021; Mangachena & Pickering, 2021). In the past there were greater limits on the time periods when tweets could be accessed, but this changed in 2021, and may change again. Privacy and ethics are important when using social media, just as they are for other engagement data such as surveys and focus groups (Veal, 2017; Pickering & Norman, 2020). Also, information about those sending the tweets can be limited, and reflecting privacy and ethical considerations, often must remain restricted including minimizing access and use of data (Di Minin et al., 2021). There can be challenges in interpreting the content of tweets, as tweets, by their very nature, are short strings of text, and hence they do not provide the opportunity to understand in detail the context and reasons behind the views expressed (Orellana-Rodriguez & Keane, 2018; Pickering & Norman, 2020). There can also be complications in interpreting the meaning of tweets including when coding uses a literal meaning approach as taken here and in other studies (Ladle et al., 2016; Orellana-Rodriguez & Keane, 2018). For instance, literal coding does not address the metaphoric meaning of the tweets among those posting and reading them, or easily identifying irony, sarcasm or satire. Furthermore, issues can arise in fully understanding the meaning of hashtags, abbreviations and emoticons that are a characteristic of this short form of communication (Leetaru, 2019; Toivonen et al., 2019). Most importantly, Twitter only represents some people's views, and more often those who are wealthy, well educated people, particularly from some countries (Leetaru, 2019; Wojcik & Hughes, 2019), and only a very small proportion of people visiting a park will tweet about it (Wilkins et al., 2018; Toivonen et al., 2019; Pickering & Norman, 2020). Therefore, Twitter will remain a complementary method to those traditionally used to understand the multiple values people ascribe to specific landscapes including in national parks.

5 Conclusion

Twitter is increasingly used globally in public discourse, and, as shown here can be used to provide insights into how people engage with specific landscapes including in mountain national parks. However, as with many types of social data there are important considerations about biases and the accuracy, types of data that can be obtained and how representative it may be of who, how, when and why people engage and value landscapes. What is clear is that with the increasing centrality of social media in peoples lives and the level of influence and engagement with platforms such as Twitter, further research exploring these mediums of communication and exchange and how they can be used to understand people nature interactions will be required.

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Chapter 8
Earth Observations of Human-Nature Interactions from a Cultural Ecosystem Service Perspective

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Significance Statement Reconciling nature conservation and cultural ecosystem services (CES) has become fundamental to manage mountain protected areas. The timely monitoring of CES opportunities at large scales is therefore a pressing need. We combined social media data and Earth observations (EO) into a multi model inference framework to assess CES opportunities in two contrasting mountain Biosphere Reserves in Southern Europe: Peneda-Gerês (Portugal) and Sierra Nevada (Spain). EO indicators expressing people's accessibility to leisure elements and landscape visual-sensory characteristics appear to be effective candidates for the monitoring of attributes underlying CES. Our findings recognise EO as complementary tools to socio-cultural approaches for the evaluation of CES, aiding stakeholders in their management decisions focused on the resilience and sustainability of mountain protected areas.

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1 Introduction

Integrating biophysical and social aspects of ecosystems has become a cornerstone in conservation and sustainability mechanisms in protected areas worldwide (Daily, 2000). In these areas, local communities depend on and co-exist with protected landscapes, playing an important role in the management of ecosystems and their resources (Venter et al., 2014). In this context, the UNESCO "Biosphere Reserve" regime was launched to help reconciling conservation goals and the sustainable use of natural resources (Van Cuong et al., 2017), placing cultural benefits from ecosystems, generally known as cultural ecosystem services (CES), as a topic of interest in mountain socio-ecological systems (Schirpke et al., 2016, 2020).

CES offer an opportunity to explore how people interact with ecosystems, capturing multiple values from nature pertaining, for instance, to spiritual and inspirational enrichment, cognitive development, recreational engagement, or aesthetic fulfilment (Chan et al., 2012). Among others, CES opportunities promote tourism revenues, shape human heritage and traditions, and sustain public support for conservation investments (Wood et al., 2018). Nevertheless, under unsustainable management options, the over-exploration of CES may bring undesirable effects, for example by promoting human pressure and impacts on strictly protected biodiversity values (Buckley et al., 2016). Therefore, knowing where and how CES are shaped inside Biosphere Reserves is key to promote conservation policy, management, and communication.

Large digital data shared online have been increasingly used by researchers to support the identification and monitoring of CES at several scales (Richards & Friess, 2015). From this "digital conservation" perspective (Arts et al., 2015), the use of social media data to infer on CES is receiving particular attention (e.g. Egarter Vigl et al., 2021). The content analysis of publicly shared social media data, such as photographs, has been helpful to e.g., infer on aspects of nature appreciation (Vaz et al., 2020), monitor visitors' movements (Tenkanen et al., 2017), or identify visitors' preferences in protected areas (Hausmann et al., 2018).

Earth observation (EO) technology has also emerged as a promising tool to capture information on CES opportunities (Braun et al., 2018; Van Berkel et al., 2018; Vaz et al., 2019). The use of ancillary data from Geographic Information Systems (GIS) and satellite information can be particularly useful to describe and analyse the

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biophysical context and nature attributes that support CES opportunities, for instance by informing on the location of accessible cultural features (e.g., hiking trails or monuments) or by inferring on landscape visual-sensory characteristics (e.g., colour diversity and complexity) which are attractive to people (Tveit et al., 2006). Particularly when combined with social media analysis, EO can constitute a promising tool for CES monitoring in mountain protected areas (Vaz et al., 2019, 2020).

Nevertheless, despite the potential of EO and social media for addressing CES in mountain landscapes, their combined application is still far from being completely explored. Following our previous research on the subject (Vaz et al., 2019, 2020), this chapter uses publicly available data from the two digital sources to infer on CES opportunities in Biosphere Reserves. Specifically, we aim to: (a) identify which attributes contributing to CES prevail in the Biosphere Reserves, considering social media users' information; and (b) understand how those CES attributes relate with different biophysical and landscape settings, captured through GIS and satellite EO data. Our approach is tested in mountain landscapes from two contrasting Biosphere Reserves in the Iberian Peninsula (Southwestern Europe): Peneda-Gerês (Northern Portugal) and Sierra Nevada (Southern Spain).

2 Methods

2.1 Test Areas

Our approach focused on two mountain protected areas: Peneda-Gerês (part of the Gerês-Xurés Biosphere Reserve, in Northern Portugal) and the Biosphere Reserve Sierra Nevada (Southern Spain; Fig. 8.1). Elevation in Peneda-Gerês (950 km^2 area) ranges between 100 and 1548 m. The climate is Warm-Summer Mediterranean (following the Köppen-Geiger climate classification). The mean annual temperature ranges between 13 and 15 °C and the total mean annual rainfall is 2000 mm. Elevation in Sierra Nevada (1722 km^2 area) goes from 860 to 3482 m. The climate is mostly Hot-Summer Mediterranean, with mean annual temperature of 0 (above 3000 m) and 12–16 °C (below 1500 m), and total mean annual rainfall is 600 mm (reaching more than 1500 mm as snow during winter and above the 2000 m elevation). Both mountain areas hold several protection regimes (from Natural and National Parks to broader Natura 2000 Special Protection Areas), showing remarkable biodiversity values in the wider Mediterranean hotspot. The socio-economy in both reserves is grounded on recreational and touristic activities and traditional land use practices devoted to local agro-pastoral and farming revenues.

2.2 Empirical Approach

For the two test areas, we followed a three-step approach (Fig. 8.1A–C). First (A), we compiled a georeferenced dataset of in-field photographs from social media and

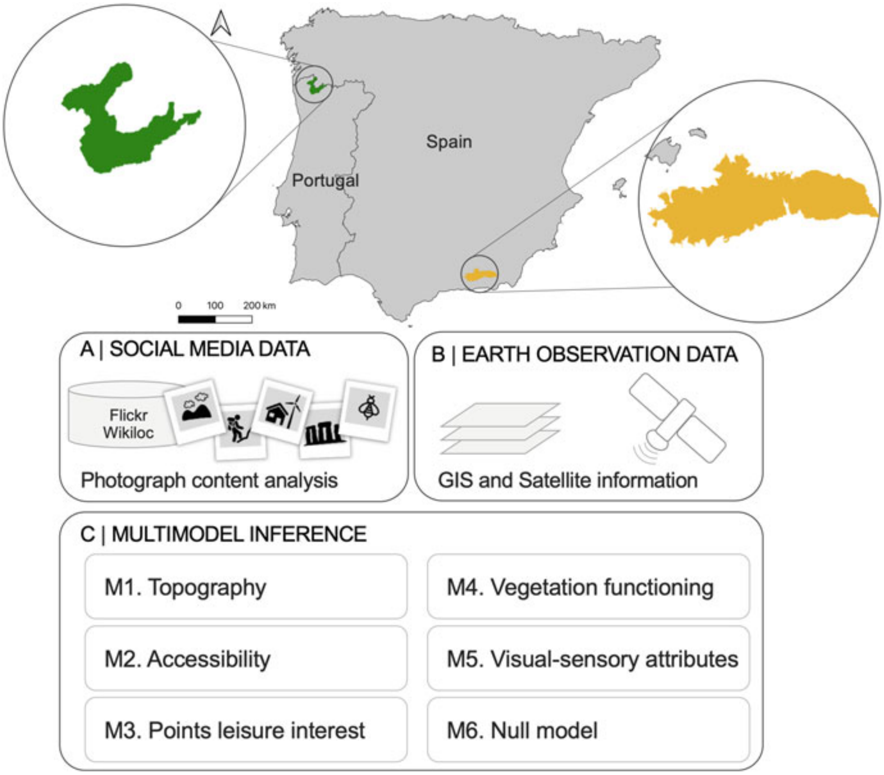

Fig. 8.1 Location of the test areas in the Iberian Peninsula (Southern Europe): Peneda-Gerês, in Portugal, and Sierra Nevada, in Spain

classified the possible CES opportunities displayed in each photograph. Then (B), we compiled a set of EO variables, including satellite information and ancillary GIS data, expressing attributes pertaining to topography, accessibility, points of leisure interest, vegetation functioning and landscape visual-sensory attributes, as potential predictors of the prevalence of those CES opportunities. Finally (C), we applied a Multi Model Inference (MMI) to evaluate the explanatory power of the selected predictors on CES (inferred from the social media content).

2.3 Social Media Data

We evaluated the content of social media photographs from Flickr and Wikiloc platforms, to identify nature attributes underlying CES opportunities, here understood "as the characteristics of elements of nature that provide opportunities for people to derive cultural goods or benefits" (Haines-Young & Potschin, 2018). Photographs were collected using the Application Programming Interface (API) from each social media platform together with Python tools, for the years 2015 to 2018 (see Vaz et al., 2020 for details on data collection). We considered this time period to coincide with the time from which satellite data from Sentinel 2 became available for both test areas (section: Earth observation data). For each photograph, we registered its spatial location (latitude and longitude) and manually classified its main content in one of the following categories: (1) Landscape and nature, i.e. 'wide-open' shots of nature, often with a visible horizon, representing people's enjoyment of landscape aesthetics (Richards & Friess, 2015); (2) Flora and fauna, i.e. close-up shots of animals or plants, broadly aligning with the CES of species appreciation (Goodness et al., 2016); (3) Recreation and sports, representing people engaging in recreational activities such as skiing or cycling (Richards & Friess, 2015); (4) Cultural heritage, dominated by cultural structures, e.g. historic monuments, relating to cultural heritage and spiritual enrichment (Blicharska et al., 2017); and (5) Rural tourism, i.e., human activities relating to social enjoyment, such as gastronomic enjoyment (Riechers et al., 2016). Given the experience of the team on the topic (e.g. Vaz et al., 2019, 2020; Ros-Candeira et al., 2020; Moreno-Llorca et al., 2020), and to minimise classification biases, the manual classification of the photographs was done by one author (ASV), being then independently verified by other two authors (RML and ASC). We excluded photographs with irrelevant subjects (e.g., advertisements, pamphlets, or drawings). Photographs protected by users' privacy were neither downloaded nor analysed. The final set included 1644 and 761 georeferenced photographs for Peneda-Gerês and Sierra Nevada, respectively.

2.4 Earth Observation Data

We considered an initial set of candidate variables, derived from the most updated and freely available satellite platforms and ancillary GIS data for modelling the distribution of CES opportunities in each test area (Table 8.1). GIS data included information on: (1) topography (i.e., elevation and slope), (2) visual (viewshed dimension) and physical (presence and distance to rivers, roads and trails) accessibility, and (3) points of leisure interest, namely presence and distance to touristic lakes, ski resorts, public recreational facilities, and villages (e.g. Schirpke et al., 2016; Yoshimura & Hiura, 2017). Satellite data from Sentinel-2a/b L1C images (available from the year 2015 to 2018) was considered to obtain information on: (4) vegetation functioning, i.e. through the Normalized Difference Vegetation Index, and (5) landscape visual-sensory attributes, including the amount and diversity of landscape colours using the visual RGB spectrum (e.g. Braun et al., 2018; Van Berkel et al., 2018). Following Vaz et al. (2019), visual-sensory attributes were computed separately for each meteorological season of the year: Winter (December–February), Spring (March–May), Summer (June–August) and Autumn (September–November). Based on a series of spatial autocorrelation tests with increasing moving-window sizes, a grid cell size of 500 $\times$ 500 m spatial resolution was considered suitable for subsequent analyses (see Vaz et al., 2020 for details).

Table 8.1 Types of predictors considered in each competing model (M) for both test areas with a brief methodological description

Variable types	Variables	Methodological description	Input data
M1 – Topography			
Elevation	Average elevation*	For each grid cell, we calculated the average and st. dev. of elevation and slope from all original pixels contained in that cell	Digital elevation model (20 × 20 m resolution)
	St. dev. Elevation		
Slope	Average slope*		
	St. dev. Slope		
M2 – Accessibility			
Roads	Road presence	For each grid cell, we considered the presence (or absence) of roads, rivers or trails in the cell (as 1/0) as well as the lowest distance from the cell to the closest road, river or trail	Local road network map
	Road distance*		
Rivers	River presence		Local river network map
	River distance*		
Trails	Trail presence		Local trail network map
	Trail distance*		
Viewshed dimension	Average viewshed*	For each cell, we calculated the average and st. dev. of the viewshed dimension values from all pixels contained in that cell	Digital elevation model (20 × 20 m resolution)
	St. dev. viewshed		
M3 - points of leisure interest			
Lakes	Lake presence	For each cell, we considered the presence or absence of lakes, ski resorts, public facilities or local villages in the cell (as 1/0) as well as the minimum distance from the cell to the closest lake, ski resort, public facility or local village	Local official distribution maps
	Lake distance*		
Ski resorts	Ski presence		
	Ski distance***		
Public facilities	Public presence		
	Public distance*		
Local villages	Village presence		
	Village distance*		
M4 - vegetation functioning			
Spatial NDVI	Average spatial NDVI*	We first calculated the average and standard deviation of the NDVI (Normalized Difference Vegetation Index) for the period 2015–2018 in each pixel (10 m); then the mean and st. dev. for all pixel values were calculated for each cell, reflecting the spatial variability of NDVI within each cell	Sentinel-2 MSI L1C images (10 m pixel resolution; time series 2015–2018)
	St. dev. Spatial NDVI*		
Temporal NDVI	Average temporal NDVI	We first calculated the average and standard deviation of the NDVI in each cell; then the mean and st. dev. of each cell were calculated for the period 2015–2018, reflecting the temporal variability of NDVI in each cell	
	St. dev. Temporal NDVI		

(continued)

Table 8.1 (continued)

Variable types	Variables	Methodological description	Input data
M5 - visual-sensory attributes			
RGB band reflectance	Average red spring, summer, autumn, winter	For each cell, we calculated the average and standard deviation of reflectance values for bands 2 (blue), 3 (green) and 4 (red) based on the original pixel values per meteorological season	Sentinel-2 MSI L1C images (10 m pixel resolution; time series 2015–2018)
	St. dev. Red spring, summer, autumn, winter		
	Average green spring*, summer*, autumn*, winter*		
	St. dev. Green spring*, summer**, autumn*, winter*		
	Average blue spring, summer, autumn, winter		
	St. dev. Blue spring, summer, autumn, winter		
Richness of RGB clusters	RGB clusters spring*	We performed a k-means unsupervised classification of the RGB bands (10-classes) per meteorological season for each cell; then, we computed the number of clusters in each cell per meteorological season	
	RGB clusters summer*		
	RGB clusters autumn**		
	RGB clusters winter*		
Diversity of RGB clusters	Shannon spring**	Based on the classified data described above, we computed the Shannon diversity index in each cell per meteorological season	
	Shannon summer**		
	Shannon autumn**		
	Shannon winter**		

The set of uncorrelated variables (Spearman value >0.6) used in the multi model inference is identified with asterisks for both areas (*), Peneda-Gerês only (**) and Sierra Nevada only (***). St. dev. stands for standard deviation

Input data was obtained from https://www.dgterritorio.gov.pt and https://snig.dgterritorio.gov.pt for Peneda-Gerês, and from https://laboratoriorediam.cica.es for Sierra Nevada

2.5 Multi Model Inference

The number of photographs of each CES category in each grid cell was used as response variable in a Multi Model Inference (MMI) framework (Burnham & Anderson, 2002). Six competing models (M) were used to test the hypotheses that CES were mostly explained by: M1 - topography; M2 - accessibility; M3 - points of leisure interest; M4 - vegetation functioning, and M5 – landscape visual-sensory attributes. Generalized Linear Models (GLM) with Poisson distributions (for count data) were fitted separately for each CES category (Burnham & Anderson, 2002) and implemented in the R software. The maximum number of predictors per model was set to four and only predictors with a pairwise Spearman value lower than 0.6 and Variance Inflation Factor (VIF) lower than 5 were considered, to avoid multicollinearity issues (Fox & Weisberg, 2018). A total of 27 and 22 predictors were considered for Peneda-Gerês and Sierra Nevada, respectively. For model comparison, we calculated the Akaike Information Criterion difference (ΔAICc), as ΔAICc = AICc initial - AICc minimum (where AICc initial is the second order AICc of the competing model and AICc minimum is the second order AIC of the best model in the set). We calculated the weight (wi) of each competing model, that represents the proportion of evidence from a competing model in relation to the total evidence from all models (ranging between 0 and 1). We also computed the Nagelkerke deviance D2, corresponding to the difference between the residual deviance of each competing model against the deviance of the null model (M6), as a goodness-of-fit measure of each competing model. Only models with a D2 value higher than 0.10 were considered (following Dormann et al., 2018).

3 Results and Discussion

From our results, the categories of CES attributes “landscape and nature” and “fauna and flora” were largely found in the content of social media photographs in both test areas, being congruent with the natural values that typically dominate protected areas (Hausmann et al., 2018; Richards & Friess, 2015). The category “recreation and sports” was also amongst the most frequently identified categories in Sierra Nevada, a pattern in agreement with the offer of high mountain-related activities (such as skiing). “Cultural heritage” and “rural tourism” were the least frequent in both areas, despite holding popular cultural traditions and festivities as well as rural villages of touristic importance (Fig. 8.2).

In Peneda-Gerês, “landscape and nature”, “fauna and flora” and “recreation and sports” were primarily explained by landscape visual-sensory attributes expressing the richness of colour diversity, particularly during the meteorological seasons with higher spectral contract, i.e., Autumn and Spring (Fig. 8.3, Table 8.2). This trend highlights the relation between landscape colour seasonality and landscape appreciation (Tveit et al., 2006), as previously suggested in Vaz et al. (2019). The easiness

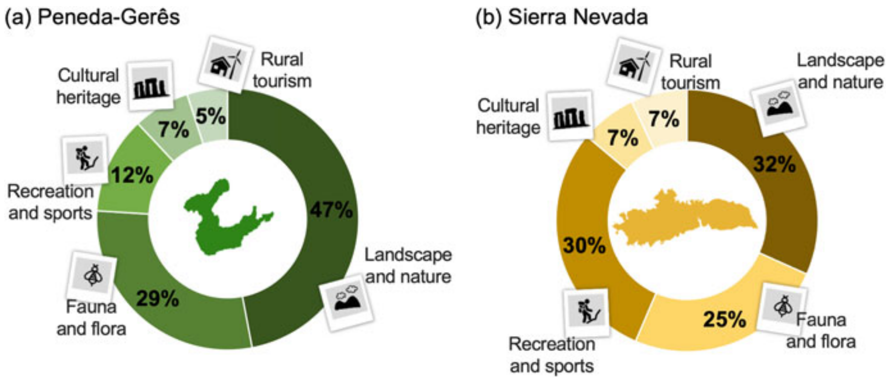

Fig. 8.2 Proportion of social media photographs assigned to each cultural ecosystem service in (**a**) Peneda-Gerês and (**b**) Sierra Nevada showing the prevalence of photographs capturing "landscape and nature" appreciation, "fauna and flora" and "recreation and sports". "Cultural heritage" and "rural tourism" were the least represented CES opportunities

	Competing models	Landscape and nature wi | D2	Fauna and flora wi | D2	Recreation and sports wi | D2	Cultural heritage wi | D2	Rural tourism wi | D2
Peneda-Gerês	**M1** | Topography	0.00 | 0.04	0.00 | 0.01	0.00 | 0.05	0.00 | 0.06	0.00 | 0.00
	M2 | Accessibility	0.00 | 0.11	0.00 | 0.07	0.00 | 0.11	0.00 | 0.14	1.00 | 0.16
	M3 | Leisure	0.00 | 0.11	0.00 | 0.06	0.01 | 0.12	1.00 | 0.25	0.00 | 0.07
	M4 | Functioning	0.00 | 0.02	0.00 | 0.01	0.00 | 0.01	0.00 | 0.09	0.00 | 0.00
	M5 | Visual-sensory	1.00 | 0.12	1.00 | 0.10	0.99 | 0.18	0.00 | 0.24	0.00 | 0.16
	M6 | Null model	0.00 | 0.01	0.00 | 0.00	0.00 | 0.00	0.00 | 0.00	0.00 | 0.02
Sierra Nevada	**M1** | Topography	0.00 | 0.01	0.00 | 0.01	0.00 | 0.14	0.00 | 0.06	0.00 | 0.06
	M2 | Accessibility	0.00 | 0.10	0.00 | 0.03	0.00 | 0.06	0.00 | 0.21	0.00 | 0.16
	M3 | Leisure	1.00 | 0.31	0.08 | 0.12	1.00 | 0.38	1.00 | 0.51	1.00 | 0.33
	M4 | Functioning	0.00 | 0.08	0.00 | 0.03	0.00 | 0.11	0.00 | 0.26	0.00 | 0.21
	M5 | Visual-sensory	0.00 | 0.25	0.92 | 0.15	0.00 | 0.32	0.00 | 0.36	0.00 | 0.26
	M6 | Null model	0.00 | 0.00	0.00 | 0.00	0.00 | 0.01	0.00 | 0.01	0.00 | 0.00

Fig. 8.3 Multi Model Inference (MMI) results: Akaike weights (wi) and explained adjusted deviance (D2) for each competing model. A gray shading (D2 > 0.10) is used in the figure to highlight the model with the highest explanatory power (dark gray) and those that follow (light gray), for each category of nature attributes underlying cultural ecosystem services (inferred from the content of social media photographs)

of visual and physical accessibility (namely through the viewshed dimension and distance to rivers) and the distance to public leisure facilities were also of high predictive relevance for landscape appreciation and recreational engagement. The importance of these variables in the creation of CES opportunities has already been

Table 8.2 Summary of results from each competing model holding explanatory power (highlighted in Fig. 8.3) for the distribution of social media photographs in Peneda-Gerês and Sierra Nevada. Models are presented from the best to the least fit hypothesis, based on the Akaike Information Criterion difference (ΔAICc) (see Fig. 8.3)

	Model	ΔAICc	Top predictors	Predictor type
Peneda-Gerês	**Landscape and nature**			
	M5 - visual sensory	0.00	RGB clusters spring (+)	Richness of RGB clusters
	M3 - leisure	48.71	Public distance (+)	Distance to public facilities
	M2 - accessibility	66.91	Average viewshed (+)	Viewshed dimension
	Fauna and flora			
	M5 - visual-sensory	0.00	RGB clusters autumn (+)	Richness of RGB clusters during autumn
	Recreation and sports			
	M5 - visual-sensory	0.00	RGB clusters summer (+)	Richness of RGB clusters during summer
	M3 - leisure	9.87	River distance (−)	Distance to rivers
	M2 - accessibility	15.93	Average viewshed (+)	Viewshed dimension
	Cultural heritage			
	M3 - leisure	0.00	Public distance (−)	Distance to public facilities
	M5 - visual-sensory	42.31	RGB clusters autumn (+)	Richness of RGB clusters during autumn
	M2 - accessibility	47.23	River distance (−)	Distance to rivers
	Rural tourism			
	M2 - accessibility	0.00	Road distance (−)	Distance to roads
	M5 - visual-sensory	16.48	RGB clusters spring (+)	Richness of RGB clusters during spring
Sierra Nevada	**Landscape and nature**			
	M3 - leisure	0.00	Lake distance (−)	Distance to lakes
	M5 - visual-sensory	147.47	RGB clusters spring (+)	Richness of RGB clusters during spring
	M2 - accessibility	376.56	Trail distance (−)	Distance to trails
	Fauna and flora			
	M5 - visual-sensory	0.00	RGB clusters spring (+)	Richness of RGB clusters during spring
	M3 - leisure	106.77	Lake distance (+)	Distance to lakes
	Recreation and sports			
	M3 - leisure	0.00	Ski distance (−)	Distance to ski resorts

(continued)

Table 8.2 (continued)

	Model	ΔAICc	Top predictors	Predictor type
	M5 - visual-sensory	4.80	RGB clusters summer (+)	Richness of RGB clusters during summer
	M1 - topography	34.00	Average slope (+)	Slope
	M4 - functioning	43.86	St. dev. Spatial NDVI (+)	Spatial heterogeneity of NDVI
	Cultural heritage			
	M3 - leisure	0.00	Lake distance (+)	Distance to lakes
	M5 - visual-sensory	409.4	RGB clusters summer (+)	Richness of RGB clusters during summer
	M4 - functioning	695.3	St. dev. Spatial NDVI (+)	Spatial heterogeneity of NDVI
	M2 - accessibility	761.5	Average viewshed (−)	Viewshed dimension
	Rural tourism			
	M3 - leisure	0.00	Lake distance (+)	Distance to lakes
	M5 - visual-sensory	60.59	RGB clusters summer (+)	Richness of RGB clusters during summer
	M4 - functioning	75.28	St. dev. Spatial NDVI (+)	Spatial heterogeneity of NDVI
	M2 - accessibility	102.9	Trail distance (−)	Distance to trails

Next to each model, we indicate the most explanatory predictors and whether these predictors were positively (+) or negatively (−) related to the CES categories

suggested for other mountain landscapes (Schirpke et al., 2016; Tenerelli et al., 2016; Vaz et al., 2019). CES pertaining to "cultural and heritage" and "rural tourism" were found to be primarily explained by the existence of human infrastructures, particularly in more accessible areas (e.g., closer to trails; Table 8.2).

In Sierra Nevada, CES opportunities were mostly driven by their proximity to points of leisure, including lakes, leisure infrastructures, and ski facilities, alongside with accessible features (i.e. trails). Nevertheless, landscape visual-sensory attributes, and particularly NDVI heterogeneity and richness of visible spectral colours, were also found to determine CES incidence. Landscape visual-sensory attributes during Spring were of particular relevance for explaining the cultural appreciation of "fauna and flora", which may well reflect the time in which animals (e.g., through active physiological behaviours) and plants (e.g., through colourful leaves and flowers) become more evident for the visitors (Table 8.2).

Overall, differences found in the predictors of "landscape and nature" and "recreation and sports" between both areas suggest that, in Sierra Nevada, visitors may rely largely on the presence of leisure infrastructures for their nature-based activities. For instance, skiing is extremely popular in high-altitudinal areas of Sierra Nevada and can only take place in the protected area due to sport facilities. Contrastingly, visitor preferences in Peneda-Gerês may be more determined by the visual-sensory characteristics of the landscape, without necessarily being constrained by human infrastructures. The occurrence of infrastructures was also prominent for “rural tourism” in Sierra Nevada, converging with the prevalence of rural villages of touristic importance in the region (e.g., Alpujarras), in contrast to Peneda-Gerês, where “rural tourism” category was more associated to accessibility. Despite these differences, the distribution of CES attributes associated to “fauna and flora” was mostly explained by visual-sensory properties in both areas, which may indicate the pursuit for wildlife appreciation in more diversified and natural landscape mosaics. Similarly, “cultural heritage” attributes were also largely explained by the same predictors in both protected areas, and much associated to the existence of public facilities and local villages.

The combined results for Peneda-Gerês and Sierra Nevada obtained in this study advance our understanding of the potentialities of using EO and social media data to identify opportunities for CES in mountain protected areas. Considering also previous research on these and other protected areas (Vaz et al., 2019, 2020), this study reinforces that the combination of satellite-derived metrics on vegetation functioning and colour diversity with GIS data, expressing accessibility efforts and the location of leisure facilities, can be used to inform cultural benefits in mountain protected areas, and thereby support the timely monitoring of human-nature interactions over wide spatial scales. Inevitably, some methodological considerations should be highlighted. For instance, in a MMI framework, the predictive power of a model is evaluated against the power of the other competing models, not necessarily meaning that the whole variation in CES is explained by that model. Also, although we can infer on the prevailing CES opportunities from the content of social media photographs, extrapolating which nature elements are indeed most preferred and selected by people should be done considering psychological (e.g., perceptions) and social (e.g., values) variables, that inevitably rely on the use of complementary socio-cultural approaches, such as participatory mapping or questionnaire-based surveys.

The combination of online interactions (i.e. through social media) and EO data used in this chapter showed to be promising to assess and monitor ecosystem features that underly CES opportunities (e.g. wide-view landscapes), yet the demand for those features and the way people enjoy them (e.g. “beautiful landscape”) will need further elucidations. Creating community science initiatives and encouraging citizen participation (inside and outside social media) to advance knowledge about nature’s cultural benefits to people in the targeted protected areas would constitute a further step to develop CES monitoring systems and to adopt more adequate management decisions. Considering that the EO data used in this chapter can be spatially projected (in a map) and timely updated, it can aid local managers in the identification of areas with synergies between biodiversity conservation and cultural/touristic values (Turnhout et al., 2013). It can also help to identify potential conflicts between tourism and strictly protected zones in Biosphere Reserves (Van Cuong et al., 2017), and thereby guide awareness campaigns or even target reinforcement actions to restrict accessibility and safeguard wider natural values in the mountain Biosphere Reserves.

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Chapter 9
Gendered Values, Roles, and Challenges for Sustainable Provision of Forest-Based Ecosystem Services in Nepal

Jyoti Sedhain and Elson Ian Nyl Ebreo Galang

Significance Statement Women empowerment and participation in forest management are essential to sustain critical natural benefits or ecosystem services (ES) that forests provide. In mountainous landscapes in Nepal, women are the core users or dependents of key forest-based ES such as food, fodder, and fuel to support their families' wellbeing. With the country's Community Forestry program, they gained capacities to participate and eventually become the stewards of sustainable management of these ES. However, several social-ecological challenges such as deforestation, illegal felling, and climate change threaten both the supply of forest-based ES and women's capacities for sustainable management. These results highlight the need to strengthen support for women in forest management to enable them to adapt better to the impacts of these challenges.

Keywords Forest management · Gendered values · Women participation · Community forestry · Migration

1 Introduction

Nepal is a landlocked mountainous country in the South Asian region with an area of almost 150, 000 sq. km. and an altitude ranging from 70 to 8, 848 m above sea level. Recent estimates show that the country has 40% of forest cover (Department of Forest Research and Survey [DFRS], 2015) with these forests providing various natural benefits or ecosystem services (ES) to huge populations in the country (Paudyal et al., 2017; Lamsal et al., 2018). These forest-based ES are particularly critical as sources of livelihoods (e.g., trading raw materials) and daily subsistence (e.g., fuel) to communities in the upland mountains that have poor access to socio-economic activities, social services, and infrastructures (Maren et al., 2013; Birch et al., 2014; Adhikari et al., 2018). Lowland mountain communities also benefit as

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the forests regulate soil and water retention, avoiding natural disasters such as landslides and flash floods.

As part of maintaining the sustainability of Nepal's forests and the benefits these provide, the country has been actively implementing the *Community Forestry* program and creating *Community Forestry User Groups* (CFUGs) which are institutionalized local groups that serve as stewards for specific forest patches or areas. By the end of 2017, there is over 1.8 million ha of forests under the program managed by more than 19, 000 CFUGs – around one-third of the country's entire population (DFRS, 2015). The program aims to not only conserve these forests but improve the participation of marginalized groups in the decision-making and forest management processes. Specifically, active engagement and empowerment of women have been an important core of this program (Agarwal, 2010). Through the years, these CFUGs, especially those that are considered women-managed CFUGs, have recognized and embraced gendered values, roles, and practices towards the management of forests and the use of forest-based ES (Giri & Darnhofer, 2010; Bhandari et al., 2018). Women's leadership and participation have proven essential in adapting to the skills, capacities, and needs of women. However, unprecedented social-ecological challenges (e.g., climate change) and other emerging global challenges (e.g., widening inequalities) have been detrimental to both the status of the forests and the gains from the program (Kozar et al., 2020; Sapkopta et al., 2020).

Given this rationale, we aim to provide empirical information on how social-ecological challenges in the mountains of Nepal are affecting gendered values and practices towards sustainable management of these forests and the provision of forest-based ES. We first establish the differentiated gendered roles on forest management and values of forest-based ES among members of CFUGs. We then discuss the gender-based perspectives on social-ecological challenges that CFUGs consider detrimental to sustainable forest management.

2 Methodology

We focus our study on the mountainous landscapes of the Chitwan District of Nepal [83 50′–85 00′ E and 27 15′–27 40′ N] (Fig. 9.1). This district has the following characteristics: total land area of around 2200 sq. km with 14% considered having very steep slope; elevation range from 245 m to 2, 000 m above sea level; and sub-tropical climate with a rainy season from June to September. In 2011, the District recorded almost 580, 000 residents with 52% females. Sixty percent of the district has forest cover and is being managed by 89 CFUGs.

For this study, we selected four CFUGs from Chitwan District which include (1) Ranikhola CFUG which covers 200 ha with 162 households, (2) Kankalni CFUG which covers 749 ha with 2098 household users, (3) Chelibeti CFUG which covers 55 ha with 171 households, and (4) Chaturmukhi CFUG which covers 309 ha with 344 households. Out of the 2781 households in all four CFUGs, we randomly

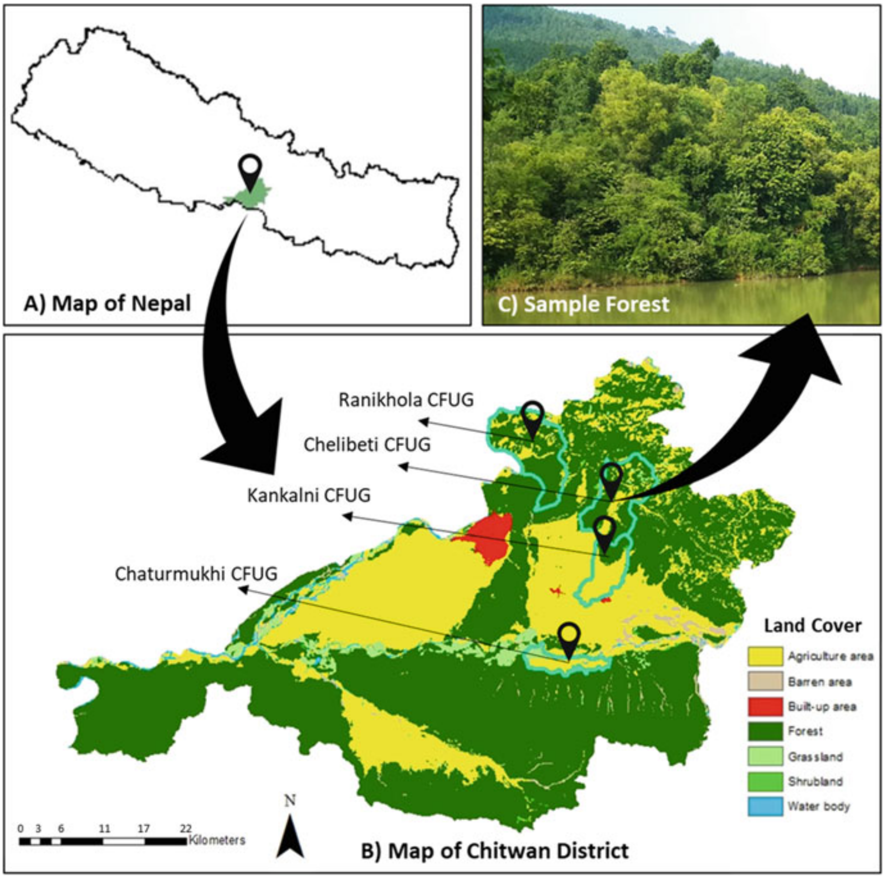

Fig. 9.1 Land cover map of Chitwan District showing the locations of the four Community Forestry User Groups (CFUG) included in this study (**b**). Inset above shows relative position of Chitwan District in Nepal (**a**) and a sample view of the forest in Chitwan District (**c**). (Photo by Jyoti Sedhain)

selected 380 household representatives, balancing gender count (i.e., 187 females and 193 males), for a survey using a structured questionnaire with questions about gendered roles in forest management, values of forest-based ES, and perceptions on social-ecological challenges for the landscape. We present the summary socio-demographic information about our survey respondents in Table 9.1.

We supplemented the quantitative results of the survey with qualitative narratives from 12 key informant interviews (KII). These KIIs included women leaders, the elderly, officers of CFUGs, school teachers, and local government officials. Additionally, we held eight focus group discussions (FGD) with 7 to 12 target members of the CFUGs participating in each to provide a more in-depth understanding of the gendered social-ecological dynamics within these landscapes.

Table 9.1 Summary socio-demographic information about the CFUG members in Chitwan District, Nepal who were surveyed in this study

	Women (%[a])	Men (%[b])
Age		
15 to 30	25	16
30 to 45	45	32
45 to 60	24	36
60 above	5	17
Education		
Did not go to school	51	35
Primary school	9	18
Secondary school	21	21
Vocational	14	22
College	5	4
Length of membership in the CFUG		
1 to 5 years	10	8
5 to 10 years	23	12
10 to 20 years	41	55
20 years above	22	20
Not yet a member	4	5

[a]As percentage of the total number of females (n = 187)
[b]As percentage of the total number of males (n = 193)

Table 9.2 Dependency on key provisioning forest-based ES among CFUG members in Chitwan District

	Women (%[a])	Men (%[b])
Food	100	100
Raw materials	57	42
Fuel	67	72
Fodder	78	78
Timber	32	39

[a]As percentage of the total number of females (n = 187)
[b]As percentage of the total number of males (n = 193)

3 Results and Discussions

3.1 Values of Forest-Based Ecosystem Services

Our approach to identifying values of forest-based ecosystem services (ES) provided by the mountain landscapes of Chitwan District was to assess dependency on key provisioning ES (Table 9.2). We determined that these provisioning ES, as supported by other literature (e.g., Paudyal et al., 2017), are essential for the wellbeing of the upland communities since the difficult physical conditions (i.e., steepness with poor roads) posed by the mountains make commercial access or alternatives of them difficult. Moreover, we define dependency as regular obtainment of these key ES from the forests to support either their diet, income, or survival. Our results present that both men and women have high dependencies (>50% of respondents per gender) on food, fuel, and fodder.

All respondents depend on forests for food, such as fruits, nuts, wild meat, and wild or cultivated plants, which are eaten directly or prepared as part of meals. We identify that the most common farming systems in the landscape practiced by households are various forms of agroforestry systems in which fruit, timber, or native forest trees are combined with annual plants (e.g., vegetables) or livestock/ poultry raising.

The majority of both genders also recognize forests as sources of fuel which are parts of trees (i.e., twigs, branches) that are directly used or processed as charcoals for cooking and household heating. This mirrors Nepal's huge national reliance on fuelwoods as the main source of energy (Kandel et al., 2016). Huge equal proportions in both genders also identify fodder for animals as essential ES from the forest in which tree parts and perennial shrubs are used as feedstuff. This can be explained by 84% of the respondents owning and raising livestock, mostly cattle and goats, which are their main protein sources.

While all three forest-based ES are valued by the majority of both genders, our KIIs and FGDs revealed an important difference. Like other literature has shown too (e.g., Lama et al., 2017), men undergo seasonal migration of at least six months to neighboring India, Gulf countries (e.g., Qatar), and Southeast Asian region (e.g., Malaysia) for jobs which provide their families' main sources of income (Ministry of Labour, Employment and Social Security [MLESS], 2020). This migration usually happens after the monsoon or around mid-May to June. As in the case of other reported communities (Gill, 2003; Lama et al., 2017), traditional migration patterns (i.e., before the 2000s) in our study sites involved men leading the preparation and planting of cash and other valuable horticultural crops in suitable areas of the landscape. Their wives and children will tend on these crops until men return just in time before harvests. They also used to stock key forest-based ES (e.g., fuel, fodder) to leave for their families. However, this has evolved with recent development and economic progress among nearby urban centers (Gill, 2003; MELSS, 2020). In our study sites, when not migrating, it was revealed to us that men would now rather choose non-agricultural or non-forestry works (e.g., employment or small business) in nearby urban centers instead of engaging in forestry or agriculture-related works in the landscapes. This new condition leaves women in these CFUGs to serve as the key ES users and managers. Specifically, women spend more than three-quarters of their day looking for food, fuel, and fodder in the forested landscape as compared to men. All year-round, they remain in the communities, feeding their families, managing their family's resources, and tending their livestock. This situation is also reflected in the majority of women's dependency on the forests for raw materials (e.g., fibers) which are directly or processed for trading and, in turn, serve as an additional income for their families. In one of the FGDs, a woman participant commented:

> We cannot depend anymore on men in the village to obtain items from the forests, that's why we women should be active. If we need men's help for some physically-demanding works to get these items, we need to ask for help from other villages! - *Elderly woman housewife*

Our KIIs and FGDs, as supported by our respondents' socio-demographic (Table 9.1), also show how women's lack of even basic education hinders them from obtaining jobs outside the villages. Women who have the education also face tougher competition as jobs available for women in urban centers are very few. Thus, while men have accessed these increasing opportunities in the urban centers, women do not have considerable options given such educational and job availability barriers. To support these increased roles and responsibilities, Community Forestry guidelines have explicitly provided power to women in benefit sharing and legal authorization to decide on their family's property and finances.

Timber from the forests is the least recognized forest-based ES for both genders. Timber is not traded for income but is instead used to build or repair their homesteads and wooden furniture. Men in households are traditionally the ones who do these works during their off-season stay in their villages; however, this pattern is now threatened with the changing job priorities among men.

Overall, these findings in this section point to how women's value for forest-based ES can be considered as more significant because of their longer and more intense reliance on these benefits for their family's daily and year-long survival. Seasonal outmigration by the men, difficult physical/topographical conditions, and lack of outside opportunities have all shaped women's high dependency on their landscape as they interact with it for food, fuel, and fodder daily.

3.2 Gender Roles in Sustainable Forest Management

Community Forestry (CF) has been recognized to empower women in the sustainable management of forests and the ES these provide (Agarwal, 2010; Bijaya et al., 2016). Our results (Table 9.3) support this in which almost the same proportion of men and women are engaged in the five main roles identified by CF guidelines for sustainable forest management. In contrary to traditional perceptions that women are passive actors in forest management, our findings below allow us to assert that women are as actively involved as men across the CFUGs (Varghese & Reed, 2012; Wagle et al., 2016).

Almost all respondents participate in seedling propagation and silvicultural activities such as weeding, pest management, and pruning/trimming. Each CFUGs

Table 9.3 Participation in the main roles in forest management among CFUG members in Chitwan District

	Women (%[a])	Men (%[b])
Seedling propagation	99	98
Silvicultural activities	97	98
Forest fire management	29	29
Forest ranging	3	4
Planning	8	7

[a]As percentage of the total number of females (n = 187)
[b]As percentage of the total number of males (n = 193)

maintain their respective tree nurseries in which households co-grow seedlings and later on plant these in pre-identified areas of their respective forests. Eventually, households maintain these seedlings until they grow mature enough to be left on their own. Almost a third of both genders have also been active in forest fire management, a regular occurrence in these mountain landscapes (Matin et al., 2017). Other key roles (i.e., forest ranging and planning) were participated by significantly fewer in both genders. Forest ranging is a paid assignment for a selected few in which members of the CFUGs are tasked to rove and check the forest area/ patch for potential problems (e.g., encroachment). Our KIIs and FGDs show that this was traditionally a men's assignment; however, we also now show how CFUGs have capacitated some women to deliver such a role.

On the other hand, planning includes the formulation of activities and projects. Community Forestry guidelines additionally require that 50% of decision and executive positions should be held by women members. While planning is open to all members of the CFUGs, our results found that only those who are officers in these positions, both men and women, are involved in the planning process. We see this as an area of further improvement. Nonetheless, our interviews and discussions also revealed that more women than men attend CFUG meetings and which we see as a good indicator of women's interests in these processes. In complement, an interesting emerging theme is the increasing men's support for women's participation in decision-making processes. In a KII interview, the respondent shared that:

> My husband highly encouraged me to participate in the meetings and to serve our CFUG executive committee. He supports me to attend these meetings and do other things outside my responsibilities for the household. I feel empowered to raise my voice in the meetings and bring women agenda in forest planning.- *Woman officer in one of the CFUGs*

While women have less education than men in these communities (Table 9.3), the Program has provided women the skills development training and capacity-building activities to provide them with competencies to effectively deliver these roles. Community Forestry guidelines even require that a quarter of CFUG's fund should be used for gender-friendly strategies and projects. We also found that 60% of women respondents felt that the Program has given them more confidence to take charge of their respective forest areas/patches and handle forest-based ES.

In this section, we demonstrate that women's interactions with their landscape are not limited to obtaining these forest-based ES but also as stewards of these forests. Such roles could be further magnified with women's year-long stay in these landscapes. Also, having empowered women who can effectively participate and independently deliver responsibilities is particularly important in these mountains as government foresters and environmental workers have minimal resources to regularly observe and monitor progress and activities.

3.3 Social-Ecological Challenges in Mountain Landscapes

These critical ES provided by the forests (Table 9.2) and the gains of women in sustainably managing them (Table 9.3) are under threat for various social-ecological challenges (Table 9.4). Among these is deforestation and/or illegal felling of trees which have been recognized by a majority of both men and women. Deforestation is clearing portions of the forest which, based on our interviews, were mostly because of illegal conversion to monocultural agricultural lands.

Deforestation in our study sites could be traced back to the institutional and governance issues we have identified concerning CF guidelines. Forests under the CF program or those managed by these CFUGs are considered government-owned lands. However, the program also allows the leasing of portions of these lands to members of the CFUGs for exclusive maintenance and use, following standards by the program and benefit-sharing agreements with the CFUG. However, we found that there are emerging conflicts between numerous lessees and the government because of the conversion of the leased forest portion to agricultural lands. The main reasons for this include (1) perceived increasing difficulty to obtain the forest-based ES (esp. food) that might be due to impacts of other social-ecological challenges (e.g., increased demand for ES due to additional users through encroachment as discussed below) and (2) increasing realization that monocultural agriculture can provide immediate food and cash. We learned that the Chitwan District Forestry Office uses tripartite negotiations among their office, the CFUGs, and the concerned lessee to solve such issues.

On the other hand, illegal felling or the practice in which individual or few trees in the forest are unlawfully cut is usually done by the poorest members of the CFUGs. This practice is usually done at night when forest ranging is very limited. Cut trees are sold as timber; thus, becoming a fast cash source for those most financially needy. Institutional and governance issues in CF have also been credited as one of the main drivers of illegal felling. Specifically, CF guidelines allow the cutting of trees, especially those that are old and deformed that pose risks to the community. However, each CFUG has an annual allotment on the number of trees that can be cut. These are supposed to be sold based on benefit-sharing agreements in each CFUG.

Table 9.4 Perceived social-ecological challenges affecting forest-based ES in Chitwan District, Nepal

	Women (%[a])	Men (%[b])
Climate change	40	31
Infrastructure development/ Urbanizing effects	34	41
Forest fires	16	16
Migration	10	9
Deforestation/ Illegal felling	74	72
Encroachment	40	38

[a]As percentage of the total number of females (n = 187)
[b]As percentage of the total number of males (n = 193)

Because this process is could be tedious given all the administrative steps that have to be followed and benefits cannot be solely owned, several observe illegal felling.

Another important challenge that a significant percentage of both genders have identified is encroachment. Specifically, non-members of CFUGs or those from other villages would enter their CFUG's perimeters to obtain forest-based ES, increasing competition and endangering sustainable levels of supplies of such services. In a KII interview, the respondent informed us that:

> There are now many illegally-built huts and even shifting cultivation areas created by non-members of our CFUG. I feel like this is because of the population increase, continued poverty, lack of awareness, and lack of necessary actions taken by the government- *Woman officer in one of the CFUGs*

Interestingly, apparent gendered differences can be seen in recognizing climate change and infrastructure development as challenges. A higher proportion of women, especially those 45 years old above (Table 9.1), identify climate change and its emerging impacts such as increased frequency of forest fires, longer droughts, and more unpredictable weather patterns. This was well summarized by one of the participants of an FGD who shared that:

> All that is happening before was just in time. We know when we would plant and harvest. . .when the plants will flower and fruit. *Middle-aged woman farmer*

One possible reason for this higher recognition trend among women is their year-round stay in the communities as compared to seasonal stay by men, allowing them to more extensively compare the full-year climactic dynamics in the landscapes. These changes are adversely impacting women's health and wellbeing as they are the ones who are more immersed in the field to obtain various forest-based ES (Table 9.2). To adapt to these impacts, women have either to spend more time and effort when out in the forests; ask their children more time too to help out; or simply reduce the use of these ES (e.g., shifting to cooking meals which are quicker to cook, thus using fewer fuelwoods).

Infrastructure development such as road construction and the urbanizing effects these bring (i.e., increased commercial activities and consumerist lifestyle) is a challenge that more men are particularly keen about. The synthesis of men's narratives indicates their concerns about how such development has recently been limiting local demands of their traditional enterprises and occupation. For example, several men respondents claim that the demand for traditionally made items (e.g., rattan or bamboo-based household items) has drastically reduced recently as community members now have access to plastic or their more modern counterparts. Numerous women echo this as well since the majority of women are the ones dependent on the forests for raw materials (Table 9.2). However, our KIIs and FGDs disclose a more hopeful tone in which women hope that their families have better access to social services and children have better access to education. Nonetheless, both men and women have reservations on how continued infrastructure development might eventually affect their established social-ecological dynamics in the future. In a KII, one respondent said that:

> For me, increased road access has both positive and negative benefits for the community. Positive benefits are improved job creation at the local level and easy access to education, health services, and other basic needs and facilities. However, people are now preferring quick, easy, and cheap things from the markets in the urban centers. This has direct impacts on the traditional and local industries - *Young woman self-entrepreneur*

Other challenges that were identified by at least a tenth of respondents in each gender are forest fires and migration. Forest fires are either natural which are caused by lightning or man-made which usually result from poorly managed charcoal making or shifting cultivation in portions of the landscape. Our discussions and interviews also revealed that human mistakes have increasingly caused some forest fires. This is because when forest paths are cleared multiple times a year, some would choose to burn collected litter and cuttings without proper control.

Finally, as discussed in the earlier section, migrations coupled with changing job priorities have been a rising cause of concern lately. These upland communities have been seeing huge proportions of younger populations, like those 30 years old and below (Table 9.3), moving out of the mountains more permanently this time instead of just seasonal labor migrations. Even if this could mean that there is lower demand for these forest-based ES, there are also apprehensions that future manpower to effectively manage the forests can be endangered. Moreover, a synthesis of our interviews indicates that women are afraid that the strong social ties in the community that has long shaped sustainable management of these resources might slowly fade out.

In this section, our findings present that the sustainable provision of forest-based ES in mountain landscapes is already being affected by social-ecological challenges. Impacts of each, as well as collective impacts as one affects the other, are now being experienced not only in terms of supply of these ES but also on the overall social-ecological dynamics in these upland communities (e.g., increasing natural resource-based conflicts). We further argue that women are more vulnerable than men to experience heavier impacts of these challenges as women are the ones who use and manage these forest resources more intensively, as presented in the previous sections.

4 Conclusions

Our study presents that the forests in the mountain landscapes of Chitwan District, Nepal are sources of key ecosystem services (ES) that are valued by women as much as men to support their family's living and livelihoods. We consider the values of these forest-based ES to be more substantial for women as they benefit more directly, spending the majority of their daily activities throughout the year to source these ES from the landscape.

We also show evidence that the Community Forestry program, through membership with Community Forestry User Groups (CFUGs), has empowered these women by providing them skills and capacities that allowed them to be as proactive as men in participating in various roles in the sustainable management of these forests. Thus, women have become not only the main beneficiaries of these ES but as the lead stewards of these forests. However, these make women also the more vulnerable group in the CFUGs to the emerging impacts of various social-ecological challenges. Interactions of these challenges might further exacerbate one another. For example, climate change might reduce ES supplies across the landscape, potentially worsening encroachment problems. Thus, we believe that women's skills and capacities must be further expanded and supported to enable them to respond or adapt better to the impacts of these challenges. The Community Forestry program should also regularly revisit its guidelines and mechanisms so that CFUGs could continue enjoying the ecosystem services while effectively managing their mountain landscapes.

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Chapter 10
Environmental [In]Equity: Accessibility to Green Spaces in a Rapidly Urbanizing Mountain-City

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Significance Statement Open Green Spaces (OGS) provide a range of cultural ecosystems services including health benefits through recreational and tourism opportunities. Rapid and oftentimes unplanned urbanization can result in the loss of OGS, negatively affecting urban dwellers' health and wellbeing. An example is the rapidly expanding city of San Carlos de Bariloche, located in the Argentinean Patagonia, surrounded by the iconic Nahuel Huapi National Park. The study reported here sought to assess the availability and distribution equity of public OGS in Bariloche. The study found inequalities in access and distribution; 'wealthier' neighbourhoods offered more OGS than poorer neighbourhoods. Better regulation of development is required and future land use plans need to preserve and protect future OGS sites and improve access points to existing OGS to ensure more equitable access to diverse natural landscapes.

Keywords Environmental justice · Patagonia · Urban parks · Open green space

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1 Introduction

Open green spaces (OGS), including publicly-accessible parks and natural areas, provide many ecosystem services to urban dwellers (Byrne & Sipe, 2010; Byrne et al., 2009; Liu et al., 2017). Social benefits include improved health and wellbeing, social cohesion and identity, and recreation opportunities. OGS support biodiversity, provide carbon sequestration, improve air and water quality, intercept storm water, and regulate temperature, among other benefits (Konijnendijk et al., 2013). Urban residents who frequently visit OGS are reported to experience better sleep, improved mood, lower blood pressure, stronger immune systems including suppressed cancer, and reduced levels of stress and anxiety (Li, 2010; Li et al., 2011; Morita et al., 2007). OGS confer such benefits not only to individuals, but also to broader communities, making neighbourhoods safer and more liveable (Parks Canada, 2014). However, many urban dwellers lack easy access to OGS, presenting an environmental equity concern (Byrne et al., 2010). This can be especially pronounced in counties experiencing rapid urbanization.

In Latin America, more than 80% of the population lives in urban areas (ONU-Habitat, 2012). Argentina is the most urbanised country, with 92% of the population living in cities, and is more urbanised than Europe and the USA (Bolay, 2018). In recent decades, Argentinean cities, as with many Latin American cities, have experienced rapid and poorly regulated growth, often entrenching social inequalities and heightening socio-economic marginalisation and disadvantage (Rigolon et al., 2018; Sánchez et al., 2007). Such rapid and unplanned urban growth also has many negative socio-ecological consequences, including the loss of public OGS and reduced access to mountains, lakes, rivers, and coastal areas (Moretto & Zalazar, 2014). While our understanding of the benefits stemming from green and open space accessibility, including contact with nature, is now well recognised in countries such as the United States, United Kingdom and Australia, these issues are comparatively poorly understood in Latin America, presenting an important knowledge gap (Boulton et al., 2018).

A recent review of published scientific studies found only 46 articles studying urban green space accessibility in countries of the so called 'Global South' (Rigolon et al., 2018). From those 46 studies, eight articles assessed Latin American cities and only one article referred to an Argentinean city – Buenos Aires (Rigolon et al., 2018). Most studies conducted in Latin America have shown distribution inequities – typically, 'wealthier' residents live closer to open green spaces than more socio-economically vulnerable residents. Also, wealthier residents tend to have access to a greater number and higher quality of OGS (Rigolon et al., 2018). This study aimed (i) to assess the availability and distribution equity of public open green spaces in San Carlos de Bariloche, Rio Negro, Argentina and (ii) to open a discussion about the reasons behind the unequal socio-spatial distribution of these important nature spaces.

2 Methods

2.1 Case Study

San Carlos de Bariloche is one of the fastest growing Patagonian Andean cities in Argentina with a 21% intercensal growth rate surpassing provincial and national growth rates (Niembro et al., 2019). The city's urban-footprint extends over 270 km^2 and has an estimated population of over 136,800 people (calculated based on Niembro et al., 2019). Bariloche is also subject to important amenity migration processes (González et al., 2009), driving uncontrolled and fast-paced urban-development (Niembro et al., 2019), with concomitant social and environmental impacts, including inequalities in access to urban and peri-urban OGS.

Bariloche city is surrounded by Nahuel Huapi National Park (NHNP), the first Latin American park and one of the major parks in Argentina. Bariloche is known for its amazing mountain landscapes, natural forests, and glacier-lakes, which make it one of the main national and international tourism destinations in Argentina. Although the city is surrounded by the NHNP, public access to the park is limited as most of its boundaries neighbour private land. Similarly, although the city abuts Lake Nahuel Huapi, much of the shoreline is held in private ownership with few public beaches and access points.

These constraints to publicly accessible OGS prompted us to investigate residents' accessibility to officially created, gazetted, and publicly managed OGS. For this study we consider OGS as comprising all publicly available natural or seminatural areas within the municipal boundary (Fig. 10.1). We followed the classification used by Byrne and Sipe (2010) distinguishing between pocket/playground parks typically smaller than 1 Ha, neighbourhood parks sizing between 1 Ha and 5 Ha, community parks ranging from 5 Ha to 10 Ha, district parks sizing from 10 Ha to 25 Ha and regional parks (over 25 Ha).

2.2 Data Collection and Analysis

Data used to conduct the spatial analysis comprised: the last Argentinean 2010 georeferenced-census (INDEC, 2020) including the Unsatisfied Basic Needs Index (NBI) a measure of poverty, developed by INDEC (2020), public open green spaces (Municipalidad de Bariloche, 2021), and neighbourhoods (Open Street Maps). Because the published geo-census information did not match neighbourhood boundaries, the census information was combined with the neighbourhood layer using QGIS 3.10. The resulting layer contained census information. That information includes NBI (Unsatisfied Basic Needs) by neighbourhood, as calculated using QGIS. With the resulting neighbourhood layer, and using Hot Spot (Getis Ord Gi) analysis, we assessed the city's population distribution, highlighting areas with

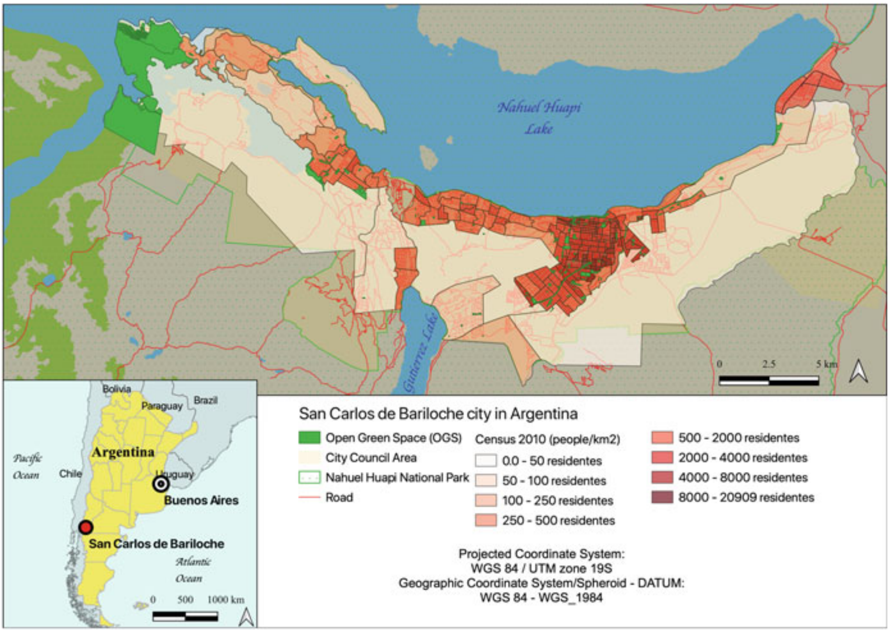

Fig. 10.1 Location of San Carlos de Bariloche city in Patagonia-Argentina showing open green spaces in comparison to the city's socio-demographic profile

higher probabilities of: (a) population concentration and (b) higher density of population with unsatisfied basic needs.

Assessing open green space availability and distribution can be done in many ways. The most common method is assessing the city's "Green Area Index" (GAI) and "Green Space Ratio" -GSR- (Garcia et al., 2020). These indexes are both a measure of OGS provision. As shown in the equations below, GSR (Eq. 10.1) represents the percentage of area covered by OGS in an urban area while GAI (Eq. 10.2) represents the amount of green space per person in squared meters (m^2/resident). Using these measurements enables researchers and policy-makers to better assess greenspace distribution within a city, including at smaller neighbourhood scales. For instance, with the polygon layers representing the neighbourhoods and OGS we calculated, using Eq. 10.1, the GSR for the whole urban area as well as per neighbourhood individually. This approach provides valuable information to urban planners, furnishing detailed information about existing OGS's provision and accessibility, potentially enabling future planning for more equitable, sustainable and liveable neighbourhoods (Carrus et al., 2015; Wolch et al., 2014).

$$\text{Green Space Ratio (GSR)} = \frac{\Sigma\, OGS(m^2) * 100}{Urban\ Area\ (m^2)} \tag{10.1}$$

$$\text{Green Area Index (GAI)} = \frac{\Sigma\, OGS(m^2)}{Population} \tag{10.2}$$

Although these measures are widely used and generate valuable information, in some cases GAI and GSR indexes may not provide clear results. For instance, these measures may indicate that there is sufficient provision of green space when, in reality, that green space is concentrated in one sector of the city. For this reason, we also employed a standard proposed by the World Health Organization (2017), specifying that all residents should have an OGS of at least 0.5 Ha close to their home. Although the WHO used 300 m Euclidean distance from home, we used instead 500 m as COVID restrictions in some cities in Argentina allowed people to commute only that distance to access nature for recreational purposes. Using QGIS, we calculated a 500 m Euclidean buffer area computing the unserved neighbourhood areas for all OGS as well as for those over 0.5Ha. We then calculated the difference between the neighbourhood served area versus unserved area, identifying whether all residents have the same access opportunities to OGS within 500 m of their homes.

Some scholars contend that spatial analyses alone can mask as much as they reveal with respect to OGS access, because they tend to treat OGS homogeneously (Boulton et al., 2018). To address this concern, and account for potential differences in the design and character of OGS, we also assessed residents' preferences for natural settings. These settings included larger, natural landscapes, not available within the urban core. We conducted a visitor survey in peri-urban day-use areas of the Nahuel Huapi National Park. Two of the selected sites, Seccional Lago Gutierrez (16 km from Bariloche CBD) and Refugio Neumeyer (24 km from Bariloche CBD) are located on the outskirts of Bariloche, while the other two sites, Refugio Frey and Refugio Jacob are located further in the mountains. The intercept survey sought to understand people's preferences and needs for recreational opportunities in more naturalistic settings. The instrument assessed: (i) recreational activity type, (ii) landscape preferences, including from highly-natural to highly-modified green spaces, and (iii) duration of visit. The visitor survey was conducted during high visitation periods in Summer 2017, where all visitors arriving and leaving the sites were invited to participate. We distinguished between residents and tourists. The sample size resulted in 421 completed-questionnaires, exceeding the minimum sample size to represent Bariloche's population and required to ensure a 95% confidence interval for the statistical analysis (Veal, 2011).

3 Results

3.1 Spatial Analysis of Urban OGS

Bariloche city has 409 OGS, including plazas, coastal areas and parks. Most of these OGS (86%) are pocket parks, smaller than 0.5 Ha (68%), or parks smaller than 1 Ha

(18%). Also present are 47 neighbourhood parks (11%). These OGS are mainly managed landscapes, with some lawn area and recreation equipment, including playgrounds for children and some sports facilities (e.g., football pitch, skate park). Bariloche also has five community parks, located mostly within the city proper, which are managed for recreation and tourism, three district parks, located in the peri-urban area of the city and four regional parks, all located in the peri-urban western side of the city, where fewer people live. In total, Bariloche has over 1514 ha of OGS with a 16% Green Space Ratio (GSR) and a Green Area Index (GAI) of approximately 111 m^2/person. However, 84% of the total green space area is located exclusively in the peri-urban area, 26 km west of the city centre. What this means, is that most residents lack everyday access to these larger OGS; instead, they may only have access to smaller, highly modified OGS within the urban core. Excluding those seven big peri-urban parks, the GAI index is just 17 m^2/person and the GSR is 2.5%.

Moreover, parks in Bariloche are not evenly spatially distributed, meaning residents lack adequate access to OGS. For instance, 52% of all 113 neighbourhoods have no OGS at all, while those neighbourhoods with OGS have an average 6.3% GSR per neighbourhood, with 12 neighbourhoods presenting under 1% GSR, 34 presenting between 1% and 10% GSR and only 8 neighbourhoods presenting over 10% GSR. In addition, calculations based on a 500 m Euclidean distance show that 39% of all neighbourhood areas lack easy access to OGS, and this percentage increases to 57% when considering access to OGS over 0.5 Ha (Fig. 10.2).

These inequalities are more evident in vulnerable neighbourhoods, where the likelihood of people having unsatisfied basic needs increases dramatically (Fig. 10.3b). For instance, we counted 27 parks -of which 18 are small parks and only nine have more than 0.5 Ha- where the spatial hotspot Getis Ord Gi cluster analysis significantly indicated a likelihood concentrated poverty. Many residents in those neighbourhoods live further than 500 m to any OGS (Figs. 10.2 and 10.3). Exacerbating such inequalities, in Bariloche, is the fact that many residents in those under-served neighbourhoods have limited ability to travel to natural areas, leaving them with few options for nature access. In contrast, wealthier residents have both the means to travel (transport, money and time) and access to a larger amount of OGS near their homes – a salient environmental inequality.

Compounding the OGS availability issue is another problem – as suggested earlier, design of OGS matters. Our findings suggest OGS design seldom accounts for residents' needs. Much of the existing OGS in the city fails to provide opportunities for accessible non-modified nature-contact, presenting an important policy shortcoming. In planning OGS, many planners use provision standards designed for a homogeneous population (Boulton et al., 2018). Planners here, and elsewhere, have seemingly failed to account for the differential needs of children, older people, teenagers and people with disabilities, among others (Byrne et al., 2010). For example, and not surprisingly, in Bariloche most citizens are concentrated near the inner core and Central Business District (CBD), where larger OGS (i.e. district or regional scale parks) are uncommon. Although larger OGS provide opportunities for everyday nature-contact and active recreation, their spatial distribution is skewed towards comparatively advantaged populations (Figs. 10.2 and 10.3). Most residents

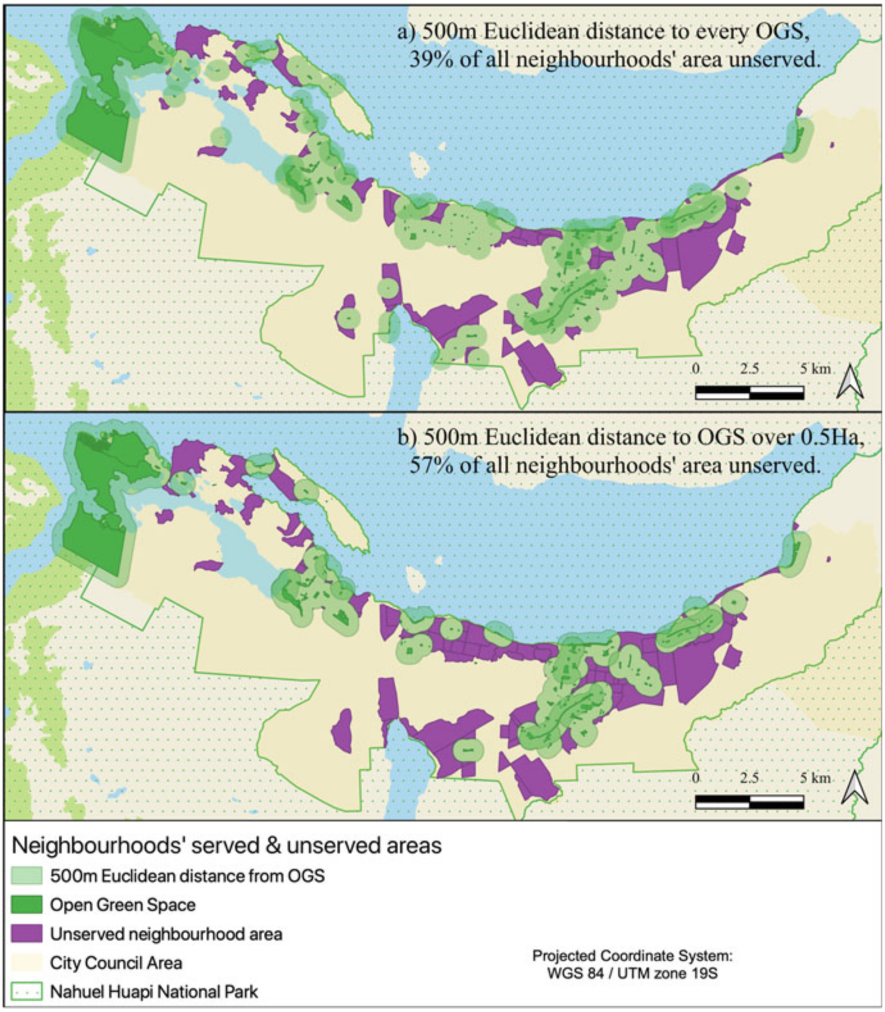

Fig. 10.2 Open Green Space (OGS) distribution in Bariloche city showing the neighbourhood lacking OGS as well as the areas within the neighbourhoods falling outside the 500 m linear distance from (**a**) any OGS and (**b**) OGS larger than 0.5 Ha

in higher density neighbourhoods appear to have ready access to very-small parks, but are precluded from accessing nature-based recreation opportunities on the peri-urban fringe, such as running, hiking or mountain biking.

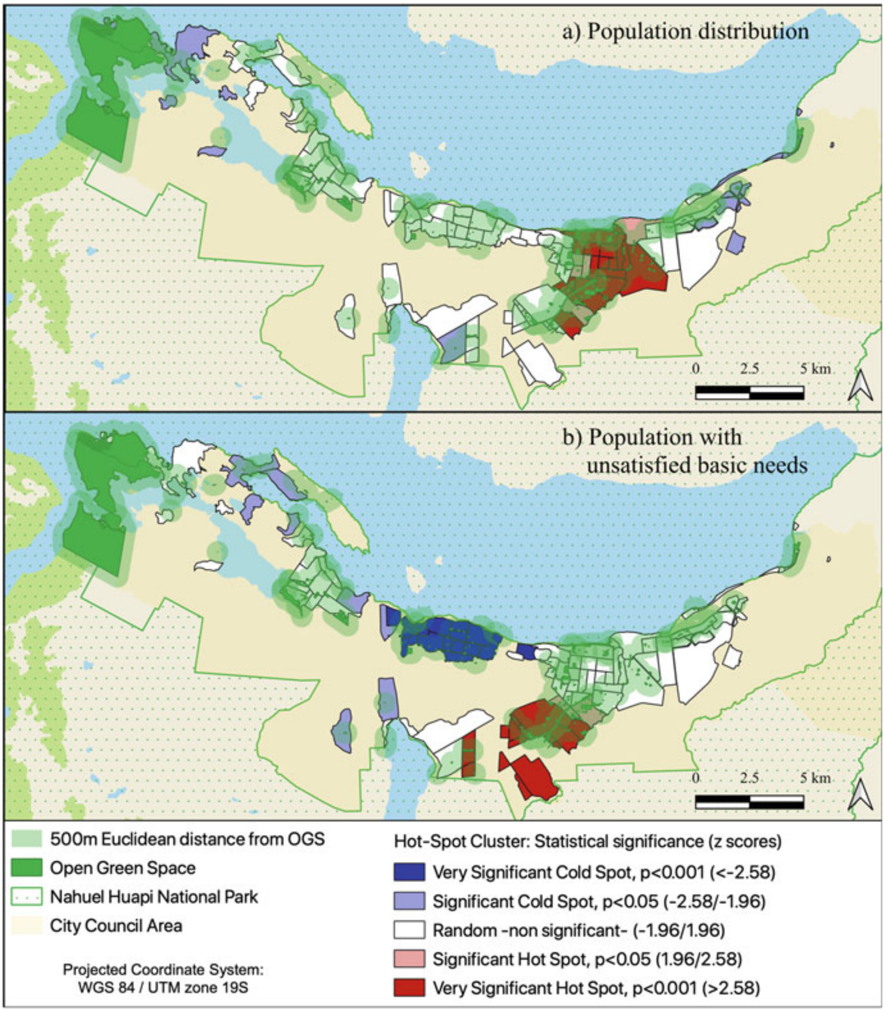

Fig. 10.3 Urban green spaces distribution in Bariloche's city and 500 m linear distance (Euclidean) from parks compared with the city's population concentration and the places where most people present unsatisfied basic needs. The spatial Hot Spot (Getis ord Gi) analysis indicates a) neighbourhoods with significantly high population density (red[s]) and vice versa in blue[s] and b) neighbourhoods where it is significantly more likely that people have unsatisfied basic needs (red [s]) and vice versa in blue[s]

3.2 Natural Areas' Visitors' Survey

To validate the results of the GIS analysis, we conducted a survey within larger, peri-urban OGS areas in Bariloche. This intercept survey showed that most users – both tourists and locals – prefer unmodified landscapes (96%), whereas only 4% reported liking "highly modified landscapes" such as urban-parks. Hiking was the most common recreational activity, representing 60% of large OGS usage, followed by trekking (26%). Most users tended to spend between 2 and 4 h (39%) or over 5 hours (22%) in the larger OGS, while under a fifth (19%), spent less than 2 h. These results indicate that residents with the ability to access larger OGS have strong preferences for natural spaces and opportunities for active recreation.

4 Discussion

Since the creation of the first public parks, OGS have been recognised as the 'green lungs' of the city. Paradoxically, on occasions such as the COVID-19 pandemic, when people's needs for fresh air are especially evident, OGS access remains out of reach of many city dwellers in Bariloche, presenting an environmental inequality. Although Bariloche is surrounded by Nahuel Huapi National Park, not all residents have easy access to that natural landscapes – a common issue in relatively large cities, even those in close proximity to protected areas, such as Los Angeles, USA or Lavras, Brazil (Byrne et al., 2009; Garcia et al., 2020). In Bariloche, this phenomenon could be related in part to the city's "proximity" to the National Park, with urban planners possibly assuming that this large protected area to some extent compensates for fewer nature spaces in the city. For instance, Bariloche's urban planning policies indicate that the totality of the urban area footprint is developable, failing to set aside land for OGS (Rodriguez, 2022). Planning policies seemingly fail to account for residents needs for accessing nature-based recreation opportunities.

Another phenomenon to consider is that rapid and poorly regulated urban growth has been characterised by informal neighbourhoods intruding into what were once natural areas (Niembro et al., 2019; Rigolon et al., 2018). Such patterns of urban growth are typical in the developing world, and can deliver land-access equity of a sort. The most vulnerable groups meet their housing needs through informal settlements, but these are very precarious settlements with a range of challenges, including exposure to natural hazards, waste management issues and urban service provision (Byrne, 2021). It is usually beyond the capacity of urban authorities to regulate these settlements, resulting in disparities not only in housing quality, but also in access to ecosystem service benefits.

Typically, once informal settlements have gained empowerment and social-recognition, the authorities have no other option than formalising the situation, eventually providing infrastructure and services to those "new neighbourhoods". Not only does this result in the incremental loss of OGS, it also means disparities related to access to nature's service benefits become formalised and locked in to the city's morphology. In Bariloche, this has been happening for some decades (Niembro et al., 2019), making proper urban planning and especially OGS planning almost impossible. Bariloche is recognised nationally, and also promotes itself, as a 'beautiful-landscape' and 'very-natural' city, where local residents and visitors 'can enjoy' contact with nature in every corner and as easily as 'just going out'

(Patagonia, 2021), yet our research suggests that for many residents, the lived experience is different.

Our analysis of OGS' distribution shows greenspace equity in Bariloche is not just a matter of the city having too few parks. The GSR per neighbourhood analysis highlights diverse inequalities related to distribution, access and socio-ecological benefits. This situation was aggravated during the COVID-19 pandemic, when city lockdown restrictions to prevent the spread the virus SARS-CoV-2 confined residents to their immediate neighbourhoods. In some cases, authorities restricted people's travel to a maximum of 500 m from their residence. As with other cities, the mental health and physical wellbeing implications of being confined to greenspace-deprived neighbourhoods are still to be fully understood. Given that in Bariloche about 39% of the neighbourhoods do not have access to UGSs within 500 m Euclidean distance, and that existing parks do not provide for the diverse needs of citizens, it is likely that there will be medium to long term negative health effects (Ives et al., 2018; Pouso et al., 2020).

The study reported here has analysed the availability and distribution of public OGS using spatial information. However, the study presents some limitations. For instance, the geo-census data published as "census-radius" do not match the neighbourhoods' shapes, necessitating the generalisation of results per neighbourhood. Therefore, results reported should be interrogated more robustly through future research, such as surveys to determine the nature preferences of residents in the urban core.

5 Conclusion and Final Remarks

Urban and peri-urban open green spaces play an important role in urban dwellers' daily routines, recognised for their ability to improve and maintain physical and mental health. It is imperative then, that greater efforts are made to protect extant OGS and to remedy disparities in access and distribution. The methods and results of this study can help identify under-served neighbourhood areas, prioritising the authorities' efforts to remedy socio-spatial disparities in OGS access. Future urban-plans for mountain cities like Bariloche should consider alternative mechanisms for setting aside a wider variety of greenspace areas, suitable for providing urban dwellers with the opportunity to access diverse natural landscapes within walking distance of where they live. Traditional planning mechanisms are clearly not working, especially in the case of informal settlements. Innovative practices might include using informal greenspaces alongside infrastructure such as pipelines and railroads to create linear natural corridors, joining different neighbourhoods and parks, larger natural areas, and even long accessible coastal areas. Other more controversial approaches could include working with squatters to set aside land in informal settlements for urban nature – potentially as multi-functional spaces for stormwater management, food-growing, silviculture and eco-tourism.

Future research could test some of these ideas and new techniques for OGS provision, aiding developing countries where informal housing and land 'taking' is a major issue. This may include traditional planning approaches, such as working with the authorities to strategically plan future growth areas, based on current information such as population trends, to include OGS in planning and associated recreational activities and health benefits. Alternative approaches might also entail working with vulnerable group leaders, to help minimise the impacts of informal neighbourhoods, and work with, rather than against, the 'problem', knowing that at some stage those 'informal-settlements' will become formalised and thus require proper consideration for future OGS needs and nature's service benefits.

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Chapter 11
Ecosystem Services and Sustainable Development in the European Alps: Spatial Patterns and Mountain-Lowland Relationships

Uta Schirpke

Significance Statement Mountain regions provide various goods and services to people such as fresh water, timber, climate regulation, and recreation. This chapter illustrates the spatial distribution of eight key ecosystem services across the European Alps and adjacent lowland areas and analyses linkages with sustainability. The results indicate important spatial mismatches between (semi-)natural mountain environments and densely populated lowlands and between ecosystem services and sustainability. More attention should be paid on transportation processes and human well-being across different spatial scales to support the sustainable development of mountain socio-ecological systems.

Keywords Human-nature interactions · Socio-ecological system · Mountain-lowland systems · Spatial mismatches · Sustainability indicators

1 Introduction

Mountain socio-ecological systems provide multiple ecosystem services such as fresh water, timber production, climate regulation, and recreation (Grêt-Regamey & Weibel, 2020), which are mostly co-produced through human-nature interactions. Beneficiaries are not only the local residents and tourists but also the people living in the adjacent lowlands (Grêt-Regamey et al., 2012; Schirpke et al., 2019a). For example, lowland populations often obtain fresh water from the mountains or visit mountain regions for recreational activities. Hence, service-providing areas are often dislocated from benefitting area (Syrbe & Grunewald, 2017), as the capacity of ecosystems to provide goods and services greatly depends on spatial characteristics and environmental conditions such as climate, land use/cover and topography

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(Mengist et al., 2020). Such spatial discrepancies require the transportation of goods or the movement of people to benefit from the services provided, if the demand for certain ecosystem services exceeds the provision at the local level (Serna-Chavez et al., 2014). In mountain-lowland systems, hotspots of ecosystem services supply are predominantly located in mountain areas, whereas the beneficiaries are mostly located in the lowland areas (Grêt-Regamey et al., 2012; Schirpke et al., 2019a). These spatial misbalances can create dependencies of people in the lowlands from services provided by mountain regions (Grêt-Regamey & Weibel, 2020; Meisch et al., 2019).

In mountain ecosystems, which are highly susceptible to global change, an increasing demand for ecosystem services such as outdoor recreation may lead to increasing pressure on mountain ecosystems (Jäger et al., 2020b). Therefore, a profound understanding of interactions between human activities and ecological processes in such vulnerable system is fundamental to develop sustainable management strategies that aim at maintaining the supply of multiple ecosystem services and at preserving biological diversity (Huber et al., 2013), not only locally or regionally but also at cross-national level. Spatially explicit and quantitative analyses of multiple ecosystem services are therefore essential to generate knowledge about mountain-lowland interactions of multiple ecosystem services (Mengist et al., 2020). In particular, analyses that account for supply, demand and actual use of goods and services contribute to an enhanced understanding of spatial interactions and incongruences (Spake et al., 2017).

In this chapter, quantitative and spatially explicit analysis of multiple ecosystem services in the European Alps and adjacent lowlands is presented, focusing on mountain-lowland interactions. Key ecosystem services include fresh water, grassland biomass, fuel wood, filtration of surface water, protection against mountain hazards, carbon sequestration, outdoor recreation and symbolic species. By linking and further elaborating data provided by previous studies (Schirpke et al. 2019a, b, c), this chapter highlights (1) differences in the spatial distribution of ecosystem services across mountain and lowland areas, (2) spatial mismatches between supply and demand requiring transfer processes, and (3) spatial linkages between ecosystem services and sustainability. Finally, recent and future challenges in mountain socio-ecological systems under global change are indicated.

2 The 'Alpine Space Programme' Cooperation Area

The 'Alpine Space Programme' cooperation area (hereinafter referred to as ASP) is located in central Europe and includes the European Alps as well as the surrounding foothills and lowlands (Fig. 11.1). It covers about 390,000 km^2 and comprises Austria, Switzerland, Liechtenstein and Slovenia, as well as several regions of France, Germany and Italy. The ASP is characterised by significant topographical and climatic differences, different populations and cultures, resulting in a high variety of landscapes. The core mountain range, the European Alps, represent one

Fig. 11.1 The 'Alpine Space Programme' cooperation area and distribution of major land cover types in the mountain and lowland area

of the largest continuous near-natural areas in Europe and the landscape is strongly influenced by traditional small-scale farming (Flury et al., 2013), with the exception of the valley bottoms. Instead, large-scale intensive agriculture and metropolitan regions dominate the surrounding lowlands and foothills (Dematteis, 2009). The ASP has a population of about 70 million, mostly living in strongly urbanized areas in the lowlands. The European Alps are one of the most important European tourist destinations with more than 100 million visitors each year (Batista e Silva et al., 2018), besides offering a wide range of recreational opportunities to the people living in the ASP.

To disentangle the differences in ecosystem services between the mountain regions and the lowland areas, this study separated mountain areas from lowland areas by applying a threshold of terrain ruggedness (difference in elevation >200 m between the value of a cell and the mean of an 8-cell neighbourhood of surrounding cells; Körner et al., 2011). Mountain areas, covering 47% of the total area (37% of the municipalities), are characterized by a high share of near-natural ecosystems, whereas lowland areas are dominated by agriculture and have a higher share of artificial surfaces (Fig. 11.1).

3 Spatial Distribution of Key Ecosystem Services

Eight key ecosystem services (Table 11.1) were identified for the ASP through literature review, expert workshops and a user survey and account for specificity, representativeness, easiness of communication as well as controllability at different policy levels (Schirpke et al., 2019a). The geospatial datasets of all ecosystem services are available at the municipality level (www.alpes-webgis.eu),

Table 11.1 Indicators of eight key ecosystem services, distinguishing supply, actual use and demand.

Category	Ecosystem service	Indicator		
		Supply	Actual use	Demand
Provisioning service	Fresh water (WA)	Water availability[a]	Water use[b]	Water abstraction[c]
	Grassland biomass (GB)	Gross fodder production[d]	Net fodder energy content[e]	Feed energy requirements[f]
	Fuel wood (FW)	Wood biomass increment[g]	Wood removals[h]	Potential fuel wood requirements[i]
Regulating service	Filtration of surface water (FS)	Potential nitrogen removals[j]	Effective nitrogen removals[k]	Nitrogen loads[l]
	Protection against mountain hazards (MH)	Protection forest[m]	Object-protecting forest[m]	Infrastructure in hazard zones[m]
	Carbon sequestration (CS)	CO_2 sequestration by forests[n]	CO_2 sequestration by forests[n]	CO_2 emissions[o]
Cultural service	Outdoor recreation (OR)	Outdoor recreation availability[p]	Visitation rates[q]	Potential beneficiaries (residents and tourists)[r]
	Symbolic species (SY)	Habitat distribution of symbolic plants and animals[s]	Occurrence in hotel names[t]	Not assessed

[a] http://www.wikialps.eu/doku.php?id=wiki:water_use
[b] http://www.wikialps.eu/doku.php?id=wiki:water_abstraction
[c] http://www.wikialps.eu/doku.php?id=wiki:gross_fodder_production
[d] http://www.wikialps.eu/doku.php?id=wiki:net_fodder_energy_content
[e] http://www.wikialps.eu/doku.php?id=wiki:feed_energy_requirements
[f] http://www.wikialps.eu/doku.php?id=wiki:wood_biomass_increments
[g] http://www.wikialps.eu/doku.php?id=wiki:wood_removals
[h] http://www.wikialps.eu/doku.php?id=wiki:fuel_wood_requirements
[i] http://www.wikialps.eu/doku.php?id=wiki:nitrogen_removals
[j] http://www.wikialps.eu/doku.php?id=wiki:nitrogen_removal_2
[k] http://www.wikialps.eu/doku.php?id=wiki:nitrogen_loads
[l] http://www.wikialps.eu/doku.php?id=wiki:protection_forest_calc
[m] http://www.wikialps.eu/doku.php?id=wiki:co2_sequestration
[n] http://www.wikialps.eu/doku.php?id=wiki:co2_emissions
[o] http://www.wikialps.eu/doku.php?id=wiki:recreational_offer
[p] http://www.wikialps.eu/doku.php?id=wiki:visitation_rate
[q] http://www.wikialps.eu/doku.php?id=wiki:habitats_of_symbolic_species
[r] http://www.wikialps.eu/doku.php?id=wiki:occurrence_in_hotel_names
[s] http://www.wikialps.eu/doku.php?id=wiki:water_availabilty
[t] http://www.wikialps.eu/doku.php?id=wiki:beneficiaries

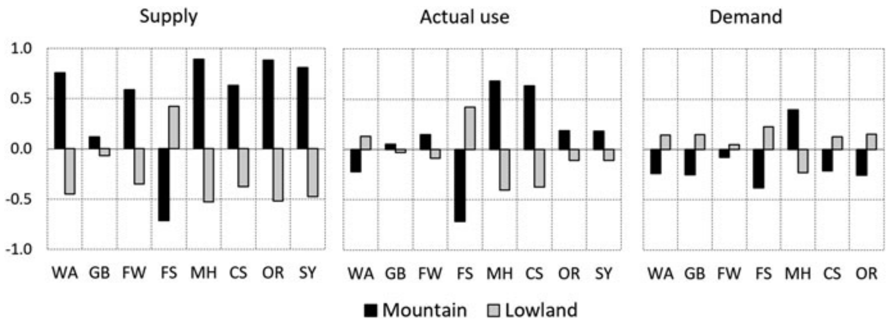

Fig. 11.2 Z-scores depicting the deviation of ecosystem service values of mountain and lowland area from the average of the entire study area. Positive z-scores refer to above-average values and negative z-scores to below-average values. Fresh water (WA), grassland biomass (GB), fuel wood (FW), filtration of surface water (FS), protection *against mountain hazards (MH), carbon sequestration (CS), outdoor recreation (OR), symbolic species (SY)*

differentiating between supply, actual use and demand. Ecosystem services supply is defined as the capacity of ecosystems to provide ecosystem services, while the actual use indicates the level of use (Burkhard & Maes, 2017). The demand for ecosystem services indicates the amount of a service required and/or desired by society (Wolff et al., 2015). For most ecosystem services, supply, demand and actual use were quantified at the landscape scale on a pixel basis with a resolution of 25 m (grassland biomass, fuel wood, filtration of surface water, protection against mountain hazards, carbon sequestration) or 100 m (fresh water, outdoor recreation, symbolic species) using various spatially explicit indicators (Table 11.1). Some indicators, such as the number of residents and tourists, were only available at the municipality level. All indicators were subsequently aggregated to the municipality level and area-weighted mean ecosystem service values calculated. In this chapter, we use the max-standardized mean values at municipality level for analysing spatial relationships.

The spatial distribution of supply, actual use and demand for the eight ecosystem services varies greatly across mountain and lowland areas within the ASP (Fig. 11.2). The supply and actual use of most ecosystem services is higher in mountain regions compared to lowland areas, with the exception of filtration of surface water and fresh water for the actual use. This can be explained by the higher amount of natural and near-natural ecosystems in mountain areas and related biophysical processes as well as by the location of benefitting areas for goods or cultural services. In contrast, lowland areas have a higher demand for ecosystem services due to higher population density and a more intensive agricultural use. Only the demand for protection against mountain hazards is higher in mountain regions due to topography.

4 Spatial Mismatches Between Supply and Demand and Transfer Processes

Differences between ecosystem services supply and demand at the municipality level indicate great spatial variations of deficits or surpluses (Fig. 11.3). In particular, fresh water, fuel wood, protection against mountain hazards and outdoor recreation have a surplus in ecosystem services supply in mountain regions. Deficits can be found for carbon sequestration across the entire ASP and for all other ecosystem services, with the exception of filtration of surface water, in various locations in the lowlands.

Each ecosystem service has specific spatial relationships between service-providing area and benefitting area (Syrbe & Grunewald, 2017), which leads to different transfer processes (Fig. 11.4). These include the active transport of goods to the beneficiaries through human infrastructure for provisioning services, i.e. fodder and fuel wood are transported by road, rail or ship and fresh water by pipelines. Passive biophysical transport through ecological processes from polluting areas to service-providing ecosystems occurs for regulating services such as filtration of surface water or carbon sequestration, while protection against mountain hazards does not involve transfer processes. For cultural services, it may be necessary that people move to natural environments to benefit from recreational opportunities, or, in case of symbolic species, ideas or information are distributed through printed or digital media. In the study area, the direction of the spatial transfer is mainly from the mountains to the lowland areas for fresh water, fuel wood as well as symbolic species due to spatial mismatches between demand and supply. In the case of outdoor recreation, the main direction is from the lowlands to the mountains, which is mainly related to the unequal distribution of appealing landscapes with high recreation potential across the ASP. Carbon sequestration is directionless, while filtration of surface follows the water flow.

5 Spatial Linkages Between Ecosystem Services and Sustainability

Although the concept of ecosystem services focuses on human well-being and human-nature interactions, ecosystem service assessments usually do not evaluate their results with regard to sustainability (Huber et al., 2013; Schirpke et al., 2019c), i.e., whether managing mountain landscapes for increasing or maintaining the provision of specific ecosystem services also supports the sustainable development of mountain socio-ecological systems. Considering the three dimensions environment, society and economy as equally important, sustainable development aims at supporting long-term socio-economic progress while protecting the environment.

To evaluate the spatial overlap between ecosystem services and sustainability for mountain and lowland regions, sustainability indicators at the municipality level

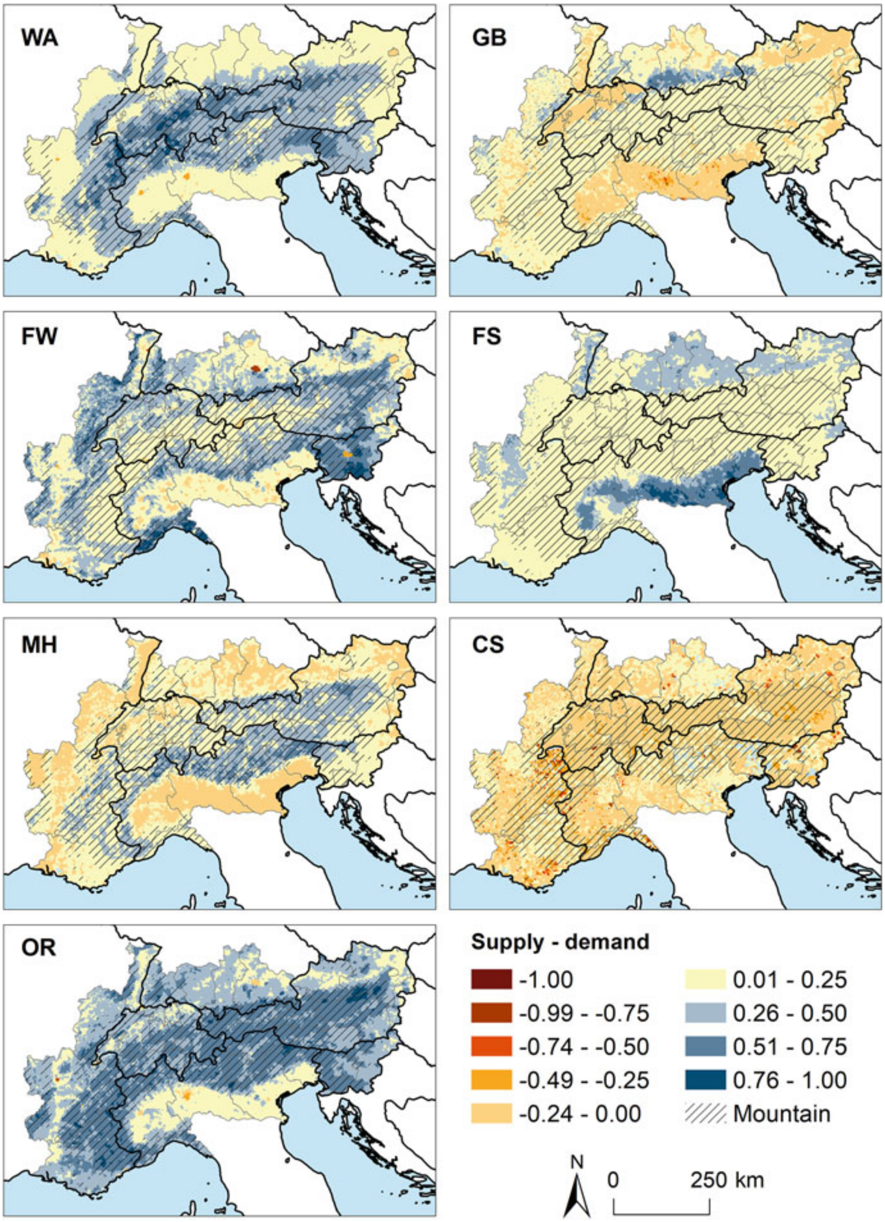

Fig. 11.3 Differences between supply and demand for standardized ecosystem services values at municipality level. Fresh water (WA), grassland biomass (GB), fuel wood (FW), filtration of surface water (FS), protection against mountain hazards (MH), carbon sequestration (CS), outdoor recreation (OR). Demand for symbolic species (SY) was not assessed

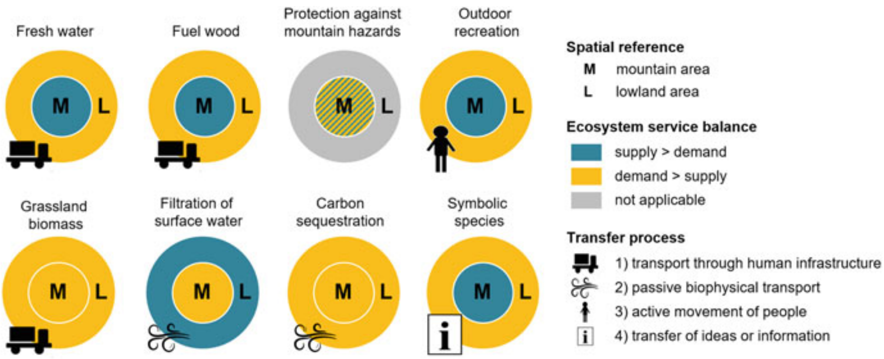

Fig. 11.4 Generalized scheme of spatial interactions and transfer processes between mountain areas (M) and surrounding lowlands (L) for eight ecosystem services. For each area (M, L), the colours indicate whether this area is a service-providing area (supply > demand) or a service-demanding area (demand > supply). The different symbols indicate four different types of transfer processes (1–4). Figure modified from Schirpke et al. (2019b)

were used from Schirpke et al. (2019c). The 24 indicators represented the three dimensions of environment, society or economy and were related to various topics such as biodiversity, land use, population, households and labour market (Fig. 11.5). A total sustainability index was calculated by standardizing all indicators to values between 0 and 1 and by subsequently aggregating them to a total value with the three dimensions equally represented.

The sustainability index is generally higher in mountain areas than in most lowland areas due to above-average values for indicators related to environment (Fig. 11.6). Nevertheless, indicators related to society are generally stronger in lowland areas, whereas those related to economy and environment are mostly above average in mountain areas (Figs. 11.5 and 11.6). These spatial differences are also reflected in the spatial distribution of supply and demand for ecosystem services. Accordingly, areas of high supply of ecosystem services often coincide with high sustainability, while, in particular, urbanized area with a high demand for ecosystem services in lowland areas have low sustainability values. These results suggest that the supply of ecosystem services may reflect well the environmental dimension of sustainability, although a high supply does not imply a sustainable use of natural resources. In contrast, social and economic dimensions are rather related to the demand side, indicating misbalances between more rural or urban areas.

6 Recent Developments and Future Challenges

The spatial analysis of multiple ecosystem services in the ASP indicates significant supply-demand mismatches across landscapes, i.e. mountain regions are generally hotspots of ecosystem services supply, whereas highly urbanized areas or intensively

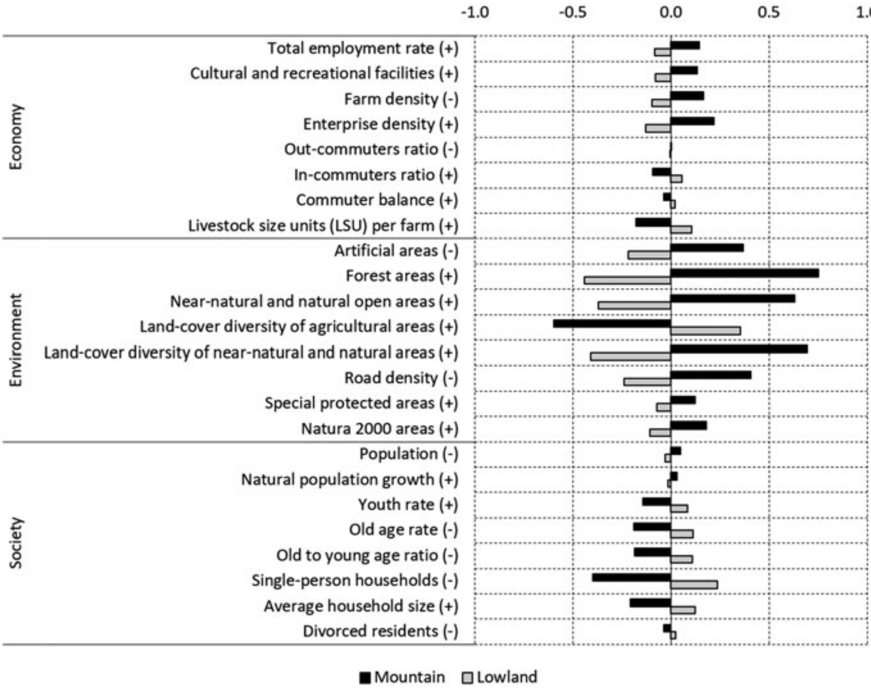

Fig. 11.5 Sustainability values of mountain and lowland areas represented by 24 indicators that are attributed to the three dimensions environment, society or economy. Z-scores depict the deviation of sustainability values of mountain and lowland areas from the average of the entire study area. Positive z-scores refer to above-average values and negative z-scores to below-average values. The influence of each indicator on the respective dimension of sustainability is indicated by + = positive and - = negative

used agricultural areas, mostly located in the adjacent lowlands, are related to high demand for ecosystem services (Grêt-Regamey et al., 2012; Schirpke et al., 2019a). Consequently, the spatial flow is directed from mountain regions towards lowland area for many ecosystem services, but transfer processes often involve interactions at the global level (Schirpke et al., 2019b). Such dependencies will become even more important in the future due to global change (Grêt-Regamey & Weibel, 2020). For example, changing rainfall patterns are likely to increase water stress in the southern parts along together with an increasing water demand of the urban population in the lowlands (Meisch et al., 2019), which leads to higher levels of water insecurity and a higher necessity to obtain water from the mountain regions. Accordingly, the southern regions will be affected by a decline in the production of grassland biomass due to water scarcity, while productivity may increase in low-elevated hillslopes due to increasing temperatures provided that there is enough precipitation (Jäger et al., 2020a).

In mountain regions, past land-use changes have already altered the supply of ecosystem services, inducing a shift towards forest-related ecosystem services on the

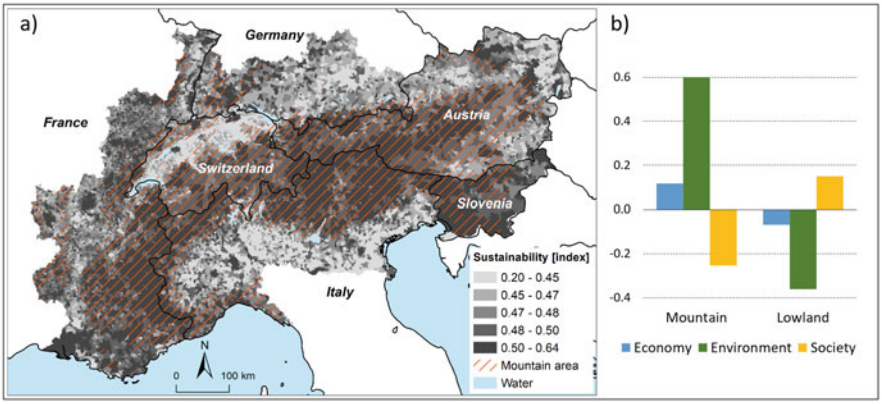

Fig. 11.6 (**a**) Total sustainability index based on 24 standardized indicators (see Fig. 11.6) representing one of the three dimensions of environment, society or economy, which are equally represented. (**b**) Mean values (z-scores) of the three dimensions economy, environment and society for mountain and lowland areas

expense of grassland biomass production and various cultural ecosystem services at the subalpine and alpine zone, while the production of agricultural products increased in the lower elevated valleys (Egarter Vigl et al., 2016; Locatelli et al., 2017). Spatially explicit scenarios based on socio-economic developments suggest that this trend will generally continue and be amplified by legacy effects (Tasser et al., 2017; Schirpke et al., 2020b). Hence, regulating ecosystem services will become more dominant in higher areas, while the lower areas will focus on provisioning services. Cultural services that greatly depend on the composition of the landscape, such as aesthetic or symbolic values, could be increasingly at risk due to the abandonment of mountain grassland (Schirpke et al., 2020a). At the same time, socio-demographic changes, including population growth and altered leisure behaviour, are expected to increase the recreational use of natural environments (Guo et al., 2010). A higher spatio-temporal expansion of recreational activities, however, may add pressure on mountain environments by degrading sensitive ecosystems and leading to higher disturbance of wildlife (Jäger et al., 2020b). Additionally, it can be expected that conflicts between recreational user groups or with non-recreational interested parties such as forest managers, hunters, farmers, nature conservationists will become more frequent, which may lead to restriction of recreational use or limit the provision of non-recreational services (Schirpke et al., 2020a).

7 Concluding Remarks

The above-indicated developments call for more attention to a sustainable use of natural resources and the development of nature-based solutions in mountain regions as well as adjacent lowlands (Grêt-Regamey & Weibel, 2020). However, a focus on the provision of selected ecosystem services may neglect trade-offs among different ecosystem services and disregard socio-economic aspects (Huber et al., 2013; Spake et al., 2017; Schirpke et al., 2019a). Accordingly, the herein presented results underline that, in addition to accounting for the demand side, it is necessary to integrate the mapping of ecosystem services with socio-economic and environmental data representing aspects of human well-being to improve the understanding of the complex interrelationships within mountain socio-ecological systems. Here, sustainability indicators may be useful to reveal spatial misbalances and to monitor the effects of landscape management and land-use policies over time. Further assessments of human values and benefits may also provide in-depth insights on social relations and human-nature interactions (Mengist et al., 2020), which should be considered in decision-making in addition to account for multiple ecosystem services as well as the complex spatial relationships between areas of supply and areas of demand.

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Chapter 12
Human-Nature Relationships for the Flathead Wild and Scenic River System: Analyzing Diversity, Synergies, and Tensions in a Mountainous Region of Montana, USA

Christopher A. Armatas, William T. Borrie, and Alan E. Watson

Significance Statement Natural resource planners face the challenging task of sustaining the diverse range of human-nature relationships supported by mountain systems. Planners of the Flathead Wild and Scenic River system cannot reasonably consider and communicate each individual human-nature relationship in the planning process. We present a social science approach that facilitates public engagement by having members of the interested public prioritize human and ecological meanings and services. Statistical analysis distills the diverse range of human-nature relationships into a limited number to be considered by river planners. Six typified human-nature relationships are explored, and through an understanding of synergies and tensions, planners gain knowledge to support both decision-making and communication for sustaining the integrated mountain system.

Keywords River planning · Q-methodology · Public engagement · Protected areas

1 Introduction

The Flathead Wild and Scenic River (WSR) system, in northwest Montana, USA, supports the well-being of a diverse range of people, communities, and ecosystems – in other words, it fosters a broad spectrum of human-nature relationships. The headwaters flow out of the mountains, passing through and along the Bob Marshall Wilderness Complex and Glacier National Park, two of the earliest and most iconic

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protected area designations in the United States. The Flathead River eventually emerges into the Flathead Valley and Flathead Lake. The mountain system surrounding this watercourse is home to ecological and biological diversity, small residential populations, an agricultural landscape, dams and hydropower production, an aluminum plant (closed in 2015 and now designated as a superfund site), and a vibrant tourism industry. Additionally, the aboriginal territories of several Native American tribes encompass the area, and the economic and cultural importance of the Flathead River is clearly represented in a decade long negotiation and recently ratified 'water compact' between local tribes, and state and federal government entities (Aadland & Dietrich, 2020).

The residents within the mountain system have long struggled to preserve the environment for recreational and tourism opportunities while also maintaining a traditional connection to resource utilization (e.g., timber, hydropower) (Drummond et al., 1975). For instance, the impacts of a proposed hydropower dam (Craighead, 1957) and a proposed coal mining operation (Espeseth, 1979) received early attention, though such threats have, in large part, subsided with legal protections such as Wild and Scenic River designation (WSRA, 1968). Today there is an increasing tension between protecting the environment, maintaining multiple recreation experiences, and growing tourism. This tension is underpinned by factors that are typical of mountain systems, including a remote location far from major markets, and cultural characteristics such as an independent spirit leery of government regulation, and strong backcountry hunting and fishing traditions. The mountainous region of interest in this chapter is constituted, in large part, of public land and waters administered by the United States federal government. As such, there are formal planning processes that require public engagement to better understand stakeholder interests and, additionally, provide the opportunity for decision-makers to communicate the direction of public land management to, in part, foster public support and understanding (USDA Forest Service, 2012).

For the Flathead WSR system, a nested social-ecological system that directly affects the social, economic, and ecological conditions of the broader mountain system, an ongoing planning effort will establish the direction of management for the next several decades. With 349 km of its upper reaches protected under the Wild and Scenic Rivers Act (WSRA, 1968), the Flathead WSR system includes three forks of the Flathead River; to be designated as Wild and Scenic, a river must "possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values". The three Flathead rivers, individually and combined, provide outstanding opportunities for untrammeled conditions, solitude, primitive and unconfined forms of recreation, challenge, remoteness, as well as for camping, angling, hunting, wildlife viewing, horse-packing, and other forms of shore-based recreation (Fig. 12.1). Whitewater, as well as wide river valley locations feature rafting, kayaking, and canoeing experiences, as well as a range of popular fishing, swimming and picnicking opportunities. It is this diverse combination of recreation that creates a unique and outstandingly remarkable value. Other outstandingly remarkable values include historic uses such as trapping, homesteading, and artifacts of early conservation management, ethnographic values reflecting

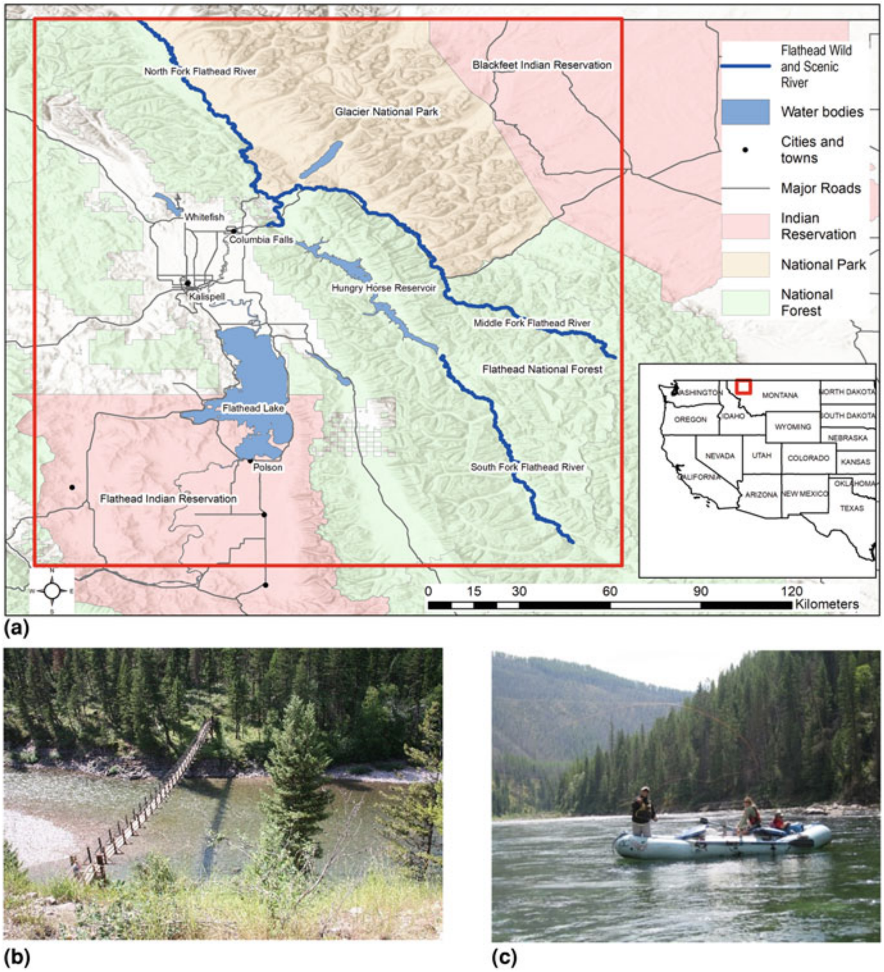

Fig. 12.1 Map (**a**) and images (**b** and **c**) of the Flathead Wild and Scenic River system. (Photo credits: C. Armatas)

continuous human presence going back to at least middle Paleolithic times with all three forks used as travel routes, spiritual practices and subsistence purposes.

Given the diversity of human-nature relationships related to the Flathead WSR, planners and managers face the challenge of understanding, communicating and, to the greatest extent practicable, supporting and accommodating these relationships. This study demonstrates the role that social science can play in both recognizing and understanding these important human-nature relationships, as well as a process that allows land managers and policy makers to demonstrate their engagement with a plurality of relations to nature that cannot necessarily be traded off against one another. This study explores a diverse range of human-nature relationships for the

Flathead WSR system; we then discuss the complexities of maintaining socio-cultural, ecological, and economic sustainability within an integrated mountain system.

2 Methods

We conceptualize human-nature relationships broadly (Armatas, 2019), in a manner consistent with Flint et al. (2013), which moves beyond worldviews or attitudes related to the appropriate role, or positionality, of humans with regard to nature (e.g., humans as ‘master’ or ‘steward’) (van den Born et al., 2001; Bauer et al., 2009). That is, we agree with Dvorak, Borrie, and Watson (2013:1519) that the term human-nature relationship is “quite nebulous”, and suggest that the broad concept can be defined and partially captured with notions such benefits and uses, meanings and values, and place attachment and identity, to name a few. However, when empirically investigating human-nature relationships, we suggest that, inevitably, the idea is reduced to being comprised of component parts, or *elements* (Armatas, 2019). For this study, we chose human and ecological meanings and services (HEMS) (Williams & Watson, 2007) as the framing elements of the human-nature relationship. Ecosystem services (de Groot et al., 2002) is another way to think of human-nature relationship elements, though it is a concept that has been largely framed through an economic and anthropocentric lens. The use of ‘meanings’ within the HEMS framing provides language that explicitly highlights the importance of, for instance, wildlife beyond human uses (e.g., intrinsic value). That is, we believe the use of HEMS as a framing facilitates communication within the context of the Flathead WSR system in a way that underscores the various ways people relate to the resource (e.g., economic, cultural, spiritual, intrinsic). HEMS, as a broad framing, is more akin to ‘nature’s contribution to people’ (Díaz et al., 2018), which aims to be inclusive of different worldviews without assuming that all elements of the human-nature relationship are perceived as positive contributors.

To explore the various human-nature relationships for the Flathead WSR system, we applied Q-methodology (Brown, 1980; Watts & Stenner, 2012) which, foundationally, uses a ‘Q-sort’ where participants prioritize HEMS related to the Flathead River system in a structured way (i.e., HEMS are prioritized in relation to one another, thus requiring tradeoffs). The method facilitates an understanding of differential perspectives, thus resisting a central tendency of opinion, by exploring a limited number of Q-sort groupings (i.e., factors defined by people sorting similarly). The HEMS for this study were primarily derived from a governmental report outlining values of the Flathead River system (Flathead National Forest and Glacier National Park, 2013) and through discussions with natural resource managers and planners. An initial, expansive list of potential HEMS, known as the ‘concourse’ in Q-methodology (Brown, 1980), was created. The concourse was then distilled into the list of HEMS to be sorted by participants (Table 12.1); a process that included

Table 12.1 Human and ecological meanings and services (HEMS) to be sorted by participants

Ecological meanings and services	
1. Water quality 2. Wildlife habitat and connectivity 3. Aquatic habitat 4. Biodiversity and abundance of wildlife (including threatened and endangered species) 5. Pure fisheries where no non-native fish are present (for example—Westslope cutthroat and bull trout populations in south fork)	6. Diverse and abundant fisheries (full complement of native fish) 7. Rare plant life (often found in wetlands) 8. Diverse and abundant plant life (including seed collection from intact native plant communities)
Human services	
9. Non-motorized river recreation and going with the pace of the river (for example—Rafting, canoeing, fishing from a boat) 10. Motorized river recreation 11. Shore-based recreation and activities (for example—Mountain biking, snow-shoeing, stock use, watching the river flow by) 12. Large-scale exploration in a short amount of time (for example—Driving for pleasure) 13. Wildlife viewing, including photography 14. Viewing geologic features or exploring caves 15. Guided recreation 16. Catch and release fishing 17. Dispersed camping without services 18. Developed camping with services 19. Staying in rustic forest service cabins 20. Economic support to local communities (for example—Jobs and visitor spending) 21. Comfort, safety, and convenience	22. Subsistence activities (for example—Hunting, fishing, foraging for food) 23. Native American use of the river system (for example—Exercising treaty rights, religious/spiritual practices) 24. Easy access to river (for example—Paved vehicular river access sites, or easily accessible trailheads for river-side hikes) 25. Challenging, adventurous, and/or unique river access (e.g., south fork hike or pack, or air delivery to Schafer meadows) 26. Experiences with limited planning, or ability to go on short notice (for example—Day hikes, day floats) 27. Extended, independent, and self-sustained experiences (for example—Multi-day floats or backpacking) 28. Personal achievement from testing and developing skills and abilities
Human meanings	
29. A place for wildness 30. Solitude 31. Quiet soundscapes 32. Clear night sky 33. Scenic beauty, aesthetics, and inspiration (for example—Views of dramatic and rugged peaks) 34. Finding remote and vast places where people rarely visit 35. Being free from society and its regulations 36. Learning how to function and cooperate as a group 37. Social time with friends and/or family—Social bonding 38. Sharing an experience with others outside ones group (camaraderie with strangers) 39. Connecting to the past, and passing stories and knowledge to younger generations 40. A symbol of America's identity, and national heritage and pride	41. Opportunities to reflect and learn about social history and past inhabitants (e.g., tribal groups, homesteaders, early rangers) 42. Educational and research resource (for example—Botany, geology, wildlife) 43. Native American history and knowledge (for example—Culturally scarred trees) 44. History of land management and conservation (for example—The network of historic Forest Service cabins) 45. Homesteading and trapping history and culture (for example—Numerous homesteads and the Polebridge mercantile) 46. Transportation history (for example—The great northern railway through John Stevens canyon) 47. History of mineral use and extraction (for example—The inside north fork road, built by the Butte oil company in 1901)

Note: The numbering of the HEMS is for presentation purposes only. Participants did not sort HEMS with associated numbers, and they do not convey any prioritization herein (i.e., water quality is not to be viewed as the most important HEMS) iterative discussions with managers and planners, as well as pilot tests with people from both within and outside the federal land management agencies.

During late summer and early fall of 2019, participants who attended either a public planning meeting or were contacted at the river, nearby campground, outdoor business or office completed a Q-sort of HEMS. For the Q-sort, each of the HEMS in Table 12.1 was listed on a separate card, and participants were asked to place the importance of each HEMS from “most important” to “most unimportant” along a quasi-normal distribution. Figure 12.2 presented in the results section shows the forced distribution participants were asked to sort along. Q-methodology focuses on the expression of a plurality of perspectives, without concern about the prevalence or distribution of perspectives across a population. Therefore, sampling is purposeful.

For analysis of the Q-sorts, factor analysis is applied to a correlation matrix of all Q-sorts, which yields a limited number of typified perspectives, or archetypes. Generally, the goal of analysis is to distill the perspectives of many people (157 in the case of this study) down to a tractable number of archetypical Q-sorts, or the weighted average of several Q-sorts done similarly (6 archetypes in this study). One benefit of such a distillation is that, in practice, decision-makers can understand, communicate, and consider *six* perspectives (as opposed to 157 perspectives).

For the reader more interested in this analysis, we recommend: (1) general information about the method and associated statistical analysis (Brown, 1980; Stephenson, 1954; Watts & Stenner, 2012) and; (2) information about the method and associated statistical analysis that is specific to Federal land management and planning (Armatas et al., 2017; Steelman & Maguire, 1999).

3 Results

In total, 157 people completed Q-sorts, with 100 of them participating in one of two public meetings held by the Federal land management agencies in relation to planning of the Flathead WSR system. The remaining 57 people were contacted in several public locations and included people at campgrounds, floaters and anglers, landowners adjacent to the Flathead River, and Native American tribal members with traditional lands within the integrated social-ecological system. Analysis yielded a six-factor solution based upon statistical criteria including consideration of factor loadings and the Scree test of eigenvalues. These six typified relationships, or archetypes, represent six empirically distinct viewpoints of what is important in the Flathead WSR system and how each reflects different priorities and relationships in the system. We selectively highlight examples of the results for the purpose of underscoring both the diverse human-nature relationships and the complexity of planning for the Flathead WSR system; additionally, we highlight how this approach can aid understanding of tensions and synergies across the different human-nature relationships. For the reader interested in the full details related to this study, an archive with an unpublished report prepared for decision-makers and associated (and anonymous) raw data is freely available (Armatas et al., 2021).

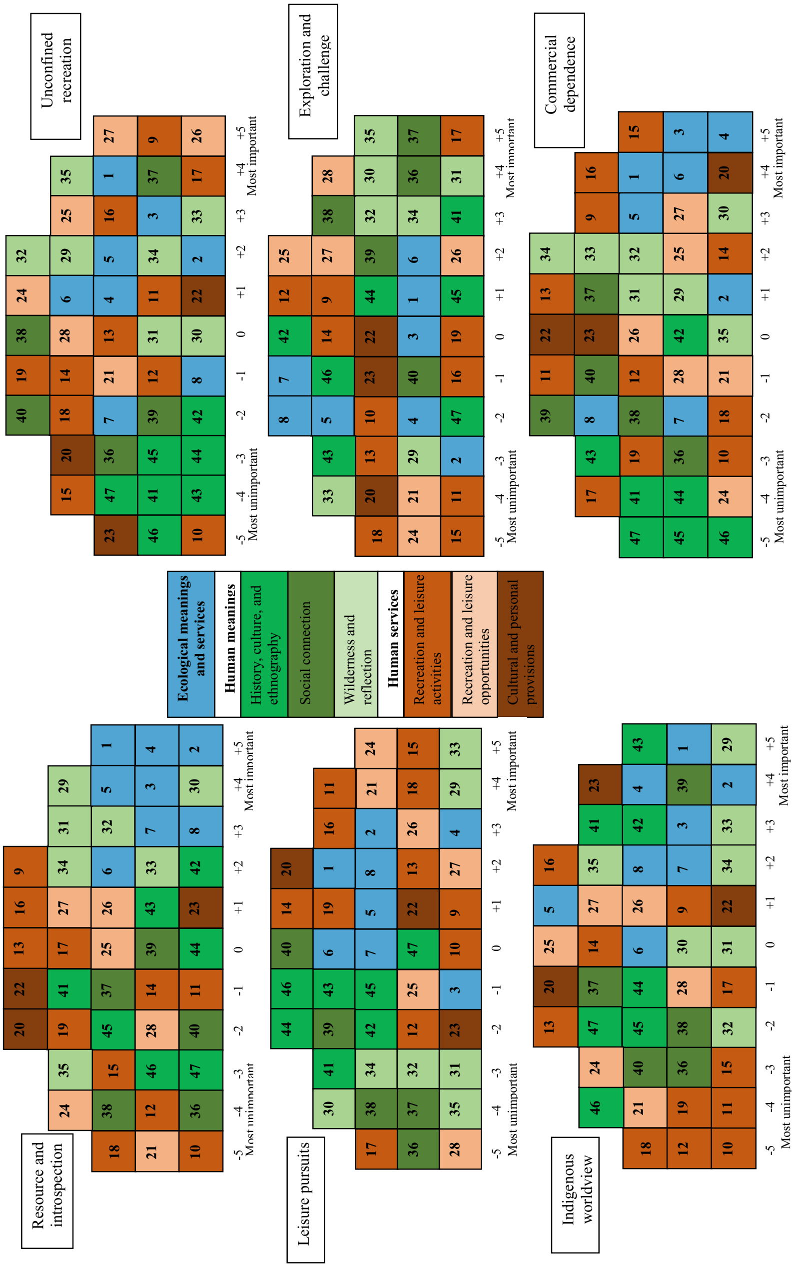

Fig. 12.2 Six archetypical human-nature relationships fostered by the Flathead WSR system

3.1 Human-Nature Relationships for the Flathead WSR System

Figure 12.2 provides a detailed representation of the diverse ways people relate to the Flathead River system. The numbers in Fig. 12.2 correspond with the human and ecological meanings and services (HEMS) listed in Table 12.1 (e.g., "1" inside a cell represents the placement of Water quality in each of the different archetypes), and the color scheme highlights the types of different HEMS (i.e., ecological meanings and services, human meanings, and human services) that are prioritized in the different archetypes. For the purposes of communication, based on examination of their factor structure, the six archetypes explored in this research were dubbed: Resource and introspection, Unconfined recreation, Leisure pursuits, Exploration and challenge, Indigenous worldview, and Commercial dependence.

Figure 12.2 highlights and illustrates the composition of each archetype. For example, human-nature relationships that aligned with the Resource and introspection archetype prioritized, in general, ecological meanings and services, and those human meanings related to wilderness and reflection. The Indigenous worldview archetype also prioritized several ecological meanings and services, but they differed from all other archetypes in their prioritization of Native American history, knowledge, and use of the river system. In general, the Leisure pursuits, Unconfined recreation, and Exploration and challenge archetypes prioritize recreation; albeit different importance for different elements of the recreation experience. For instance, the Leisure pursuits archetype highlights a human-nature relationship that may not even pertain to floating the river, and the Unconfined recreation archetype, true to its name, was heavily focused on a recreation experience that was free from regulations. Lastly, those human-nature relationships that align with the Commercial dependence archetype underscore desire to balance ecological meanings and services and deriving livelihoods.

Figure 12.2 can also highlight common ground and tensions among all human-nature relationships. There is consensus about the importance of water quality, biodiversity and abundance of wildlife, and access. Whether for community health, the recreation experience, the tourism industry, downstream agricultural operations, or cultural and spiritual benefits, maintaining particular ecological meanings and services and access to the resource are foundational to the human-nature relationships sustained by this mountain system. As an example of tensions, or areas where a change in the provision and/or protection of particular HEMS may disparately impact human-nature relationships, we highlight the general tension between a growing tourism industry and recreational use on perceived naturalness and abundant solitude. Generally, the mixed view of tourism in the Flathead River system is evident in the disagreement around the importance of economic support to local communities stemming from river use. That is, guided recreation and economic support to local communities are generally unimportant to the Resource and introspection archetype, the Unconfined recreation archetype, the Exploration and challenge archetype, and the Indigenous worldview archetype.

Another, related tension is the different recreational experiences represented by the Leisure pursuits archetype, the Unconfined recreation archetype, and the Exploration and challenge archetype, which highlights that 'recreation', as an important component to human-nature relationships, is not monolithic. Finally, we highlight the tension related to the history, culture, and ethnography HEMS, which were generally seen as a low priority to all archetypes except the Indigenous worldview archetype.

4 Discussion: Sustaining Social-Ecological Systems Through a Focus on Human-Nature Relationships

While there is no single correct 'solution' for planning for complex systems such as the Flathead WSR system, as it constitutes a wicked problem (Norton, 2012; Rittel & Webber, 1973; Davies et al., 2015), we suggest that knowledge about diverse human-nature relationships is important for two broad reasons: (1) understanding the complexities and nuance of how different human-nature relationships will be influenced by a change in HEMS and; (2) clear communication with the interested public about the diverse human-nature relationships for the purpose of facilitating mutual awareness and respect.

For the purpose of on-the-ground planning and management (e.g., weighing choices such as restricting access for recreation, investing in invasive species prevention), understanding both the commonalities across different human-nature relationships (e.g., the importance of water quality) and the areas of disagreement (e.g., the preferred direction for the tourist industry) is critical. Such knowledge will highlight which human-nature relationships are likely to be positively or negatively influenced under different planning scenarios and, while no scenario is likely to fully satisfy all, it may be possible to minimize the negative effects. Currently, planners of the Flathead WSR system are perhaps most explicitly concerned about addressing recreation related issues, including the tension between maintaining an unregulated recreation experience and an experience that provides ample opportunities for solitude, and the mixed view related to commercial use and guided recreation. While the findings from this study highlight the need to address these recreation related issues, the findings can also serve as a reminder to planners of the Flathead WSR system about the diverse range of human-nature relationships that exist, some of which have concerns extending beyond recreation. For instance, the Indigenous worldview and the Resource and Introspection archetypes generally prioritized ecological meanings and services, which underscores the potential need of planners to clearly demonstrate how future management of the system will ensure the protection of the ecosystem; in doing so, Fig. 12.2 can guide planners to focus on those ecological meanings and services that may be of high priority to most or all human-nature relationships (e.g., water quality, biodiversity and abundance of wildlife).

The wicked nature of sustaining complex systems implies a task that is, in large part, about communicating with a diverse range of people and their equally diverse human-nature relationships. We argue that clear, transparent, and consistent communication and an increasing awareness and validation of differing human-nature relationships is beneficial, based on the assumption that greater knowledge in this area may lead to increased empathy (Armatas et al., 2019) and, perhaps, social learning (Armatas, 2019). For example, this research highlights the importance of different recreation experiences for three different archetypical human-nature relationships, but in some instances these different recreation experiences may be in tension. It is possible that knowledge of these tensions with the explicit acknowledgement and validation of different human-nature relationships could influence acceptability of a management action that, for instance, limits use for the protection of solitude, even if such an action constitutes a negative influence on experiences with limited planning.

Finally, we stress a broader point, which is that by focusing on HEMS and human-nature relationships (and the corresponding deeply personal elements such as cultural connections and identity), there is less emphasis on specific people, and interest/user groups. This research stresses that human-nature relationships are not unidimensional and, given that the archetypes feature numerous HEMS, decision-makers are pushed to engage with the plurality and nuance of such relationships. Further, decision-makers are pushed to confront the challenge of communicating that the Flathead WSR does not only support jobs and incomes, but also meanings, values, identities, and attachments that, in aggregate, represent complex and intertwined human-nature relationships. Documenting what people with differing human-nature relationships may prioritize or not can guide decision-makers focus away from user- or interest-groups based on socio-demographics. If we assume that building more resilient mountain systems will require, at least in a part, a shift in behavior and worldviews that is representative of diverse connections to nature (Turner & Clifton, 2009; Mayer & Frantz, 2004), then understanding both the breadth (e.g., commercial dependence to introspection) and depth (e.g., personal bonds to the river, connecting to the past) of human-nature relationships is needed.

5 Conclusion and Future Research

The Flathead WSR system in Montana, USA supports a diverse range of people and communities, and planning processes related to the long-term direction of the social-ecological systems in the region require understanding of different human-nature relationships. This study presented social science research related to six different human-nature relationships relevant to planning for the future sustainability of the Flathead River system. Using an established practical approach for implementation into natural resource planning processes, we identified areas of agreement and disagreement. The potential benefits of this approach include support for both decision-making and communication with the interested public. A limitation that may be worth noting is that this approach does not provide any knowledge about how different archetypes are distributed across the population; without such knowledge, planners cannot know if particular decisions will be broadly popular or unpopular.

As we look towards future research, there is a need to understand how different framings and a broad approach to articulating the connection of people to nature changes peoples' perspective, if at all. In other words, empirical investigations that focus on the social learning and empathy effects of enhanced understanding of diverse and complex human-nature relationships will be critical to building more resilient integrated mountain systems.

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Chapter 13
Resilience and Sustainability of the Maloti-Drakensberg Mountain System: A Case Study on the Upper uThukela Catchment

Neo V. Mathinya, Vincent Ralph Clark, Johan J. van Tol, and Angelinus C. Franke

Significance Statement The chapter describes the conflicting interests of water users in the uThukela catchment of the Maloti-Drakensberg (MD) mountain system, including the implications of poor management on ecosystem health and livelihoods. As this is a strategic water resource area for both Lesotho and South Africa, effective management towards sustainability is critical, but is currently retarded by the complexities of shared but disputed boundaries, and competing land uses. Improved rangeland management practices, backed by education and awareness, can improve the resilience of the system. However, this requires the buy-in of all stakeholders to reduce degradation and invest in improvement of the catchment. Otherwise, degradation will exacerbate water shortages in an already water scarce region – especially during El Nino-linked droughts, predicted to become more intense with climate change.

Keywords Alpine · Degradation · Livelihoods · Mountain system · Stewardship · Wetlands

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1 Introduction

The Maloti-Drakensberg (MD) mountains cover c.40000 km^2 and include much of Lesotho, and marginal areas of the Free State (FS), KwaZulu-Natal (KZN), and the Eastern Cape Provinces of South Africa (Carbutt, 2019). The MD is home to montane vegetation unit types of the endangered Grassland and fragmented Afro-temperate Forest Biomes (Mucina & Rutherford, 2006), and hosts some of the highest numbers of range-restricted flora and fauna in southern Africa, many of which are of high conservation significance (Clark et al., 2011; Carbutt, 2019). Furthermore, it captures an array of cultural heritage sites and spectacular rock formations that serve as a major tourist attraction (Duval & Hoerle, 2018). This mountain system is also crucial in providing water to many people across much of South Africa, Lesotho and Namibia (Taylor et al., 2016; Ngwenya et al., 2019) – and in future, Botswana (Mahlakeng, 2020). Wetlands are a characteristic feature of this mountain system (Zunckel, 2003), helping to ensure a sustained flow of high-quality water into major rivers such as the Senqu–Gariep (Orange) in Lesotho/South Africa, and the umZimvubu and uThukela in South Africa.

MD water flows are primarily regulated by alpine wetlands i.e. wetland systems >2800 masl (Chatanga et al., 2019). The key ecosystem service provided by these wetlands is storing moisture from precipitation (Taylor et al., 2016). Their ability to absorb moisture buffers against extreme events of high intensity rainfall (floods) while their slow release during the dry seasons and drought periods ensure long duration of base-flow. These wetlands also trap sediments and sequester carbon - vital functions in an area inherently sensitive to erosion due to the steep topographical gradients and intense summer thunderstorms (Grab & Linde, 2014). Maintaining the integrity of the wetlands in the upper catchment areas is vital as they support perennial runoff with low sediment loads, which supports the associated land use systems.

Unfortunately, the MD is experiencing degradation and subsequent disturbance to water flows with consequences for all land use systems it supports (Turpie et al., 2021). This case study presents an opportunity to unpack the complex reality of shared boundaries, competing land-uses, livelihood needs, and the crucial role of the MD as a water tower. This hybrid scoping review unpacks the current state of degradation on the upper uThukela as a component of the MD and implications on land uses. It is intended to lay a conceptual framework for more rigorous work on deriving innovative strategies that ensure sustainable solutions to the problems affecting the MD. The review is supplemented with qualitative field notes and photographs to further elicit a descriptive narrative of the region's current reality and implications for the system's resilience and sustainability.

2 Description of the Study Area

The upper uThukela catchment is part of the northern MD Strategic Water Source Area, and includes the Royal Natal section of the uKhahlamba Drakensberg Park and the upper Tugela location. This topographically rugged catchment ranges in elevation from c.1150 m in the east to ~ 3282 m in the west. The catchment comprises 1876 km^2 and consists of nine quaternary catchments (Fig. 13.1).

The uThukela catchment is characterised by a high variability of climatic variables, with mean annual precipitation ranging from about 2000 mm in the high elevation areas to as low as 600 mm in the lower-lying areas (Blignaut et al., 2010). Mean day temperatures in winter range from below zero in the mountains to 10 °C in the valley region with frost occurring from late April to early September and almost daily in winter (June and July) (Everson et al., 2007). Natural vegetation in the catchment is dominated by the Grasslands Biome (Mucina & Rutherford, 2006) – from mid-elevation grassland vegetation units to alpine vegetation units – and with extensive patches of Afro-temperate forest on shaded, southern slopes <2000 m.

The upper uThukela catchment supports three main land-use systems:

1. Alpine wetlands and grasslands – formally "conserved" in the uKhahlamba-Drakensberg Park: Royal Natal (but in reality dominated seasonally by intense Basotho rangeland use);

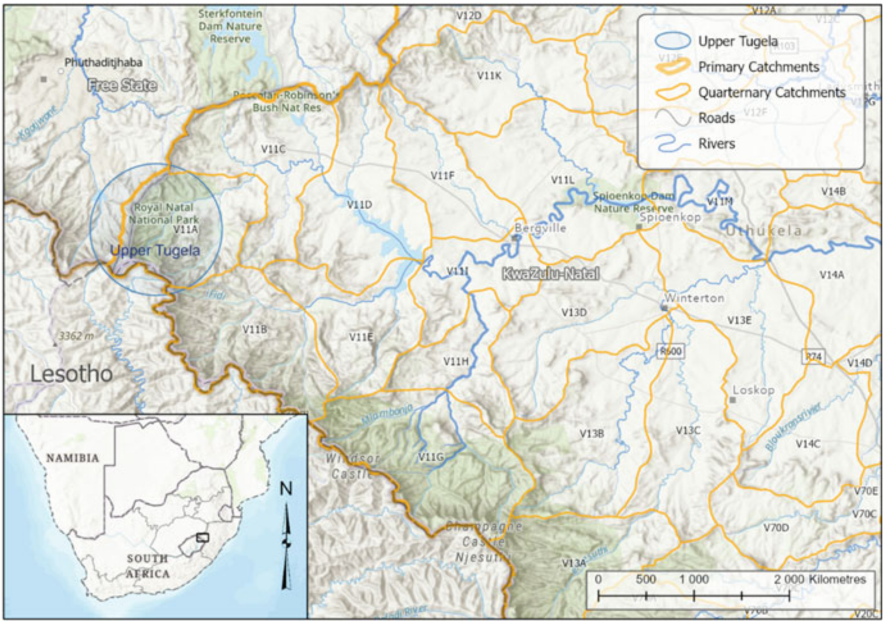

Fig. 13.1 Location of the Upper-uThukela catchment (V11A) in South Africa and its associated quaternary catchments. (Adapted from Blignaut et al., 2010)

2. Conservation areas on and at the foot of the escarpment and associated leisure recreation (uKhahlamba-Drakensberg Park: Royal Natal);
3. Commercial and smallholder crop and livestock farming

The system's water flows are regulated by alpine wetlands and associated grasslands on the summit, closely interlinking these seemingly distinct upper and lower systems.

3 Land Use and Water Linkages

3.1 Alpine Grasslands and Wetlands

The integrity and health of the grassland ecosystem found on the alpine wetlands of the upper uThukela is the essential force of water flows in this catchment, supplying water to rivers and for inter-basin transfers (Fig. 13.2). These wetlands are extremely fragile and vulnerable to disturbance yet essential to present and future water security in the region (Taylor et al., 2016). The alpine wetlands of the uThukela fall under South Africa's protected areas, but they suffer from the same problem of uncontrolled grazing by livestock as many of the less protected alpine wetlands in the MD. The alpine wetlands are primarily grazed by livestock from Basotho herdsmen, providing a key livelihood strategy for many people in the high-elevation areas of the MD of Lesotho. Especially during droughts, the alpine wetlands attract large numbers of herdsmen and their livestock, being one of the few places remaining with palatable forage.

Fig. 13.2 Water flows and linkages between the uThukela and associated land uses. (Edited Google earth images https://earth.google.com/web/@-28.67004297,29.23896474,1293.58353365a,185866.37439854d,35y,43.16894092h,0t,0r)

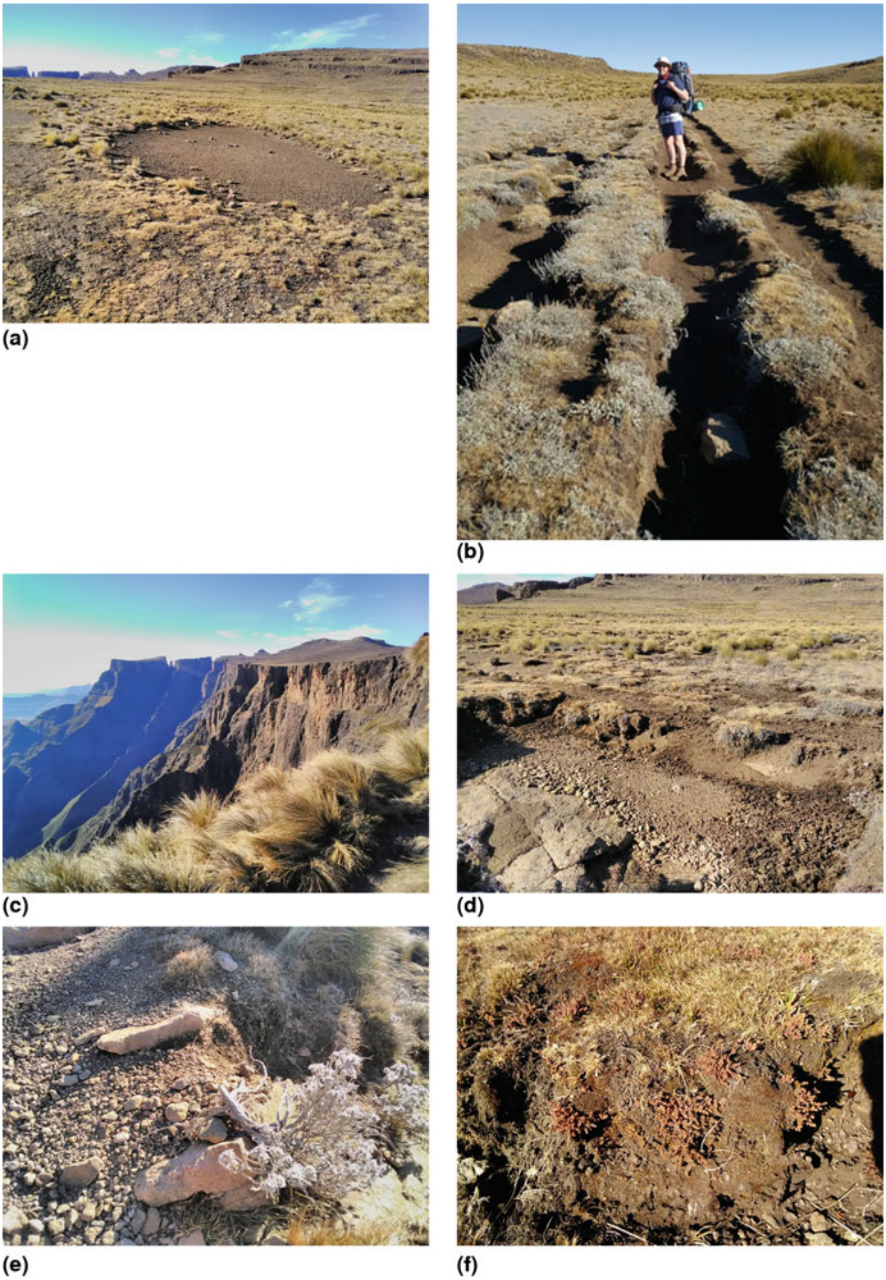

Fig. 13.3 A selection of photographs from the upper uThukela catchment: (**a**) loss of vegetative cover. (**b**) further incision of gullies. (**c**) poor grass composition. (**d**) loss of the alpine peat-biocrust layer. (**e**) bare gravel and hard rock. (**f**) tussocks and shrubs on soil pedicels. (Credits: V.R. Clark)

Figure 13.3 depicts the current state of degradation in the catchment. A proportion of vegetative cover has been lost as evidenced by large barren areas, and widely spaced distances between remaining grass tussocks (Fig. 13.3a). This bare soil is prone to cryogenic activity (e.g. needle ice action), resulting in the fine soil being elevated on small pedicels and dispersed by strong winds. In spring, persistent winds exacerbate this loss (Grab & Linde, 2014). Increasing barrenness results in less absorption of rain and snow, resulting in faster run-off during high intensity summer thunderstorms. As a result, gullies have developed (Fig. 13.3b) that are eroding these alpine wetlands, and combined with sheet erosion, are causing the banks of the uThukela River on the summit to retreat.

The grass composition (Fig. 13.3c) is poor and unrepresentative of intact alpine summits in the catchments of the MD. The current grass compliment has a poor palatability (wiry tussock grasses and tough shrubs), suggesting that the palatable grass and herbaceous component has been grazed out. The alpine peat-biocrust layer, which acts as a moisture absorbent and sponge has largely been eroded (Fig. 13.3d). As this peat-biocrust layer is lost, it is replaced with bare gravel and hard rock (Fig. 13.3e). Evidence of this can be seen from tussocks and shrubs on soil pedicels (Fig. 13.3f), indicating the original soil surface. This is the start of "alpine desertification", where the result is an alpine desert of gravel and bare rock (Sun et al., 2019) – the final stage of ecosystem collapse in this context. This is already evident elsewhere in Lesotho, e.g. in the Mokhotlong area (Grab & Linde, 2014). The degradation of the alpine wetlands leads to a major increase in the variability of water flows – from perennial to seasonal, and even to episodic and associated flash flooding.

High footpath traffic of tourists to the uThukela Falls, with the footpath running through the wetlands and along the edge of the river, may be exacerbating the degradation situation in the catchment. However, as the Elands Alpine Catchment (immediately adjacent to the uThukela Alpine Catchment, in FS) shows the same degradation as the uThukela –but sees very little tourism activities in comparison - the tourism component of the degradation challenges can be filtered out, highlighting the pervasive impact of unsustainable rangeland use.

3.2 Conservation Areas and Associated Recreation

A large proportion of the escarpment of the MD, bridging the alpine wetlands with the lower lying agricultural areas in South Africa, are protected by a string of national parks. The national parks provide a key tourist attraction in South Africa and harbour numerous tourist resorts. In general, the wilderness areas of the parks are the 'least degraded' of the three land use types, but also experiences encroaching challenges to the parks (Kruger, 2007). One of the more serious issues here is invasive plant species threatening ecosystem services (notably water production and biodiversity conservation) (Simberloff, 2001; Van Wilgen et al., 2011). These species are introduced through increased tourism activity beyond their natural dispersal range. Given the high international tourist numbers, vigilant biosecurity is necessary to ensure new potentially problematic species are detected early and addressed timeously.

3.3 Commercial and Smallholder Crop and Livestock Farming

Mixed crop-livestock farming is a dominant land use in the catchment practiced both by commercial and smallholder farmers (farmers owning small plots of land on which they grow subsistence crops and a few cash crops and rear livestock relying almost exclusively on family labour). Commercial farmers are predominantly found on lower lands of the catchment, while most smallholders are located at the higher elevation areas at the foothills of the mountains bordering the nature parks. The smallholders in these former homelands (racially and ethnically-based regions created in South Africa under the apartheid government as nominally independent tribal states) depend almost entirely on surface water streams for their drinking water, and their arable and livestock farming activities (Giller et al., 2013). On over 70% of the catchment's arable land, commercial farmers grow rainfed maize and soybeans during summer and irrigated wheat and vegetables during the winter season, while smallholders mainly grow rainfed maize and, to a lesser extent, dry beans and sorghum (Mthembu et al., 2018).

Although at different scales, both commercial and smallholder farmers own livestock. Due to the seasonal nature of the climate in the region, some commercial farmers grow irrigated pasture crops as supplemental feed for livestock. Smallholder farmers move livestock away from the fields to higher surrounding grasslands at the border of the parks to graze freely in the summer. During winter, the post-harvest season, animals are allowed onto the fields to graze on crop residues when vegetation in rangelands is largely unpalatable.

Farmers are faced with policy challenges, socioeconomic issues such as crime including livestock theft and biophysical constraints such as variable rainfall. These challenges are indirect drivers of the environmental impacts of agriculture in the catchment. Commercial agriculture mainly affects water quantity and quality. The quantity of water is affected through abstractions for irrigation, which reduce natural flow levels, and by replacing natural grassland by crops that use more water, therefore decreasing the groundwater recharge. Deterioration of water quality is through the application of agrochemicals that eventually make their way into streams and rivers. In addition, water quality is affected by soil cultivation methods, causing erosion through soil surface crusting and resulting in sedimentation of water resources. Smallholder farming mainly affects the environment through land degradation, because of (i) unregulated livestock trampling and grazing, (ii) cropping on steep slopes, and (iii) harvesting of indigenous trees for domestic purposes. As a result, the contrast in the status of the natural grasslands between the communal farming communities and the national parks is immense. For example, the water in the rivers is clear when flowing out of the parks but muddy when flowing out of the communal areas due to erosion, especially after heavy showers.

4 Implications of Degradations on Livelihoods

Upon degradation, the loss of ecosystem services provided by the alpine wetlands in the catchment threatens its sustainable function for water provisioning, affecting livelihoods in various ways. Firstly, Basotho herdsmen consider wetlands a critical grazing resource and depend on it for their livelihoods. However, overexploitation of wetlands leads to wetland degradation through a loss of the diversity of plant species, biomass reduction, peat loss, and soil erosion. A common sight is several hundred animals in the alpine catchment at any one time in summer (Du Preez & Brown, 2011). The ultimate losers in this are the herders themselves, as they currently have limited livelihood options other than herding, and are effectively 'locked in' to this lifestyle through macro-political and macro-economic situations (Du Preez & Brown, 2011). The political climate of South Africa (having some of the world's highest levels of societal inequalities due to its political history) and the socio-economic climate of both Lesotho and South Africa as developing countries with high poverty and unemployment rates, offers limited rural livelihood alternatives. As such, there is a predominant reliance on herded animals both as a food source and employment opportunity in rural areas. The cultural status associated with large herds of animals also deters the exploration of alternative livelihoods.

Secondly, water is a crucial component of the geo-landscapes required to maintain the tourist value of the conservation areas. It is also important for economic development keeping nearby hotels functional and landscapes green and attractive to encourage tourism. Regardless of the cause, degradation of the alpine areas affects water flows, increasing the likelihood of peak flows leading to more erosion. Subsequently, these changes diminish the tourist value of the area. For instance, observations over the past decade suggest that the uThukela Falls – the second highest in the world, and a major tourist attraction – has switched from being perennial to seasonal. Whether this is true, or only linked to El Niño phases of ENSO, would need to be determined more robustly, but there is the potential (through wetland degradation) for Falls to shift permanently to short flow events after local rain showers.

Thirdly, changes in weather patterns have rendered pasture availability for livestock grazing more irregular and unreliable. In drought periods, smallholder livestock searching for quality-forage tends to concentrate in and around the wetlands, further degrading their roles for water storage and delivery in dry periods. Although literature provides no strong evidence for changes in rainfall due to climate change (Taylor et al., 2016), the impact of overgrazing is thought to be compounded by the impact of changes in weather patterns manifesting as more extremes in rainfall and droughts. It is therefore not surprising that households farming downstream are now finding it difficult to meet their food and nutrition security due to ensuing challenges of water shortages. The plight of water shortages is also felt among the commercial farming community through irrigation water pricing and associated water rights regulations increasing production risks (Agholor, 2013). At a wider scale, the otherwise perennial Orange River has run dry several times in recent years, something unheard of in the past, with major impacts on the ecological reserve and diverse livelihoods downstream in parts of Lesotho, South Africa and Namibia (Mahlakeng, 2020).

5 Challenges and Opportunities for Effective Stewardship

The upper uThukela study area is exemplary of the complex multiple national and international boundaries, diverse land-uses and needs in the mountain catchment, all interlinked by water flows regulated by the threatened alpine wetlands. The primary challenge is that wetlands are treated as a communal land, making effective stewardship by actual landowners difficult to achieve. Furthermore, shared boundaries present a challenge for maintaining the integrity of upstream wetlands sourcing water for all associated land uses across borders. International and provincial borders make it difficult to design and implement effective conservation policies. In addition, disputed location of the boundary lines between South Africa and Lesotho make responsibilities unclear. Additionally, the rugged nature and high elevation (3000–3300 m) of the terrain makes it difficult to deploy staff for management. Although the Maloti-Drakensberg Transfrontier Programme (MDTP) provides the best available platform for engaging on these issues, as yet, tangible positive results in terms of competing uses in the alpine zone in the study area are under-appreciated and remain unresolved (although in 2020, MDTP took major steps to engage on this).

Reducing stocking rates and implementing sound grazing management systems that provide for extended rest periods can restore and preserve wetlands outside protected areas. However, there is always the risk that improving grazing and livestock management may simply lead to more animals. Therefore, the removal of herdsmen out of the protected areas may be justifiable, but in the end, the trade-offs between the goals of protecting ecosystem services and provision of livelihoods need to be balanced. While eco-tourism would be the next logical livelihood option, the relatively small capacity of this industry and its associated seasonality and instability requires alternate forms of livelihood strategies. Therefore, governments need to create and foster conducive environments for small businesses to thrive by reducing the red tape, providing efficient essential government functions (e.g. health), and by not overtaxing initiatives and efforts.

A main challenge to effective solutions is the conflicting interests of the area's diverse land users. Sustainable solutions will ultimately require good diplomatic relations coupled with practical arrangements between South Africa and Lesotho. Given that this is an alpine environment with short growing seasons and that we know tremendously little about its ecology, resilience, and successional processes, recovery might be a slow process requiring direct intervention for restoration.

In the protected areas, restoration of the catchment post-livestock exclusion may be achieved using the following engineering methods: (1) Stone packs and stone-walls to slow water flow and soil loss in the worst affected areas. (2) Gabions along the rivers to allow the wetlands to recover (Wilson & Norman, 2018). (3) Revegetation using local species and artificially reseeding (Moreno-Mateos et al., 2015).

Lower in the catchment, commercial farmers could be assisted with decision support systems for their input use to reduce agrochemicals polluting water resources. Additionally, conventional cultivation methods could be supplemented with conservation practices. As complete switch from conventional to conservational practices may not be in the immediate financial interest of the farmers, the immediate trade-offs could be off-set through payments for ecosystem services as this has been shown to be a popular incentive for adoption of conservation practices by farmers (Salzman et al., 2018). In terms of smallholder crop production, ongoing development activities in the communities such as conservation agriculture (already prevalent in some communal areas around the Bergville region in KZN supported and promoted by the Mahlathini development foundation: https://www.mahlathini.org/) could be further up-scaled. Water harvesting techniques may provide some relief to water limitations and soil loss challenges as was the case for communal farming around Black Mountain in Thaba Nchu, FS (Woyessa et al., 2006). Governments could also provide alternative sources of energy to reduce reliance on indigenous trees for firewood. Alternatively, they could encourage private enterprise initiatives to harvest feral alien timber for fuel in the area on a commercial basis.

In the communal grazing areas, grazing activities are currently trapped in a classical 'tragedy of the commons' where sustainable agricultural practices are unpopular as people continue to farm the same way they have for decades due to cultural believes and indigenous knowledge, creating barriers to increase productivity through novel techniques. The situation may be remedied through education and novel partnerships with livestock farmers and the government, private sector as well as non-governmental organisations (e.g. Meat Naturally PTY (https://www.meatnaturallyafrica.com)) that provide communities with the knowledge and tools to break down former economic barriers, while motivating them to invest in restoring rangelands and wetlands. For example, the Meat Naturally model entails that farmers be trained and then required to implement environmentally-friendly grazing plans, while Meat Naturally creates an economic opportunity and sustainable livelihood for farmers by linking them with commercial buyers of meat products.

In terms of macro-economic solutions, uplifting the entire value chain of smallholder livestock farmers so that they can get more value from their livestock products could improve the catchment's ability to drive livelihood diversification away from herding and more towards value-addition (processing), an important long-term initiative to reduce overall pressure on rangelands. Although only a limited number of Basotho herdsmen may end up working as tour guides or at a tourist lodge, education on the importance of nature conservation could help minimise degradation, while securing the tourism industry. Furthermore, the current trend of emigration to urban areas from the former homelands downstream could be encouraged through education for the younger generations and better job opportunities and access for the older ones. This proposition is hinged on the idea that population pressure leads to land scarcity and to make a livelihood out of agriculture one needs to acquire or rent land. Therefore, together with the general disinterest of the youth in agriculture in the former homelands (Swarts & Aliber, 2013), this idea supports the encouraged emigration of youth as they are more flexible, more mobile, more agile and are increasingly landless (Bezu & Holden, 2014). Additionally, people generally switch out of low productivity sectors such as agriculture to more prominent ones such as manufacturing in South Africa.

Quantifying and monitoring climatic variables as well as effects of land management on water flows in MD catchments is crucial for better planning of future water security. Long-term trans-boundary socio-ecological research is required to foster a deeper understanding of the social, geopolitical, ecological as well as biophysical factors governing this alpine system.

6 Conclusions

The upper uThukela catchment is important for ecosystem services and providing livelihoods to surrounding communities. The primary driver of degradation in the catchment is overgrazing by livestock. Degradation of alpine wetlands directly affects the system's water flows with effective management retarded by the complexities of shared and disputed boundaries as well as competing land uses.

Improving the health and integrity of alpine wetlands through direct intervention can buffer them against climate change. Through better land-use and management practices, backed by education and awareness, the resilience of the catchment could be improved. Whilst ensuring resilience requires governance that takes into account socio-economic diversity in the use of a system and spatial diversity of natural resources utilization, all stakeholders must first buy into reducing degradation and investing in the improvement of the system. Otherwise, degradation will lead to increased water shortages in an already water scarce region.

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Chapter 14
Invasive Alien Plants in the Montane Areas of South Africa: Impacts and Management Options

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Significance Statement Invasive alien plants (IAPs) in South African mountains are both threatening and supporting ecosystem services and human well-being for local communities, as well as those in nearby lowland areas. Higher elevation mountain areas have distinct IAP compositions compared to lower elevation mountains due to their unique climatic conditions. Management of IAPs in these montane settings presents many challenges and needs to work on multi-value-based approaches that ensure the inclusion of communities in the decision making. We advocate for more mountain-specific research that can guide and upscale National Resource Management to implement programmes that are relevant to the socio-ecological circumstances in these high elevation areas.

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1 Introduction

Mountains in South Africa (SA) support critically important ecosystem services (ES) – notably water production – and are exceptionally rich in floral and faunal biodiversity and endemics (Mucina & Rutherford, 2006). For example, almost the entire Cape Fold Mountains falls within the Fynbos biome which is a biodiversity hotspot (Goldblatt & Manning, 2000), while most of the eastern Great Escarpment falls into the endangered Grassland Biome (Mucina & Rutherford, 2006). Yet these montane habitats are often marginalised regions, and are under threat from detrimental land-uses, unsustainable use of natural resources, climate change, poor governance, and invasive alien plants (IAPs) (Clark et al., 2019). Invasive alien plants are direct drivers of change in these ecosystems and threaten their role in the provision of nature's contributions to people (NCP). Yet the extent to which mountains have been invaded has not been accurately assessed. This lack of knowledge is a reflection of the fact that SA's mountains have been poorly studied. No mountain range in southern Africa has been comprehensively assessed for the purposes of valuing ecosystem services (ES), assessing threats or making policy recommendations (Clark et al., 2019).

While IAPs are known to have ecological consequences in adventive ranges, they are often deliberately introduced for their material or cultural benefits to communities. This is particularly true for mountain areas whereby given the socio-economic conditions, people are often more reliant on the natural resources around them. In light of the potential conflicts of interest, there is a need to expand research so that management interventions are guided by accurate information from both ecological and social perspectives. This chapter explores available information by (1) first describing the mountainous areas of SA, (2) discussing the most abundant IAPs in these areas, (3) outlining their major impacts on ES, and (4) addressing management challenges.

2 Defining Mountain Areas

South Africa is dominated by an extensive interior plateau >1200 m (3,900 ft) above sea level (asl) that covers c. 40% of its surface area; this interior plateau is bounded to the west, south, and east by the 5000 km-long southern African Great Escarpment (Clark et al., 2011), reaching its highest elevations in the Maloti-Drakensberg (3450 m, Mafadi Peak). In the south-western part of the Cape region, rugged fold mountains dominate the landscape (reaching 2325 m in the Klein Swartberg Peak);

these are situated 100–150 km south of the southernmost section of the Great Escarpment. Mountains in SA reach relatively low elevations compared to other regions globally (Clark et al., 2011). There are six major mountain ranges in SA with the Great Escarpment and the Cape Fold Mountains together providing most of the mountainous terrain (some 226,061 km^2, or 18.5% of the country), while smaller ranges (e.g. Magaliesberg, Soutpansberg, Waterberg, Witwatersrand; elevation rarely exceeds 1800 m) occur as linear outliers in the north.

For the purpose of this chapter, we delineated these mountain areas using a combination of the Topographical Positional Index (an algorithm used to measure topographic slope positions and to automate landform classifications) and roughness surfaces (Shepard et al., 2001); these were used to produce mountain area layers in ArcMap 10.3 based on altitude (Fig. 14.1).

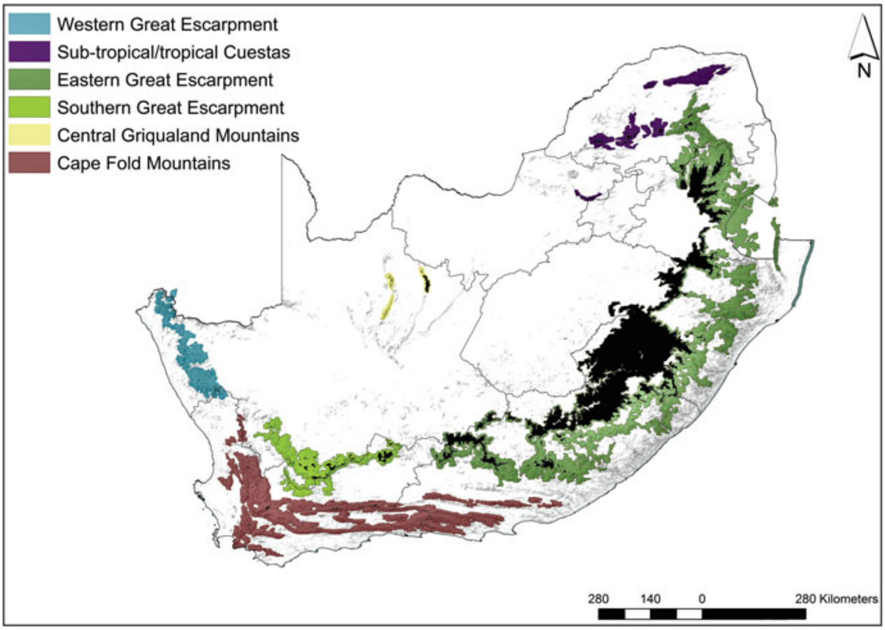

Fig. 14.1 The six major mountain ranges in South Africa. Black shading superimposed over colours indicates areas with the highest elevation of >1600 m. The Western Great Escarpment (i.e. Richtersveld and Namaqualand) are arid, receive winter rainfall, and occur in the Succulent Karoo Biome. The Southern Great Escarpment (Hantam–Roggeveld and Nuweveldberge) is arid to semi-arid winter, receives rain throughout the year and occurs in the Nama Karoo Biome. The Eastern Great Escarpment (Sneeuberg to Wolkberg) receives rainfall mainly in summer, and mesic grasslands and Afro-temperate forest are the typical vegetation. The Cape Fold Mountains (Cederberg to Makhanda), with predominantly winter rainfall, occurs mainly in the Fynbos Biome, but some areas are covered by Afro-temperate forest. The Sub-tropical/tropical Cuestas (Witwatersrand, Magaliesberg, Waterberg, Soutpansberg), receives summer rainfall and occurs in the Savanna Biome. The Central Griqualand Mountains receives sparse rainfall in summer, is arid, and forms a marginal part of the Savanna Biome

3 Invasive Alien Plants in Montane Areas

There has been a paucity of IAP monitoring targeting mountains specifically in SA. Consequently, current estimates largely rely on national monitoring surveys that often do not fully encompass the more inaccessible mountain areas and thus underestimate their true extent. We collated the IAPs recorded within the mountain areas using ArcMap 10.3. Records were obtained from the two most comprehensive occurrence species datasets available– the Southern African Plant Invaders Atlas (SAPIA) and iNaturalist records – for both high and low elevation mountain areas (Fig. 14.2). The SAPIA and iNaturalist databases vary in how records are obtained, being roadside surveys (Henderson, 2007) and citizen science observations, respectively (Unger et al., 2020). These different approaches are reflected in the variation in IAP records between the databases.

Despite the variation in IAP species and their order of abundances between the databases, they both reflect the commonalities in the types of invasions occurring in mountain areas. Both databases show a higher number of IAPs in the lower-elevation mountain areas with an average of double the records on SAPIA and 65% of the records in iNaturalist. In all montane areas, trees and shrubs make up the majority of IAPs. This woody densification is occurring across most ranges in SA, particularly from fire-driven or fire-tolerant species such as Cluster Pine *Pinus pinaster* and Black Wattle *Acacia mearnsii*.

A different suite of IAPs dominate the higher and thus moister and colder montane areas (>1600 m), mostly comprising of the eastern Great Escarpment and higher reaches of the Cape Fold Mountains (Figs. 14.1 and 14.2). High-elevation areas have distinct environmental conditions such as large temperature fluctuations, higher rainfall, and the occurrence of freezing conditions, including on occasion snow (Henderson, 2007; Mucina & Rutherford, 2006). These features are favourable only to certain types of IAPs that can withstand such extremes, thus excluding many common lowland tropical species. For example, a number of invasive Rosaceae species – including Orange Firethorn *Pyracantha angustifolia*, Nepalese Firethorn *P. crenulata*, Orange Cotoneaster *Cotoneaster franchetii*, and Rosehip *Rosa rubiginosa* – are generally more abundant (or even restricted to) high-elevation areas, where extended minimum winter temperatures are needed to trigger flowering, fruiting, and seed germination.

4 Invasive Alien Plants and Their Impact on Nature's Contribution to People

The IAPs that are most abundant in SA's mountain areas are largely trees and shrub, as discussed in the previous section (Fig. 14.2). The establishment of these woody species both threaten and support ES and human well-being for both local communities in montane areas, and those in nearby lowland areas.

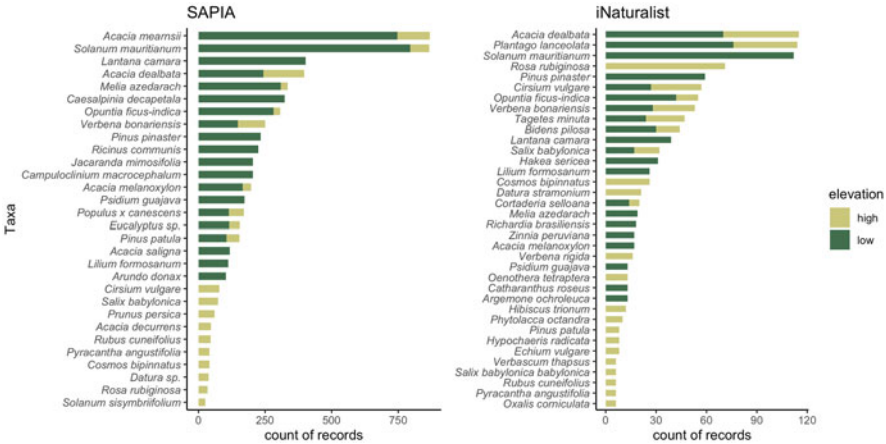

Fig. 14.2 The most abundant IAPs in high-elevation (>1600 m) and low-elevation (between 1000–1600 m) mountain areas in South Africa (see Fig. 14.1 for outline of high elevation mountain areas). Records were obtained from two databases: the Southern African Plant Invaders Atlas (SAPIA, downloaded: 2018) and iNaturalist records of naturalised plants (downloaded: 16th February 2021). Records from iNaturalist were filtered to only include Research Grade observations that were indicated to be out of cultivation

The increasing encroachment of woody growth forms is a direct driver of change in these naturally open-habitat ecosystems. In montane grasslands, landscapes are transformed into dense woody thickets; in montane fynbos, woody IAPs outcompete the shorter fynbos shrubland through their sheer adult size and numbers. These IAPs are therefore exploiting a missing ecological niche, which can result in displacing local species and transforming the vegetation structure (O'Connor & Van Wilgen, 2020).

The transformation of montane areas can result in a loss of ES and thus community access to food, natural medicines and fibre, firewood, building materials, and agricultural productivity that supports the livelihoods and economies of commercial, small-scale and communal farmers (Shackleton et al., 2007). The most concerning ES at risk is the impact of woody encroachment on SA's water security, as these areas are the source regions for the country's river systems. Woody species, especially those in the genera *Acacia*, *Eucalyptus*, *Pinus* and *Populus*, can alter the hydrology of the watercourses and reduce streamflow (Le Maitre et al., 2020). It is estimated that IAPs in mountain catchments consume more than 4% of all registered water use; if left uncontrolled this figure might become as high as 16% (Blignaut et al., 2007). In addition, IAPs can undermine water quality, thus increasing water purification costs and directly assaulting human health (Chamier et al., 2012). Water is becoming a limiting factor to development in SA, with an average precipitation of approximately 500 mm/annum, well below the world average of about 860 mm/annum (DWAF, 2013). Furthermore, SA shares its major mountain range, the Maloti-Drakensberg, with the Kingdom of Lesotho and most of the water reserve lies within the latter's territory (Hoag, 2019). The potential for IAPs to reduce the country's already limited water resources is therefore a major regional geopolitical issue (see case study of the Manica Highlands, in Clark et al. (2019)).

Invasive alien plants can also hold benefits for local people, particularly in low income, natural resource dependent communities. Most of these species were deliberately introduced for their provisioning services such as for food, aesthetic value, building material, medicine and fuel (Shackleton et al., 2007). For example, several *Acacia* species are widespread invaders with little economic importance yet are still widely used for firewood and construction material in marginalised rural areas (Kull & Rangan, 2008). Further, mountain harvested plants are an important feature in the *muthi* trade (traditional medicine) and many alien plants have been culturally integrated into these practices. Communities also benefit from their regulating and cultural services including shade and erosion control. We discuss in the case study an example of invasive Rosaceae that are largely restricted to high elevation areas whereby their invasions outline species that are providing resources but also give rise to disservices to these areas.

4.1 Case Study: Invasive Rosaceae

Several Rosaceae species from the northern temperate regions of the world are becoming increasingly invasive in mountainous regions of SA, particularly the Eastern Great Escarpment. Most were introduced through the horticultural industry, as they were highly regarded for their ability to withstand cold temperatures, and for their aesthetics including displays of red, yellow, and orange berries in autumn and winter months. These berries are now fuelling their invasion; Chari et al. (2020) showed that invasions of Orange Firethorn could be producing up to five million seeds per square meter of invaded land per annum.

South African Afromontane grasslands are typically poor in fleshy-fruited plant species, and the berries of alien Rosaceae species are particularly attractive to frugivorous birds and small mammals which facilitate their spread, not only through dispersal but also through enhanced germination rates. The spread of invasions have been rapid; Orange Firethorn only began invading the Grassland Biome in the early 1980s and is already one of the most widespread and abundant IAPs in the biome (see Fig. 14.3 for images of a typical invasion; Chari et al., 2020).

Unlike the situation with other tree invaders such as wattles (*Acacia* spp.), for which impacts have been relatively well studied in SA (Le Maitre et al., 2011), the impacts of invasive Rosaceae are still being assessed. Current evidence shows that the impacts in invaded ecosystems are likely to be significant, both environmentally and economically (Martin, 2021a). However, in the high-elevation regions of SA, natural resources are limited and some Rosaceae species contribute provisioning ES for the communities living there. Feral rosehip for example, is harvested by rural communities and sold to private companies for the global food and herbal tea market. The rosehip market is a substantial and important economic component

Fig. 14.3 A Rosaceae invasion (*Cotoneaster, Pyracantha,* and *Rosa* spp.) in the Clarens Nature Reserve, Free State province (part of the Eastern Great Escarpment mountains) showing (**a**) urban area at base of mountain with cultivated Rosaceae, (**b**) plants escaping cultivation and moving up the slopes of the mountain and (**c**) an established stand forming natural monocultures in the damp ravines. (Photos taken by K. and S. Canavan)

for communities with over 5000 tons of rosehip harvested annually, providing informal income for approximately 30,000 people in SA and Lesotho (Martin, 2021a). Introduced *Rubus* spp. (brambles and blackberries) also contribute to sustaining livelihoods, including harvesting the wild fruits for commercial uses, supplementing diets, and generating income in rural communities where it is sold for use in small scale secondary industries. The use of these IAPs poses challenging conflicts of interest for landowners and conservationists (Zengeya et al., 2017).

Management is often required for these introduced Rosaceae species, particularly when infestations impede on the provision of other ES such as when limiting access to arable land. However, many invasive populations occur on steep slopes and dangerous terrain where conventional control methods are difficult and expensive to implement. Where access is possible, some of these species form dense natural monocultures that hamper control efforts (Martin, 2021a). Careful evaluations need to be conducted for each species, as some may be important components to communities living in these resource-limited environments (see multi-valued based approaches in discussion).

5 Management Challenges

Invasive alien plants have been described as a wicked problem (Woodford et al., 2016) as they can have both positive and negative impacts on ES and the stakeholders who benefit from them. While it is clear that increasing woody densification threatens montane ecosystems, it is also imperative to explore how these plants have been integrated into these communities. Such stakeholder engagement needs to be considered and unified with any management interventions. Here we discuss management of IAP in mountain areas according to (1) what legislation is currently available, (2) multi-valued based approaches to management, (3) which nature-based solutions could be considered, and (4) current implementation programmes.

5.1 Legislation

The SA government has instituted several initiatives for sustainable development, yet there is almost no mention of mountain areas in these policies. The 'invisibility' of mountainous areas in the environmental policy domain is probably because they cover a fairly small part of the total territory, have small human populations, and are thus of limited political importance (Browne et al., 2004). However, with growing recognition of their value, particularly for water security, there has been increased investment into managing these areas. In the 1970s the Mountain Catchment Areas Act (Act 63 of 1970) was published (Van Wilgen et al., 2020). This Act was intended to protect mountain catchments by authorising the destruction of alien vegetation within five kilometres of a boundary of a mountain catchment area (Van Wilgen et al., 2020). Since then, the management of IAPs has also been addressed through the national alien-plant control programme known as Working for Water (WfW) under the Department of Environment, Forestry and Fisheries: Natural Resource Management Programme (DEFF: NRM) (Bennet & Van Sittert, 2019).

5.2 Multi-Valued Based Approaches to Management

The overall aim of any environmental management intervention is to improve the sustainability and resilience of target systems to ensure that they continue to deliver key ES. Mountain areas in SA have distinct socio-economic characteristics, especially with respect to poverty indicators. Although they house a small proportion of the total human population of the country, those communities are generally poorer, geographically isolated from resources and markets than those of most other areas and have lower political influence (Browne et al., 2004). Communities in mountains, unlike those in higher-income areas, do not often have economic diversification and still are highly reliant on provisioning ES. Strategies for controlling IAPs in these regions must recognise that some IAPs provide critical resources and this needs to be accommodated to achieve sustainable solutions (Linders et al., 2021).

The value or worth of an IAP can vary over time and between cultures. Given this interplay of multiple perspectives by different stakeholders, invasion biology has been met with problematic circumstances and in some cases direct public opposition (Zengeya et al., 2017). Such social disagreements can lead to obstruction in control efforts and demonstrate the practical need to ensure public support for successful management projects. Value-based conflicts are generally challenging to resolve (Estévez et al., 2015). Multi-value based approaches should be applied to invasive species management such as the structured decision-making process (Liu et al., 2012) and the ecosystem service multifunctionality approach (Manning et al., 2018). These strategies promote the identification of each stakeholder's objectives and potential synergies which in turn are related to ecological models and management alternatives. Such approaches share a commonality in the central role of traditional ecological knowledge in the management of ecosystems (Dean et al., 2021) and strive to maximise the multiple benefits of the invaded landscape to help communities to derive requisite benefits. Selection of appropriate control options is carried out to ensure sustainable use of multiple ecosystem services and to provide meaningful outcomes.

5.3 Nature-Based Solutions

Invasive alien plants in high-elevation areas typically occupy steep slopes and inaccessible terrain which often makes conventional control methods dangerous or impossible (e.g. see Van Wilgen & Richardson, 2012 for discussion of problems in this regard for invasive pines in mountains). One area that offers promise and reflects a nature-based solution, is in the adoption of biological control that provides an effective, sustainable and herbicide-free management option. This approach is ideal for mountain systems that are inaccessible to clearing efforts. The Northern Temperate Weeds programme was established in 2017 with the aim of targeting Northern temperate weeds that are common, widespread and problematic primarily in high-elevation mountains of SA for biological control. The programme has also helped establish an IAP working group for southern Africa mountains with the aim of bringing together interested and affected parties to both improve collaboration and coordinate management efforts (Martin, 2021b).

5.4 Implementing Programmes

Invasive alien plant management may benefit from the strong momentum being generated by NGOs around stewardship programmes in SA mountains. Although often appealing to private landowners and traditional authorities as a mechanism to exclude commercial afforestation programmes and mineral exploitation on their land, these stewardship programmes also offer increased incentive for co-ordinated IAP management in these areas. Such IAP programmes increase the ecological value of the land, and make the future deproclamation of such Protected Environments more difficult to motivate for (by e.g. mining interests). Examples of such stewardship programmes in SA mountains are the Ekangala Grasslands Project (Carbutt et al., 2008) and the Upper Umzimvubu Watershed (with an active IAP control programme) (CEPF, 2017).

6 Lessons Learnt

Invasive alien plants will continue to expand into montane areas and become endogenous pressures on these mountain systems that can alter quality of life. For example, Carbutt (2012) performed an early detection study in the Drakensberg Alpine Centre of the eastern Great Escarpment and found 23 emerging IAPs that are likely to become increasingly problematic. Yet many of these IAPs also provide material benefits that contribute to local economies and livelihoods. Due to the multiple complex interlinkages between IAPs as drivers of change, ES, and human well-being in mountains; greater collaboration across humanities, social sciences and natural science is needed (Martín-López et al., 2019).

These invasions are probably being driven by continued habitat degradation and climate change, as well as that they have not saturated their total potential area of invasion. Establishing research priorities for SA mountains in order to untangle the mechanisms driving IAP spread is essential, so that these outcomes can feed into policy, and align with broader habitat protection goals. For example, increasing the rollout of the Mountain Invasion Research Network's (MIREN) long-term monitoring protocols (Kueffer et al., 2014) in SA mountains would be a valuable start. More emphasis on transboundary collaborations – particularly between SA, and the Kingdoms of Lesotho and Eswatini – will help improve our understanding of the movement of IAPs in southern African mountains (both temporally and spatially), and help inform co-ordinated management strategies alongside the protection of livelihoods.

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Part III
Urban Systems

Chapter 15
Ecosystem Service Flows Across the Rural-Urban Spectrum

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Significance Statement Key differences exist between how rural and urban people receive benefits from nature (termed ecosystem services; ES). In rural areas, people are thought to have relatively direct relationships with local ecosystems (e.g. growing food on your subsistence farm). By contrast, within urban areas, people often have more indirect access to distant ecosystems (e.g. obtaining food from hundreds of miles away via supermarket value chain). However, this leaves many questions unanswered: e.g., What natural benefits are present within cities? When do nature's benefits flow into cities? When do the people travel out to directly receive nature's benefits? Here, we explore this issue – breaking down ES flows into two components (i.e. the movement of natural goods and the movement of beneficiaries [people]).

Keywords Ecosystem service · Flow · nature's contributions to people · Rural · Urban

1 Introduction

Nature's benefits to humans, (termed ecosystem services; ES) are intimately linked to our survival (Isbell et al., 2017). ES provide us with our fundamental basic needs (e.g. fuel, food, and water; provisioning services) and help maintain the environment we need to thrive (e.g. maintaining the quality of air and soil, providing flood control; regulating services). ES also provide us with the ability to develop our mental, physical and spiritual wellbeing; providing space for recreation, spiritual and aesthetic appreciation of nature (cultural services).

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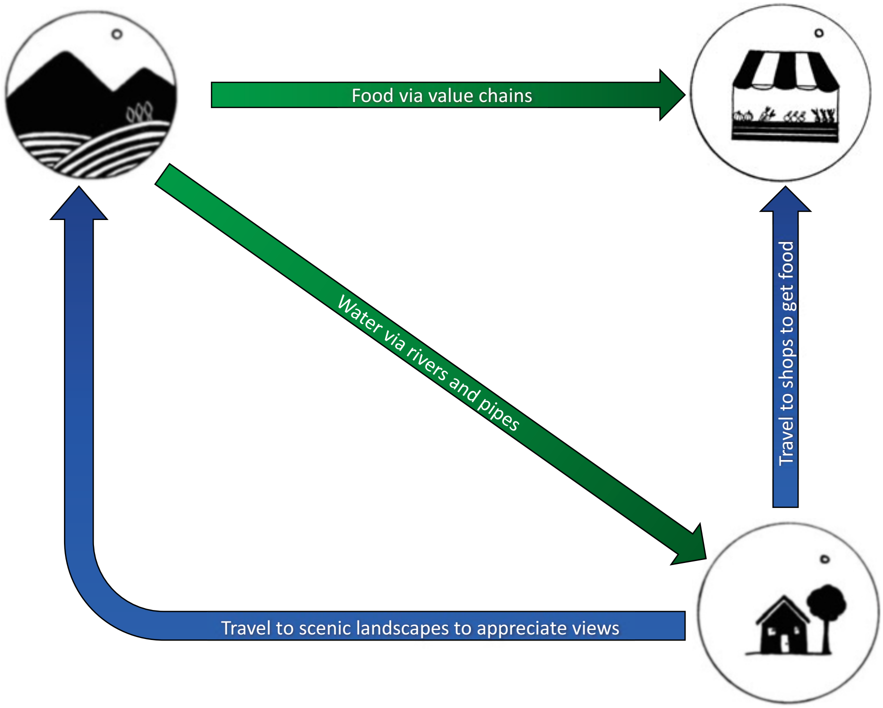

Fig. 15.1 Ecosystem services flows can be broken down into two components: the movement of natural goods (green) and the movement of people to access them (blue)

The worlds' population is expected to reach 9.7 billion by 2050, with over 70% predicted to live in urban areas. Increased global interconnectivity (i.e. through trade networks and global supply chains) has allowed urban populations to indirectly access remote ecosystems to benefit from their services. Meanwhile, there are growing calls for humanity to 'reconnect' with nature which may be in the form of material, experiential, emotional or philosophical connections (Ives et al., 2018). Better understanding how we access and connect with nature, will allow us to become a more sustainable society.

Cumming et al. (2014) highlighted theoretical differences between how rural and urban people access ES. In rural areas, people are thought to have relatively direct relationships with local ecosystems (e.g. growing food on a subsistence farm) – termed 'green-loop' systems. By contrast, within urban areas, people often rely upon indirect access to distant ecosystems (e.g. obtaining food from hundreds of miles away via a value chain) – termed 'red-loop' systems. However, this rather simplistic viewpoint, whilst useful, does not apply to all ES and modes of access (e.g. an urban resident may access a local park to recreate whilst a rural resident may also access supplies through value chains) and leaves many questions unanswered. For example, 'When do nature's benefits *flow into* a city?' and 'When do urban residents *flow out* to access services?' (see Fig. 15.1).

In this chapter, we explore the nuances of this issue by breaking down ES flows into two components: the movement of natural goods and the movement of beneficiaries (people) to access them – and how this differs between rural and urban areas for provisioning, regulating and cultural ES in turn.

2 Provisioning Services

2.1 Movement of Natural Goods for Provisioning Services

Provisioning ES (such as food) can flow from one region to another across the globe. The nature and direction of the flow are usually determined by demand, which is the product of people's needs, choices, and the value placed on those services. However, demand and the value chains to supply this demand can vary substantially between cultural and socio-economic groups; for example, between the Global North and the Global South (Horner & Nadvi, 2018).

Within the cities of the Global North, there is a seemingly ever-increasing demand for provisioning ES, making these urban areas focal points for wider environmental impact. This, in part, is driven by the fact that in the Global North the majority of the population are urbanites. Urban areas in the Global North rely heavily on rural ecosystems for the supply of natural products, which flow into cities via supply chains (Taguchi & Santini, 2019). However, within many countries of the Global North, rural areas are connected to similar national and international supply chains. Thus, goods produced within a rural location may not necessarily be used nearby as they may be processed elsewhere and enter the national supply chain, becoming disconnected from the community of origin (Ilbery et al., 2004). For example, salad grown in rural Kent, UK, might be shipped over 100 miles to be packed, prior to distribution nation-wide across rural and urban areas alike. Similarly, rural and urban people across the Global North rely heavily on international products – e.g. the vast majority of UK imports of plywood in 2017 came from China (37%) and Brazil (18%) (Forest Research, 2018). Thus, natural goods may flow similar distances towards both urban and rural beneficiaries within the Global North – even when those goods are produced locally.

The movement of natural goods across the Global South show some similarities to that observed in the Global North, yet there are notable differences – particularly in rural areas. As in the Global North, urban areas across the Global South are centres of demand and heavily reliant on distant ecosystems to supply natural goods (Cumming et al., 2014). This demand is partly supplied by surrounding rural area; e.g. charcoal demand in Dar es Salaam Tanzania is sourced from surrounding rural areas, with increases in demand met with a widening sphere of influence (Ahrends et al., 2010). Remaining urban demand for natural goods in the Global South is often met via international supply chains (Gereffi & Lee, 2012). By contrast, rural areas within the Global South are often more reliant on local ecosystems than urban areas in the Global South, or urban and rural areas in the Global North. For example in northern Ghana, many rural residents obtain bushmeat from local forests (Boafo et al., 2014). However, this rural-urban distinction is complex and varies across different products, often reliant on infrastructure and market access. For example, in West Africa, countries import (e.g. from Thailand or Vietnam) ~40% of rice the needed to meet demand in both rural and urban areas (Tondel et al., 2020).

2.2 Flow of Beneficiaries to Provisioning Services

As in red-loop, green-loop theory (Cumming et al., 2014), urban residents often access provisioning services indirectly due to the low availability of provisioning services resulting from intensive urban land uses. However, urban areas often have good infrastructure enabling the transport of ES directly to (or relatively close to) beneficiaries' doorsteps. This adds another dimension in urban-rural duality which differs between the Global North and South.

In the Global South, many urban residents do not need to travel to access water because facilities are in place to pipe water directly to their homes. By contrast, more rural people need to travel considerable distances to get water from water bodies or public water facilities (Kummu et al., 2011). In the Global North, most urban and rural residents are connected to a household water supply.

Urban residents in the Global North are often closer to food stores and consequently travel shorter distance to obtain food than people in rural areas, who are often required to drive to access the nearest store (Pinard et al., 2016). By contrast, many rural people in the Global South access food more locally than their urban counterparts, for example due to small farms sizes, poverty and lack of infrastructure (Szabo, 2016).

Fuel is obtained from nearby ecosystems by many low-income households in both rural and urban areas, mostly in countries across the Global South (e.g. fuelwood, charcoal, crop residues, and animal dung). For example, in Argentina, Cardoso et al. (2013) found the search distance for fuelwood was greater in rural areas (>4 km) where people have to travel to nearby forests, compared to urban areas (<4 km) where people have access to trees in urban green spaces. Although, people within the Global North rely on nature less for fuel than their Southern counterparts due to the availability of fossil fuels, of those that do, many urban residents have easier access to (shop-bought) fuelwood than rural residents (Smith & Morton, 2009).

3 Regulating Services

3.1 Movement of Natural Goods for Regulating Services

The concepts of 'red-loop' and 'green-loop' systems (Cumming et al., 2014) fails to capture the complex nature of regulating services. Unlike provisioning or cultural ES, regulating services are often silent or invisible processes, in which their significance only become evident when a disruption to these services occurs. Regulating services do not provide a flow of material goods like provisioning services. Instead they prevent, moderate or structure natural processes, allowing ecosystems to flourish. Thus, regulating services are less well understood in terms of how scientists can accurately monitor the scale and development of these services.

Additionally, regulating services are often not bound to a specific area as they can contribute more towards aspects of global ecosystem function (e.g. climate regulation) than local ecosystem function. For instance, carbon sequestration, in which excess CO_2 is absorbed by vegetation, is provided by forests globally. As a result, there is no significant difference in the flow of carbon regulation services between urban and rural areas. Similarly, flood regulation services provided by upstream ecosystems benefit downstream areas based on location rather than levels of building development (i.e. rural vs urban). That said, many regulating services provide both global and local benefits (such as pollination, flood and air quality mitigation services), demonstrating the complexities of regulating services and the difficulty in deciphering benefits received by urban or rural areas.

Therefore, the most pressing question becomes not how urban or rural communities receive benefits from regulating services, but rather how anthropogenic pressures disrupt these regulating services. The benefits provided by regulating services become more apparent when they are damaged or disrupted, as the loss of these benefits can severely affect ecosystem function. Once a regulating service has been damaged or disrupted, it is extremely difficult to restore. For example, across many parts of Africa vulnerability to climate change and desertification is expected to intensify due to human malpractices of deforestation and land degradation. Increased pressure from both local and global communities have disrupted natural climate regulation leading to increased flooding, droughts, soil erosion and a rise in vector borne diseases such as malaria (Wangai et al., 2016). However, scientific advancements have enabled technical solutions to offset the anthropogenic disruption of ES. For instance, carbon capture and sequestration can severely reduce green gas emissions, which in turn offsets the anthropogenic effect on climate regulation. Yet, some regulating services are not so easily substituted by present technology, and/or cannot be applied in areas like the global south without substantial financial aid (Fitter, 2013).

Historically, humanity has failed to understand the importance of regulating services and the benefits they provide, both in rural and urban areas, until these services were damaged and the distribution of benefits disrupted. In future, technical advancements may help restore and enhance regulating services, particularly as mitigating the impacts of climate change becomes more important.

3.2 Flow of Beneficiaries to Regulating Services

Evidence of movements of people to access regulating services is mixed and case-study specific. This stems in part from the less tangible and unbounded nature of regulating services, the complexity of decision-making surrounding mobility and difficulty in disentangling movement for provisioning services from the underlying regulating service. It depends upon the regulating service in question (i.e. larger-scale climate and flood regulation vs. local-scale air quality and temperature regulation), the duration and spatial scale of movement required, and people's willingness and capacity to move, which is mediated by a range of socio-economic, cultural and political factors.

Again, perhaps more pertinent than movement to access regulating services is movement in response to a loss or deterioration in regulating services. These movements can be out of necessity (i.e. temporary migration during flooding or drought; Deshingkar, 2006) or choice (for a more comfortable life).

Out-migration from cities to suburban or rural areas in search of a more favourable local climate and/or air quality has been well documented around the world and is often evidenced by higher property prices in the urban fringe. For example, air pollution has been statistically linked to increased out-migration and decreased in-migration, predominantly of educated professionals, from cities in China (Chen et al., 2017). Heat stress can also elicit migration; 25% of survey respondents across several cities of South-East Asia reported being 'very likely' to migrate to cooler climes to escape the heat (Zander et al., 2019).

Movement to escape an unfavourable climate is not just confined to urban areas. Mueller et al. (2014) showed in rural Pakistan heat stress significantly increases out-of-village migration, particularly of men, whilst temperature variation had a significant effect on migration in Bolivia, Brazil and Uruguay but not in other South American countries studied (Thiede et al., 2016). In the 1990's, growing awareness of climate change led to predictions that deteriorating climatic conditions would render many livelihoods untenable, prompting mass waves of 'climate refugees'. Yet this has not been proven and the assumption of a linear 'push' relationship between climate change and migration has since been hotly contested. As such, there are no generalisable conclusions regarding the links between environmental change and mobility because responses to environmental change are highly heterogeneous and dependent on people's vulnerability and capacity to move.

Finally, movements to access regulating services need not be so drastic and long-term, they can also be for short-term recreational purposes. Consider people flocking to parks or the coast on a hot summer day to access the temperature regulation provided by shade or the sea. In these cases, both urban and rural inhabitants travel varied distances, often determined by individual socio-economic factors, to access the regulating service (e.g. to a local or distant greenspace).

4 Cultural Services

4.1 Movement of Natural Goods for Cultural Services

Cultural ES can flow from the providing ecosystem to beneficiaries via sensorial perception (e.g. line-of-sight) or knowledge systems (e.g. the internet). For example, line of sight to natural spaces can represent a flow of sense of place and landscape (Daniel et al., 2012). In an urban context these non-travel flows are often limited to views to relatively few urban green spaces (Lin et al., 2017). In contrast, rural areas tend to be in more immediate proximity to a range of culturally valued ecosystems, which offers higher potential sensorial flow of cultural ES to beneficiaries (Swetnam et al., 2017).

Flow of cultural ES from ecosystems to beneficiaries can occur without beneficiaries seeing or travelling to the ecosystem to obtain the service. Cultural ES may also flow to beneficiaries via knowledge systems as is the case with existence value. Existence value (i.e. the benefit people gain because they value the knowledge of its mere existence) flows from an ecosystem to beneficiaries via both modern (e.g. the internet) and traditional (e.g. word of mouth) knowledge systems (Gee & Burkhard, 2010). Rural areas tend to have less developed information and communications technologies therefore they may have a slower flow of existence value ES (Salemink et al., 2017).

4.2 Flow of Beneficiaries to Cultural Services

People living in rural areas have more direct access to nature than those who live in urban areas as they are often physically closer. They may be able to access natural spaces easily on their own land or very near where they live. Therefore, there is often little cost in terms of time or money for rural inhabitants to access natural spaces (Rodrigue, 2017). Rural residents also have greater opportunities to enjoy nature through activities such as foraging, gardening, and wildlife watching (Fish et al., 2016). These practices can result in a product, but the process of getting them can translate into benefits such as connection to nature, place, and people they have shared the experience with (Fish et al., 2016).

Conversely, urban residents are less likely to live close to natural spaces and so often must make a specific trip to access the benefits of spending time in nature (Žlender & Ward Thompson, 2017). This trip does not necessarily have to be large, and could involve spending time relatively locally, e.g. in urban green space. However, access to urban green space can depend on socio-economic status.

Urban areas with more green space (both public and private) are more expensive to live in and this excludes potential beneficiaries who cannot afford to live there, reducing their access to green space and the associated benefits (Wolch et al., 2014). Alternatively, people could leave the urban area completely to access nature in rural areas, although this incurs a greater travel cost in terms of time and money (Mayer & Woltering, 2018).

Whilst proximity and access opportunities are factors in how much time people spend in green space, people's level of connection to nature, both in rural and urban areas, also plays a part. Lin et al. (2014) showed that living close to an urban green space did not necessarily mean people spent time there. Nature orientation, or connection, was a much stronger factor in predicting whether people spent time in urban green space. Those who reported a greater connection to nature spent longer in their own private gardens, urban green spaces and would travel further to spend time nature (Lin et al., 2014). Therefore, people must have some level of connection to nature to want to spend time there and gain the associated benefits (Martin et al., 2020).

5 Conclusion

Breaking down ES flows into two components (i.e. the movement of natural goods and the flow of beneficiaries) highlights that each of the three categories of ES (provisioning, regulating and cultural) can show substantial differences across the rural-urban spectrum. As the global urban population grows, these differences in ES flows may become increasingly important, and inequalities in these flows might lead to some sectors of society becoming disconnected with nature (Ives et al., 2018). Here, we have illustrated the differences in ES flows by contrasting rural and urban areas, dispelling some of the broad generalisations resulting from red-loop, green-loop theory (Cumming et al., 2014). However, we acknowledge that ES are often spatially and temporally distinct, and largely unique to the individual. Thus, future work must continue to disaggregate ES to beneficiaries with increasing resolution. Similarly, the ongoing expansion of urban areas results in a continuous spectrum and that the rural/urban categories we use here are somewhat arbitrary. As such, we finish by highlighting that the large and expanding global peri-urban zones where ES flows are not well understood. In peri-urban areas, ES flows might be predicted to be intermediary between those observed in rural and urban areas, but further research into this is urgently required.

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Chapter 16
A Typology for Green Infrastructure Planning to Enhance Multifunctionality Incorporating Peri-Urban Agricultural Land

Werner Rolf

Significance Statement This work addresses a research gap that exists when it comes to Green Infrastructure planning as a new spatial planning approach to develop multifunctional green networks. I introduce a typology for spatial planning to integrate peri-urban farmland in Green Infrastructure, supporting the development of a multifunctional open space network. This typology is based on a two-tiered approach, involving an inter- and transdisciplinary approach and an evidence synthesis. It contributes to the conceptual understanding of multifunctionality planning, provides evidence that peri-urban farmland bears potentials to address urban challenges, such as biodiversity conservation, climate change adaptation, green economy development, and social cohesion, and reveals research gaps that still need to be addressed in future.

Keywords Green infrastructure · Farmland · Sustainable land use · Stakeholder · Participation · Evidence

1 Introduction

Urbanization is an important driver of environmental change at different scales (Grimm et al., 2008). It causes habitat loss and fragmentation, over-exploitation of natural resources, pollution and climate change, with effects on human health and well-being (Raworth, 2017; Steffen et al., 2015). In Europe, about 75% of the population lived in urban areas in 2018, expected to reach about 85% by 2050 (UN DESA, 2019). While urban growth increasingly concentrates demands of ecosystem services, this leads in the same time to spatial shift of ecosystem service supply, due to dynamic land use changes, land consumption, and depletion of natural resources in the peri-urban landscape (Eigenbrod et al., 2011). As a consequence, the

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peri-urban landscape is a hotspot of multiple competing land use interests, like housing development, recreation, food production, and protection of wildlife habitat (Willemen et al., 2008).

Furthermore, urban growth has been identified as a significant factor to diminish productive farmland worldwide (Bren d'Amour et al., 2017). In Europe, more than 75% of all land uptake by urban and other artificial land development between 2000–2012 affected farmland (EEA, 2018). On the other hand, urban and peri-urban agriculture are considered as promising options for local food supply to address challenges of food justice and to promote sustainable development (IPCC, 2019). Thus, the depletion of productive agricultural land by urban growth diminishes opportunities for sustainability transformation and sustainable urban land use development.

To address these challenges, urban growth needs to take into account social, economic, and environmental dimensions to minimizing environmental degradation (UN DESA, 2019). Moreover, to address multifaceted character and to meet the demands of different interests of peri-urbanization processes holistic planning and policy approaches are needed for sustainable management of peri-urban landscapes addressing both socio-economic and spatial aspects (Shaw et al., 2020). Various different strategic spatial planning approaches have been developed in the meanwhile to address these challenges and to promote sustainable land use development in urban areas (Healey, 2006). The conception of Green Infrastructure (GI) is one of the latest thinking about spatial planning approaches contributing to sustainable development and to manage urban growth (Benedict & McMahon, 2002). It is being considered as promising and is increasingly receiving attention to promote the development of resilient cities (IASS, 2013; WBGU, 2016).

GI is understood as a strategically planned network in urban and rural landscapes, designed to deliver multiple ecosystem services (European Commission, 2013). Thus, multifunctionality is one of the core principles of GI planning. Ideally, GI planning aims to develop synergies between different functions that contribute to a number of environmental and social aims, such as biodiversity conservation, climate change adaptation, green economy development, and social cohesion (Fig. 16.1).

Although GI planning is understood as an integrated cross-sectoral spatial planning approach, there are still knowledge gaps when it comes to urban and peri-urban utilizable agricultural land and its potentials to contribute to multifunctionality of GI. On the other hand, this would complement already established knowledge about multifunctionality of urban and peri-urban agriculture on multiple dimensions with regard to the landscape level (e.g. Mougeot, 2006; Piorr et al., 2018). Furthermore, it would build upon conceptions of integrated approaches for agricultural landscapes, such 'differentiated land use' (Haber, 1971), 'diversified farming systems'(Kremen & Miles, 2012) and multifunctionality as a management tool for sustainable agriculture and rural development (Mander et al., 2007; Renting et al., 2009; Wiggering et al., 2003). Furthermore, it extends the debate about the integration of utilizable agricultural land into urban spatial planning (e.g. Mougeot, 2006; Philips, 2013; Viljoen & Bohn, 2014) by directly relating it to the GI conception.

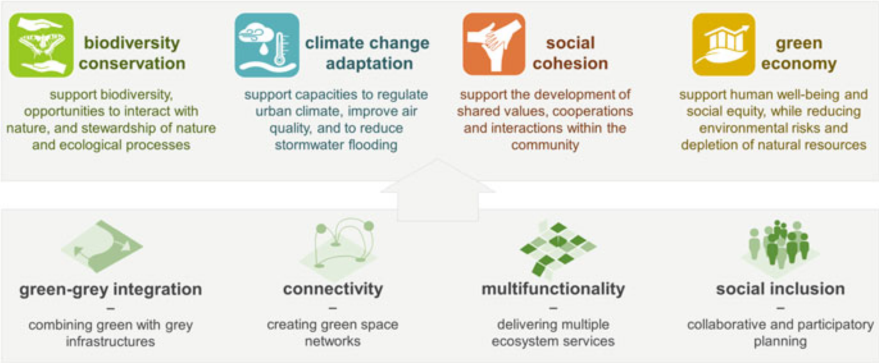

Fig. 16.1 Schematic illustration of the understanding of GI planning as conceptualized. (Adapted from Hansen et al., 2017 and reproduced from Rolf, 2020)

In this article a developed typology for the integration of multifunctional urban and peri-urban farmland in GI planning will be proposed that can be used for spatial planning to promote sustainable development.

2 Methodological Approach

The development of this typology was based on a two-tiered approach.

The first phase involved an inter- and transdisciplinary approach incorporating 15 stakeholders – researchers and local actors representing different interest sectors – to identify opportunities for multifunctional farmland suitable for GI development (Rolf et al., 2019). The study was conducted in the City of Malmö, Sweden. Malmö's peri-urban landscape is dominated by agricultural land uses under very different prevailing natural conditions and site specific potentials and constrains, ranging from large scale agricultural land with primary arable land use management to rather heterogeneous farmland with diverse topography including semi natural grassland. By adapting normative scenario techniques from Nassauer and Corry (2004) the different knowledge holders collaboratively developed several 'desirable farmland characteristics' based on their valuations and appreciations of different functions and benefits. Out of these, the participants derived 'strategic objectives' that represent abstract conclusions of the individual cases, to enable transferability to other regional contexts.

The second phase involved evidence synthesis to reflect current research outcomes and to evaluate potential of urban and peri-urban farmland to tackle major urban challenges and contributing in various ways to the quality of life and human well-being in functional urban areas (Rolf et al., 2020). To assess evidence, a four-box-model was adapted from Moss and Schneider (2000) categorizing confidence of evidence into four classes: established, limited, indirect, and unverified (inconsistent or missing) evidence.

Finally, as a result from these two phases a typology of four different spatial planning strategies has emerged that link peri-urban farmland with GI planning, supporting the development of a multifunctional green space network.

3 Four Ways for Strategic Spatial Planning of a Multifunctional Green Space Network

As an outcome of the first tier, it becomes clear that there is no 'one size fits all' solution for farmland, but strategic objectives to enhance multifunctionality needs to consider prevailing site conditions and underlying landscape parameters (primary topography, soil, water and micro climate) that define agricultural productivity (Rolf et al., 2019). Essentially, stakeholder agreed on two main strategy strands with four different objectives in total, to assist multifunctionality on highly-productive farmland on the one hand, and to assist multifunctionality on less-productive farmland on the other hand (Fig. 16.2). This study has shown that preferences can vary between different situations, and one and the same stakeholder considered functions more relevant in some places than in others.

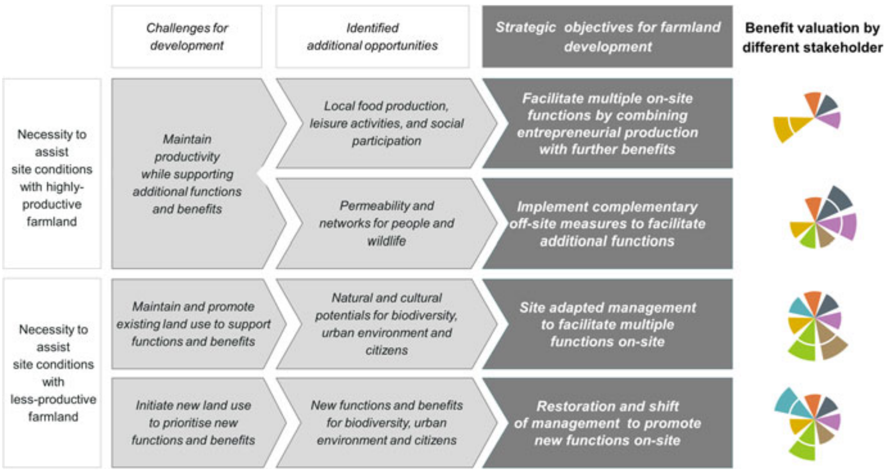

Fig. 16.2 Overview of the workshop outcomes with suggested strategy strands to assist multifunctionality in peri-urban farmland, with polar area chart used to illustrate the evaluation by the different stakeholders involved (red = urban planning, blue = urban space planning, purple = recreation planning, brown = cultural heritage conservation, green = nature conservation, yellow = agricultural management, blue = water resource management); full segment indicates core function, half segment indicates co-benefits and no segment indicates no benefit. (Based on Rolf et al., 2019)

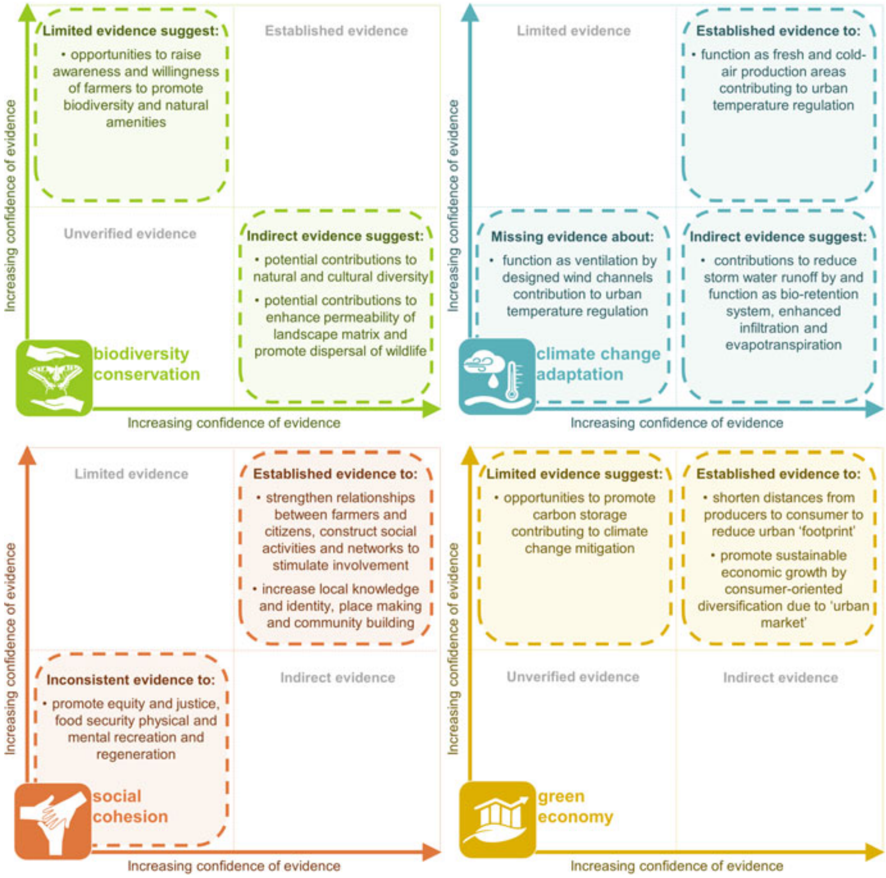

Fig. 16.3 Overview of evidence synthesis, with assessment of confidence of evidence related to potential contribution in an explicit functional urban context using the four-box-model. (Based on Rolf et al., 2020)

As an outcome of the second phase, the evidence synthesis includes 54 literature findings in total that have been assessed in accordance to the four GI objectives using the four-box-model as summarized in Fig. 16.3 (Rolf et al., 2020). In sum, although this study reveals research gaps that still need to be addressed, there is clear evidence that peri-urban farmland bears potentials to promote economic, social, and environmental benefits.

Finally, as an outcome of this two-tiered approach a typology of four different spatial planning strategies to integrate peri-urban farmland in GI planning emerged, supporting the development of a multifunctional green space network. As an abstraction of reality, these four ways can be understood as ideal types, that intertwine physical, ecological, social, as well as the economic functions, thus, contributing to multifunctional GI. They can stimulate discussion about how GI planning can and should incorporate utilizable agricultural land, especially the agriculturally dominated landscape at the urban fringe and its surroundings.

3.1 The Connecting Way – Multifunctional Farmland Corridors as Links

The connecting way aims to develop ‘multifunctional farmland corridors’ as links within agriculturally dominated green belts or rings at the urban fringe (Fig. 16.4). These, multifunctional farmland corridors function as linear network elements in a highly productive agricultural landscape.

They enhance accessibility of the wider landscape for urban dwellers and contribute to a functional recreational network, offering opportunities for leisure activities, such as walking, cycling, and riding. Accompanying margin strips promote dispersal within the landscape matrix and provide small habitat opportunities for wildlife thereby augmenting urban biodiversity. Furthermore, these multifunctional farmland corridors can be beneficial for farmers, contributing to biological pest control and pollination or prevent soil erosion, while providing farm tracks. Thus, within the agriculturally dominated landscape matrix they coherently and mutually reinforce multiple functions. The involvement of land owners of adjacent properties as well as current track users (farmers, recreational users etc.) is considered to be essential. Thus, infrastructural developments, land consolidation procedures and reparcelling offer a ‘window of opportunity’ or by subsequent integration with the existing farm infrastructure and to synergize effects.

Fig. 16.4 Illustration of multifunctional farmland corridors with potential key functions and benefits. (Rolf, 2020)

3.2 The Productive Way – Multifunctional Sites for Value Added Farm Production

The productive way is particular suitable for sites of high productivity. It aims to combine GI development with the agricultural production cycle on- site that benefits directly from the site fertility. It combines food production with the inclusion of further social functions, such as recreation, regeneration, and education, into agricultural production, and which offers new farming models and relationships between consumer and producer (Fig. 16.5).

Business models, such as rent-a-field farms or self-picking farms (e.g., fruit, vegetables, flowers) enable an 'on-field' experience for citizens in their spare time or at the weekend. Thus, it offers opportunities for alternative business models and new income situations, promoting transition pathways towards sustainable economic growth in the agricultural sector. Hence, the integration of 'productive farmland' in spatial planning strategies bears potential to support multiple benefits, contributing to the livability of the urban environment. Furthermore, it does not just offer potentials for cross-sectoral planning, collaboration and cooperation between farmers and urban development authorities, but stimulates networks and active involvement to strengthen relationships between farmers and citizens.

3.3 The Integrated Way – Multifunctional Semi-natural Farmland

Next, the integrated way of 'multifunctional semi-natural farmland' takes into account region-specific management practices that are constrained by prevailing environmental conditions (soil, climate, topography) and their geophysical constraints. It can be related to traditional agricultural management of which multiple natural and cultural values have been well investigated all across Europe (Oppermann, 2012). Accordingly, management can be very different, with or without livestock or mixed, leading to different farmland character, ranging from

Fig. 16.5 Illustration of productive farmland with potential key functions and benefits. (Rolf, 2020)

Fig. 16.6 Illustration of semi-natural farmland with potential key functions and benefits. (Rolf, 2020)

grassland systems, such as meadows and pastures, to agroforestry and cropping systems, like pastoral woodland, orchards, olive groves and other arable systems and may be in some cases also considered as high nature value farmland (Paracchini & Capitani, 2012). Interdependencies between their relevance for biodiversity and multiple ecosystem services in these agroecosystems are evident. Because it is well known that peri-urban agricultural landscape has the ability to provide a number of positive externalities to the urban public the integrated way enables to contribute integrated amenities, such as ecological and social-cultural functions and values to the quality of the urban environment (Fig. 16.6). Furthermore, the integration of semi-natural farmland as vital part in urban development, offers opportunities to promote ecosystem stewardship and collaboration, generating and catalyzing new pathways for innovative ecosystem management leading to more sustainable and balanced land use and urban growth. Quantitative analysis suggests significant spatial potential for low-intensity farmland within the peri-urban landscape (Rolf et al., 2018).

3.4 The Adapted Way – Farming Interventions to Develop Multifunctional Sites

The adapted way sheds light on farming management as interventions at sites that have not been under agricultural cultivation previously. Here, agricultural land use is being initiated as a measure to provide new functions and benefits (Fig. 16.7). Low-intensity farming can promote active ecological rehabilitation and restoration for the reparation of ecosystem processes, functions and services and to support the re-establishment of species compositions and community structure (SER, 2004). As such grassland farming systems can contribute to climate change adaption by inner-urban stormwater retention sites, supplementing green river banks and inner-city fields as ventilation corridors and urban cooling. Although empirical studies are limited, interrelations between social-cultural services farms, nature experience and education for urban dwellers, school classes seem promising. Inner-urban grazing

Fig. 16.7 Illustration of adapted farmland with potential key functions and benefits. (Rolf, 2020)

management has the potential to add aesthetical and recreational values. In sum, adapted farming may be understood as an intervention to complement or further develop multifunctional GI by providing additional benefits. Adapted farming offers new opportunities for cooperation with farmers and to develop new business models for GI maintenance. Nevertheless, agricultural production is of subordinate relevance at such sites. If farming management is supposed to support functions and provide benefits to the urban people, strong incentives are needed to involve farmers in such interventions.

4 Conclusions

This article contributes to the conceptual understanding of multifunctionality planning to enhance GI as a strategic spatial planning approach that incorporates peri-urban farmland. It shows that multifunctionality planning needs to consider ecological site characteristics that define landscape conditions. Furthermore, it suggests that multifunctionality can be very different across the whole agricultural landscape matrix. Emerging from the conducted participatory approach involving stakeholders two main aspects can be concluded:

- Multifunctionality benefits from the landscape context and promotes intertwined functions.
- The dialog between different stakeholders can be seen as an iterative process that helps to mediate conflicts and to minimize trade-offs, to actively develop synergies resulting into different intertwined functions.

As an outcome of this work, essentially four different spatial planning strategies are proposed that show the ability to link peri-urban farmland with the GI conception, contributing to the development of a multifunctional open space network. These strategies can be used as recommendations to stimulate Green Infrastructure planning for the agriculturally dominated landscape at the urban fringe and its surroundings. Furthermore, it may give impulses on how also inner-urban utilizable agricultural land may be further developed. However, these findings need to be carefully applied and need to be adapted to the local context. More importantly, they need to be negotiated with local stakeholders for acceptance and successful implementation. Thus, these strategies cannot be applied one by one but do offer promising starting points, as they are outcome of a transdisciplinary processes and co-designed in cooperation with different stakeholders including farmers as key actors.

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Chapter 17
Urban Green Spaces in a Post-Apartheid City: Challenges and Opportunities for Nature-based Solutions

Valentina Giombini and Jessica P. R. Thorn

Significance Statement Cities in sub-Saharan countries are simultaneously facing climate change, rapid urbanisation, and social inequalities. Nature-based Solutions harness nature's benefits to address these environmental, social, and economic challenges. In this study, we investigate how taking into account temporal dynamics and multiple values of nature helps to implement better Nature-based Solutions. Through satellite images and interviews with practitioners and residents, we look at how green spaces and dry riverbeds are distributed, managed, and perceived in the capital city of Namibia, south-western Africa. We find that apartheid spatial segregation legacies persist through the unequal distribution of urban green spaces, and that, although their current management limits their capacity to deliver benefits, riverbeds have the potential to support sustainable development and climate change adaptation.

Keywords Ecosystem services · Urban green infrastructure · Namibia · Environmental justice · River networks

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1 Introduction

Urban green spaces are widely recognised as multifunctional areas that can help address converging urban and global environmental change challenges (Ahern et al., 2014; Lindley et al., 2018). Studies and practical applications in cities have shown how green spaces improve the quality of life of urban residents and help to adapt to climate change by reducing, for example, the impact of heatwaves or slowing floodwater (Gómez-Baggethun & Barton, 2013; Andersson et al., 2019). Disadvantaged groups of people, however, often live in districts where green urban spaces are scarce or of lesser quality, and thus receive fewer socio-economic and environmental benefits stemming from natural areas. The adverse effects of climate change indeed frequently disproportionally affect the most vulnerable parts of society, which are often more exposed to risks and lack the socio-economic means (e.g., lack of insurance) to recover from shocks (Black et al., 2011). A closer understanding of the relationship between green urban spaces and social inequalities is therefore a critical step needed to identify effective, climate resilient development pathways, which also meet Sustainable Development Goals (Ernstson, 2013; United Nations, 2015; Langemeyer & Connolly, 2020). This chapter aims to show how the discourse on ecosystem (dis)services and Nature-based Solutions (NbS) is linked to historical racial and socio-economic inequalities. We approach this by using the case of the capital city of Namibia, focusing on riverbeds as they represent a diffuse network of natural green areas, critical for regulating water in one of the most arid countries in the world.

Many studies have shown how the distribution of green urban spaces and the delivery of ecosystem services is uneven in cities and regions around the world. Recently, influenced by the field of political ecology, there has been a growing interest to understand the causal dynamics and implications occurring around such patterns of unequal distribution (McConnachie & Shackleton, 2010; Ernstson, 2013; Sandberg et al., 2014). Research in the field of ecosystem service justice highlights that when distributional, procedural, and recognition justice is not considered, practical applications of ecosystem services approaches are unlikely to develop in a just manner, and risk to recreate or reinforce prior patterns (Friedman et al., 2018; Venter et al., 2020; Langemeyer & Connolly, 2020). Ecosystem service justice moreover interacts with other socio-economic dynamics, including power, historical legacies, race, and gender, which affect the way people receive benefits or disservices from the natural environment (Ernstson, 2013; Langemeyer & Connolly, 2020).

McConnachie and Shackleton (2010) showed how today poorer and formerly categorized non-white neighbourhoods have the smallest percentage of green areas in South African cities, while more affluent, former white neighbourhoods have the most. These results indicate that to ensure a fair distribution of ecosystem services temporal dynamics should also be considered, acknowledging the legacy of historic inequalities (Venter et al., 2020; Langemeyer & Connolly, 2020). During the apartheid regime, urban plans in South Africa and Namibia were indeed developed on apartheid principles which used strict land use zoning and racial segregation.

Business activities were concentrated in the centre of the city, “townships” for non-white communities were often built at the city’s periphery, and neighbourhoods for predominantly black, coloured, white, or other communities were built using different standards (McConnachie & Shackleton, 2010). Natural areas without built infrastructure, highways, railways, and industrial areas were built with the explicit intention to physically separate areas (Müeller-Friedman, 2006).

Accounting for the socio-cultural dynamics occurring around urban green spaces is essential to ensure that NbS are effective in increasing the well-being of people and in giving rise to benefits, advancing recognitional justice (Langemeyer & Connolly, 2020). To determine whether residents would benefit from, endorse, and contribute to managing NbS, it is critical to understand the way nature is perceived by local people (Andersson et al., 2015; du Toit et al., 2018; Shackleton & Njwaxu, 2021). In sub-Saharan Africa, however, the body of literature on ecosystem services provision, and especially on cultural ecosystem services, remains limited. There is, therefore, the concern that an inadequate understanding of the interaction between nature and local communities hinders a fair and effective implementation of NbS in Africa (Cilliers et al., 2013; du Toit et al., 2018).

Here, we present the findings of a study conducted in the city of Windhoek, Namibia, to shed light on the perceptions and dynamics surrounding a riverbed network in a post-apartheid Southern African city. Based on the mapping of the greenness of the city and on the fieldwork conducted over 6 weeks in July–August 2019, involving residents and key informants, we aim to answer the following questions:

(i) How is urban greenery distributed across four socioeconomically differentiated neighbourhoods?
(ii) Which ecosystem services and disservices are delivered by riverbeds to residents, and how do these differ across neighbourhoods?
(iii) How do access and management of riverbeds vary across the city neighbourhoods?
(iv) How do historical legacies, people’s preferences and potential ecosystem disservices influence the implementation of Nature-based Solutions such as green infrastructure?

2 Methods

2.1 Case Study of Windhoek, Namibia: An Arid, Post-Apartheid City

Windhoek is the capital city of Namibia, a country of 2.6 million people in southwest Africa which spreads across the Namib Desert and the semi-arid savannah of the Kalahari. Historically, Namibia was a German and then a British colony, administered by South Africa from the end of the First World War until its independence in 1990. Namibian citizens were therefore subject to apartheid laws between the 1950s and the 1990s. Since independence, the growth of informal settlements (or peri-urban areas or slums) and the rate of urbanisation has accelerated, as people from rural areas arrived in the city in search of employment and education opportunities (Weber & Mendelsohn, 2017). With predicted warming, drier conditions, and increased variability in the spring rainfall, internal rural-urban migration is likely to grow as people move away from subsistence farming and pastoral lifestyles (Niang et al., 2014). In 2019, 49% of the population lived in urban areas, 31.5% of which lived in Windhoek, the biggest city of the country which had 404,280 inhabitants in 2018 (Ritchie & Roser, 2019). Windhoek developed on a flood plain and the surrounding hills, in a plateau ranging between 1200–1700 m.a.s.l. in the central region of the country. Every summer growing water demand, coupled with recurrent nationwide droughts, puts the city under stress. Two main river systems run through the city (Gammans and Arrebusch) and collect the seasonal storm water from the surrounding hills into three city dams. Despite the ephemeral nature of the river network, riverbeds have the potential to foster NbS, supporting most of the city's greenery and hosting perennial trees, bushes and grasses adapted to arid conditions (e.g., acacia trees, trumpet thorn trees, dwarf shrub species) (Mendelsohn et al., 2002), (Fig. 17.1).

2.2 Study Approach

Between July and August 2019, we applied a mixed method approach, combining satellite observations of the distribution of urban greenery with interviews of practitioners and of residents living close to the city's river network, to understand how green urban spaces in the city of Windhoek are distributed, managed, and perceived. First, we computed and mapped, on the Google Earth Engine platform, the Normalised Difference Vegetation Index (NDVI) to reveal the greenness of the area of the city of Windhoek, using the greenest pixels available in the annual collection of satellite images. Second, we interviewed 12 key informants representing the City of Windhoek, NGOs, or businesses in the field of spatial planning, nature resource management, and housing, to understand how green urban spaces, including riverbeds, are managed, and what is the interaction between NbS and ongoing development. Third, we conducted 16 semi-structured interviews with residents of four neighbourhoods living close to the river network to gain an understanding of how riverbeds are used and perceived in terms of accessibility and provision of ecosystem services and disservices. Interviews were conducted in English or local dialects, translated when needed, recorded, transcribed, and manually analysed using thematic coding. The four neighbourhoods we studied represented a gradient of formal and informal land tenure arrangements and structural and socio-economic characteristics of neighbourhoods formerly racially segregated during the apartheid regime. The formal neighbourhoods included in the study were: Klein Windhoek (formerly white), Khomasdal (formerly coloured),

Fig. 17.1 (**a**) Riverbeds in Klein Windhoek, a wealthier area of the city with more green spaces along riverbeds (Van Rooy et al., 2006). (**b**) An interviewee of Khomasdal, the formerly coloured neighbourhood, showing us the riverbeds behind his house. (**c**) The "United Nations Plaza" city park in Katutura, which is a green space developed around a river section in the former black neighbourhood after independence, and frequently used for picnics, letting children play, taking photos and relaxing. (**d**) The first author interviewing residents of Okuryangava, an informal settlement with fewer green spaces along riverbeds. Behind interviewees, trees along the river can be seen, used for shade, as meeting areas, and for selling camelthorn pods for fodder. (Photo source: V. Giombini)

and Katutura (formerly black). Broadly speaking, progressing from formerly white to black neighbourhoods, the size of each property decreases and the distance to the central business district increases (Müeller-Friedman, 2006) (Fig. 17.2). The Okuryangava neighbourhood represented an informal settlement (or peri-urban area or slum) characterised by insecure land tenure, limited access to formal services such as running water, sanitation and electricity, and makeshift corrugated iron sheet housing. To gain a deeper understanding of the context of the study, we visited on foot, with the support of a local research assistant and a community guide, the riverbeds and the four neighbourhoods where the residents were interviewed.

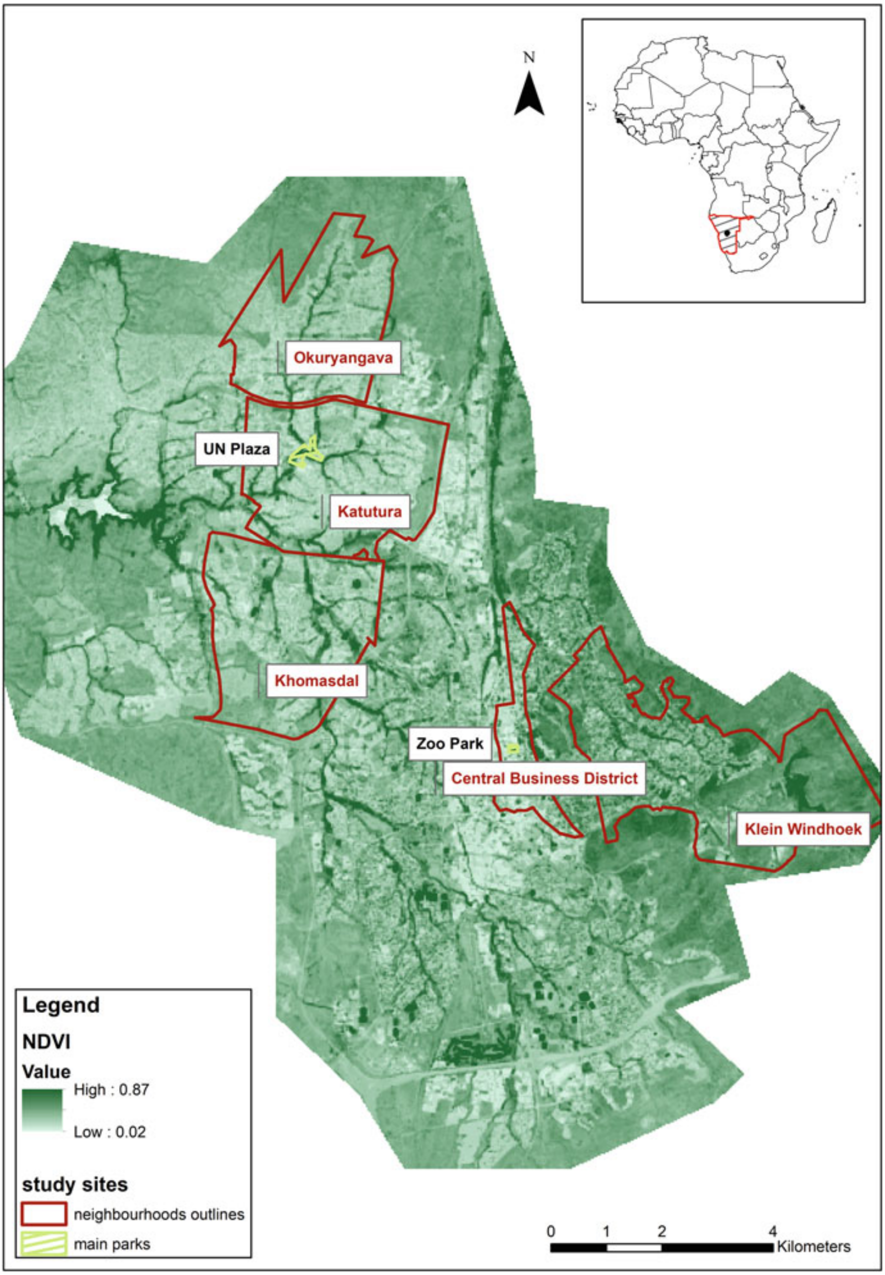

Fig. 17.2 The position of Namibia in Africa (top-right panel), and the greenness (NDVI) of the capital of Namibia. The main panel displays the NDVI values of the area of Windhoek, overlayed with the outlines of the central business district, the neighbourhoods analysed in this study, and the city parks mentioned by interviewees. The ephemeral river network (dark green) and the Goreangab dam on the top left, are clearly visible. *NDVI* = Normalized Difference Vegetation Index, representing the greenness of a pixel

3 Discussion of the Main Findings

3.1 Distribution of Urban Green Spaces Across Neighbourhoods

The analysis of the satellite images of the region showed that the area of Windhoek has overall a low degree of greenness (NDVI values between 0.020 and 0.863), consistent with the arid conditions of Namibia. Nonetheless, higher than average photosynthetic activity was evident along riverbeds, around the Goreangab dam, and in irrigated public parks or soccer fields (Fig. 17.2). Among the neighbourhoods analysed, the former white and more affluent neighbourhood of Klein Windhoek displayed the highest NDVI values (mean = 0.326), while the smallest values were found in the poorer informal settlement of Okuryangava (mean = 0.196), and in the former black neighbourhood of Katutura (mean = 0.200). The former coloured neighbourhood of Khomasdal displayed an intermediate level of greenness (mean = 0.214). As documented in several southern African cities by McConnachie and Shackleton (2010), similarly, it appears that in Windhoek formerly white, coloured, and black neighbourhoods have respectively the highest, intermediate, and the lowest values of greenery. The pattern observed in Windhoek is likely to be the combination of the fact that former black neighbourhoods were built with a higher density of houses compared to coloured areas, and that former white neighbourhoods developed on lush hilly areas and have bigger properties and gardens (Müeller-Friedman, 2006). The Okuryangava informal settlement, on the other hand, unregulated by municipal planning processes, is subject predominantly to informal rental or procurement arrangements between residents. Most of the local vegetation continues to be removed to make space for corrugated iron shacks or for energy biomass. However, larger trees are left standing to provide shade, and some bushes and plants have been planted to delineate properties, grow vegetables gardens, or embellish houses. These findings on the greenness of Windhoek highlight how social inequalities shape the way people can benefit from the environment (Sandberg et al., 2014). We argue that such inequalities should be closely examined and mitigated prior to the design and implementation of any nature-based adaptation or mitigation intervention. Studies mapping NDVI and ecosystem services can help quantify the distribution of greenery and the delivery of ecosystem service. Results can be used to prioritize intervention areas and guide the development of NbS such as urban green infrastructure (Hansen & Pauleit, 2014).

3.2 Ecosystem Services and Disservices Provided by Riverbeds Across Neighbourhoods

Key informants highlighted how riverbeds and natural features, if well managed throughout the year, mitigate the risk of both summer city-wide water stress and seasonal destructive flash floods. Interviews with residents shed light on the

Table 17.1 Services and disservices deriving from riverbeds, as perceived by residents of four socio-economically and structurally differentiated neighbourhoods of Windhoek, Namibia

Neighbourhood	Context	Ecosystem services deriving from riverbeds	Disservices deriving from riverbeds
Klein Windhoek	Wealthy and former white neighbourhood	Biodiversity observation, outdoor recreation, walking dogs	Facilitation of house robberies and mugging, diseases, and smell from overflowed sewage manholes
Khomasdal	Middle class and former coloured neighbourhood	Mental well-being, biodiversity observation, space for socializing and for children to play	Facilitation of house robberies, diseases and smell from overflowed sewage manholes, mosquitoes and snakes, youth consuming alcohol and smoking
Katutura	Poorer-middle class and former black neighbourhood	Mental well-being, biodiversity observation, space for socializing	Facilitation of house robberies, diseases and smell from overflowed sewage manholes, bushes behind which criminals can hide, mosquitoes, youth consuming alcohol and smoking
Okuryangava	Informal settlements with limited access to services	Cooling, biomass for energy, camelthorn pods and grasses as fodder, home vegetable garden	Diseases and smells from overflowed sewage manholes, bushes behind which criminals can hide to rob or assault, mosquitoes

perceived benefits provided by riverbeds (Table 17.1). In the former white neighbourhood, many residents appreciate how riverbeds have the potential to support biodiversity and outdoor recreation. In the former black and coloured neighbourhoods, the majority describes how the riverbeds allow them to relax and watch the water flow. A woman from Katutura said that *"[the river] feels good, it's quite nice there, when you sit down, you try to listen, [. . .] you just go in the middle of the river, sit there and relax your mind"*. Living close to the riverbeds in the Okuryangava informal settlement allows some households to have home gardens and to alleviate heat stress in summer, improving living conditions in corrugated iron houses with minimal ventilation. Furthermore, some residents of the informal areas sustain their livelihoods collecting and selling fodder.

Interviews with residents and key informants also outlined several ecosystem disservices (Table 17.1), intended as ecosystems' characteristics that give rise to disadvantages for people (Lyytimäki & Sipilä, 2009). The major concern of the residents of Windhoek regarding riverbeds is the risk of being robbed and the limited security of the areas. In more affluent neighbourhoods, there is the fear that living close to the riverbeds increases the risk of having one's home burgled, as riverbeds provide escape routes for criminals. In all the neighbourhoods studied, the overflow of poorly maintained sewage manholes running beneath the riverbeds spurs the fear of contracting waterborne diseases. This is especially felt in the former black neighbourhood and in informal settlements, where sewage maintenance is often limited and delayed. An interviewee from Khomasdal summed his feelings about the river saying: "*it made me feel a bit relaxed, you know, just admiring the nature, even though, the problem about it, the environment* (and) *this kind of river, is* [...] *sewage water flows there, the smell and all that makes it uncomfortable. Otherwise, I wouldn't mind sitting in the river, you know, and drinking some cool drink*". In the informal settlements, people fear being assaulted or raped when using the riverbeds for open defecation, as well as mugging when using riverbeds to commute on foot.

3.3 Perceptions of Access to and Management of Urban Green Spaces

Overall, although the riverbeds in the city of Windhoek are a diffuse network of naturally green areas, few residents perceive riverbeds as an asset or access them for pleasure other than for commuting or necessity. To enjoy natural areas, residents who can afford it drive to farms and dams on the outskirts of the city. Poorer residents, on the other hand, go to city parks like the Central Zoo Park (2 ha) or UN Plaza (3.5 ha) in Katutura (Fig. 17.1, panel (c)). Yet, such parks are generally not reachable by foot, being several kilometres away from the informal settlements. Interviews with key informants highlighted how riverbeds are not managed by the City of Windhoek to be used by the public as urban parks. The reason for this is, in part, due to issues of maintenance, financing, and clarity of mandates between municipal departments. The City of Windhoek indeed manages riverbeds by keeping them in their natural state and removing litter and invasive species. Moreover, the fact that the riverbeds and the waterways are under the jurisdiction of two separate divisions of the City of Windhoek hinders the possibility to harness synergies, such as those occurring between recreation and water management.

3.4 Challenges to the Successful Implementation of Nature-based Solutions

This study highlights how it is important for researchers and practitioners working towards implementing NbS in a given social-ecological system to also consider the historical context, the multiple values of nature in place, and the presence of underlying socio-economic and development dynamics (Ernstson, 2013; Langemeyer & Connolly, 2020). In the case of Windhoek, for example, approaches for developing urban green infrastructure will not be fully effective if synergies and trade-offs with other development issues such as housing, sanitation, transport, and economic inequalities are not navigated and sensitively addressed at the same time. Moreover, it should not be taken for granted that natural features always hold a positive value to residents. This is because individual factors (e.g., gender, age) and socio-cultural dynamics affect how nature is perceived in specific contexts (Chan et al., 2012). Spatial planners highlighted, for example, how natural areas and vacant land of post-apartheid cities hold an explicit segregation value. Müller-Friedman (2008), reflecting on her experience as a practitioner in Namibia, suggests that architecture and spatial planning approaches in the country unintentionally fortify the apartheid-built form by adopting modernist principles, viewing planning as a technical issue, and failing to recognise how the urban form is not politically and culturally "neutral". Building on this argument, we suggest that vacant and natural land in Windhoek should also not be considered "neutral" but connected to the historical legacy of apartheid spatial planning.

3.5 Opportunities for the Fair and Effective Implementation of Nature-based Solutions

The implementation of NbS represents an opportunity to overcome the aforementioned challenges. Strategically addressing the historical legacy of apartheid era's spatial planning, a green infrastructure network should be developed to incorporate, for example, naturally green riverbeds and vacant land currently separating neighbourhoods, in addition to other types of green spaces such as meeting areas, parks, and drought-tolerant botanical gardens. In the context of Windhoek, NbS should also be designed to maximise synergies with sustainable development goals (United Nations, 2015) and managed to meet the needs of local people, by limiting sewage outbursts, fostering a secure environment, and supporting recreation, urban farming, and rainwater harvesting. We argue that eliciting the local perceptions of residents represents an opportunity to investigate the plurality of ecosystem (dis)-services and values, and can help ensure a fair delivery of ecosystem services and an effective implementation of NbS (Andersson et al., 2015; Chan et al., 2012). Although riverbeds and their buffer zones are currently exposed to densification and sprawl pressures in informal settlements and their current management gives rise to ecosystem disservices, they should be considered as an asset. Being naturally green areas in one of the most arid countries of the world, riverbeds have the potential to represent the backbone of a green infrastructure network which fosters synergies between the development and climate adaptation goals.

4 Conclusions

This case study shows the importance of adopting both quantitative and qualitative methods for gaining a holistic understanding of the interactions occurring within complex social ecological systems. Interviews and other participatory processes are critical for acknowledging the multiple values of nature, exploring ecosystem services and disservices, and ensuring that local needs are met. Although more research is needed across longer temporal scales, with larger sample sizes and diverse neighbourhoods, this study highlights that practical implementations of ecosystem services approaches should acknowledge that nature and natural areas do not always hold a positive value and that their distribution might be the result of prior unjust patterns. It furthermore shows that failing to acknowledge historical legacies of apartheid spatial planning carries the risk of maintaining and strengthening green space inequity. To this end, the ecosystem service concept can provide a framework for identifying and managing disservices, harnessing synergies among ecosystem services, and exploring their interaction with sustainable development goals. Moreover, research from the field of political ecology and ecosystem service justice can greatly contribute to provide the frameworks and tools necessary to approach the discourse of NbS in a critical and foresighted way.

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Chapter 18
Green Infrastructure and Social Perception of Its Ecosystem Services Within Spatial Structure of the City – Examples from Poznań, Poland

Iwona Zwierzchowska and Małgorzata Stępniewska

Significance Statement The structure of the city and related composition and configuration of green infrastructure (GI) translate into supply and distribution of ecosystem services (ES). Therefore, we aimed to recognize the social perception of ES at the background of the spatial structure (from the dense centre to the rural-like suburbs) based on a case study of Poznań city in Poland. The findings revealed that although distribution and types of GI vary among main urban zones, inhabitants appreciate the cultural ES of GI regardless of its type or location. They expressed the demand for enhancement of recreational ES and the importance of accessibility to the green spaces. The study also emphasised the complex trade-offs between cultural and regulating ES highlighting the role of ES-oriented planning.

Keywords Cultural ecosystem services · Urban green · Parks · River valley · Post-industrial areas

1 Introduction

The ongoing processes of urban densification (EEA, 2016) and urban sprawl (Hennig et al., 2015; Patacchini et al., 2009) are common for many cities that face the challenge of developing policies that ensure the continuous delivery of key ecosystem services (ES) to maintaining resilience and vitality in urban areas (Grêt-Regamey et al., 2020). In some urban areas, mixed processes of depopulation in less favourable areas and urban development in other areas of the urban region can be observed. These complex processes contribute to the creation of an urban-rural continuum, which can be observed both within and outside the administrative boundaries of the city. Łowicki and Walz (2015) see the differences in the pattern of the rural-urban gradient as a result of legal aspects of spatial planning. Indeed,

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spatial planning determines the distribution of green infrastructure and the availability of its individual elements, which translates into the level of ecosystem services in cities (Zwierzchowska & Mizgajski, 2019). The concept of green infrastructure (GI) is widely studied by science and practice, as it can bring multiple benefits to nature and humans alike. The GI covers diverse areas of terrestrial, aquatic and water-dependent ecosystems transformed by humans to varying degrees. The above diversity translates into differences in the type and level of ES provided by GI. This overlaps with various demands for ES from society. For this reason, in order to support more ecosystem services-oriented land-use planning not only recognition of spatial composition and configuration of ecosystems is needed but also an understanding of GI users' preferences is desired.

The complexity and diversity of spatial relationship that varies in different scales and change in time are reflected in the urban-rural gradient analysis of ES. Rall et al. (2017) found that the density of cultural ES perceived decreased from the inner to the outer edges of the city of Berlin, wherein the inner-city is a place of recreational, social and cultural heritage and identity services concentration, while perceived biodiversity and spiritual, inspirational, and nature experience and educational services are more scattered. Calderón-Contreras and Quiroz-Rosas (2017) demonstrated that growing pressures of urban development results in reduction of service-providing units at the regional scale, and their low quality at the local scale.

Larondelle and Haase (2013) point out that there is no typical urban–rural gradient of ES provisioning nor a uniform urban spatial pattern of ES provisioning. What is more, Grêt-Regamey et al. (2020) highlighted that ES supply is highly dependent on the urban form and there is no simple linear relation between ES supply and green area coverage. They also highlight the importance of trees for supporting regulating ES in built-up neighbourhoods. Similarly, studies of Larondelle and Haase (2013) showed that even core cities with a high degree of imperviousness do not necessarily provide fewer ES compared to their regions because of presence of mature trees which contribute to ES. However, the regulating ES bound to trees and forest cover are higher outside the city boundaries. The local zoom-in is particularly important for more densely built-up areas. Zwierzchowska et al. (2021) found at a local scale of multifamily housing areas a variety of green space types and solution that can improve nature-based outdoor activities. They also highlight that the potential of GI to provide ES is not yet fully used.

The above discussion indicates that both quantitative and qualitative approaches to GI need to be taken into account while studying ES resulting from mixture of green and man-made infrastructure of different composition and configuration. This chapter aims to present the variety of GI and its ES at the background of the spatial structure of the city on the example of Poznań. First, we consider the diversity in the distribution and structure of urban GI from the dense centre to rural-like suburbs. Then, we discuss the social perception of GI and its ES based on the existing case studies covering different types of GI – urban parks, river valley, and post-industrial revitalized area.

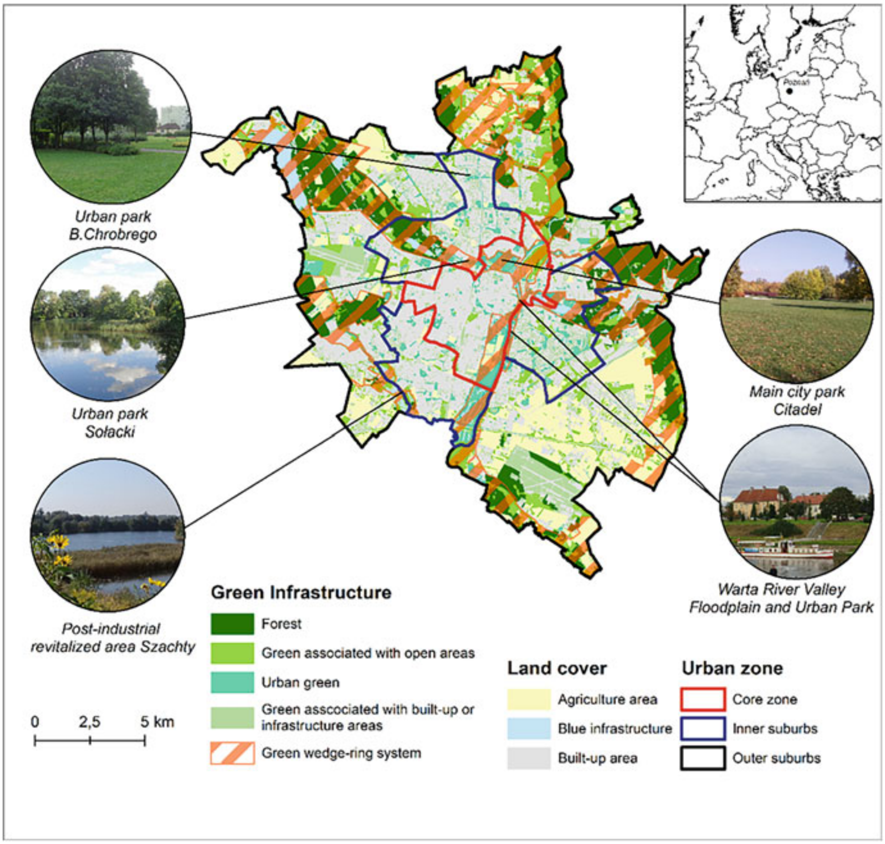

Fig. 18.1 Distribution and diversity of green infrastructure of Poznań

2 Study Area

We have analysed GI and its ES based on case study of Poznań in Poland (Fig. 18.1). The city is 0,5 M inhabitants and covers an area of 262 km^2. It is an interesting example, as the city structure was shaped through the different periods of time reflecting various patterns of development and respecting wedge-ring green system shaped from XIX century and preserved in large part in plans since 1930s. The ES of Poznań are subject of various studies and were one of the case studies within the 4th Mapping and Assessment of Ecosystem Services (MAES) report concerning urban ecosystem (Maes et al., 2016) as well as EnRoute City Lab (Maes et al., 2019). Currently Poznań is a front runner city in the project Connecting Nature (within European Union Programme Horizon, 2020) focusing on multiplication of nature-based solutions.

3 Methods

First, the quantitative GIS analysis has been applied to diagnose distribution and diversity of GI along urban core and rural-like suburbs in the administrative units functioning for local decision-making. The analysis was based on BDOT10k[1] database (2019) and Urban Atlas[2] (2018), which provide relevant land use and land cover data. The data were processed using ArcGIS 10.5.1 software. The distribution and diversity of GI have been analyzed within three main urban zones including: (1) core zone – representing historical areas characterized by dense development of tenement houses and urban villas; (2) inner suburbs – covering development areas around the city center, including both multi-family and single-family housing estates from the twentieth century; (3) outer suburbs – peripheral areas consisting of single-family housing estates and new multi-family buildings in a mosaic with industrial and agricultural areas.

Secondly, we applied quantitative and qualitative assessment of social perception and demand for ES based on a comparative analysis of surveys conducted among users of various GI categories in Poznań (Table 18.1). Data for the analysis were obtained from available original datasets supplemented with data from journal articles and theses. The scope of the individual surveys was subordinated to specific research objectives concerning ES. Hence, in spite of different sources, the questions in the surveys are partially convergent, while in some respects, they differ. On the one hand, this creates an opportunity to identify general patterns of ES for the city, and on the other hand, to show some specific aspects for GI sites located in different spatial, ecological and social conditions.

4 Results and Discussion

4.1 Distribution of Green Infrastructure in Urban Zones

In general, distribution of GI in Poznań reflects the spatial structure of urban-rural gradient (Fig. 18.2).

The core zone is predominantly characterized by high share of built up area at the level >70%. Inner suburbs show the built-up areas between 27 and 71%, while outer suburbs are in general less built-up (<35%). In the peripheral zone only few

[1]BDOT 10 k, (2019). Polish official land cover classification according to Regulation of Minister of Infrastructure and Development from 17 November 2011 concerning database of topographical objects and database of general geographic objects and standard cartographic works (Dz.U. 279 poz. 1642).

[2]Urban Atlas, (2018). European Environment Agency, Directorate-General Enterprise and Industry (DG-ENTR), Directorate-General for Regional Policy, Retrieved May 13, 2019 from http://www.eea.europa.eu/data-and-maps/data/

Table 18.1 Surveys concerning ES of green infrastructure in Poznań

Study site	Survey characteristic	Survey sample	Author/s
Old City – within the medieval city walls (core zone)	The amount of green spaces and their availability, the way of use, types of activity, factors limiting the use, factors encouraging to visit green spaces, the motives for using green areas away from inhabitants' place of residence.	70	Poniży et al. (2017)
Warta River Valley – floodplain (core zone)	Cultural ES (CES) of urban floodplain – identification of users' interactions with the river, the degree of satisfaction from the existing site arrangement, expectations for further site management.	231	Stępniewska and Sobczak (2017)
Main city park: Citadel (core zone)	The capacity of urban park for providing regulating and cultural ES versus their social perception – benefits from park, main threats and overall risk of reducing the ES, expectations for further land development.	179	Stępniewska (2021)
Urban parks: Sołacki, B. Chrobrego (inner suburbs)	Cultural ES demand and flow as reflected in park visitors' perception and behaviour at the local and city level – frequency of visits, length of stay and quality of experience in the park, perception of CES and uses of urban green spaces, CES accessibility.	99	Zwierzchowska et al. (2018) and Zaurski (2018)
Warta River Valley – urban park: Warta Park (inner suburbs)	Cultural ES in the opinion of park users – the way of spending time there, preferences for changes in terms of improving park functionality.	100	Sławuta (2019)
Post-industrial revitalized area: Szachty (outer suburbs)	Social perception of ES on municipal post-mining land – reasons for choosing the area as a place of recreation, the ES used by visitors, the range of impact of ES, current site's arrangement in the eyes of users.	204	Stępniewska and Abramowicz (2016)

administrative units are characterized by higher rate of built-up. Share of GI in urban core is lower than in other parts of the city (below 30%), however, there are some exceptions, where despite densely built-up higher share of GI is observed. These are areas that benefit from the city's green wedge-ring system that is based on the physiographic conditions of Warta River Valley and its' tributaries. The wedges run from suburbs through the centre of the city and are supplemented by the ring of greenery of the historical fortifications (including Citadel Park). Green infrastructure is more abundant in suburbs, while in the outer suburbs the share of agriculture land is visibly higher than in other zones of the city. The preliminary mapping and assessment of provisioning and regulating ES in Poznań has been presented in

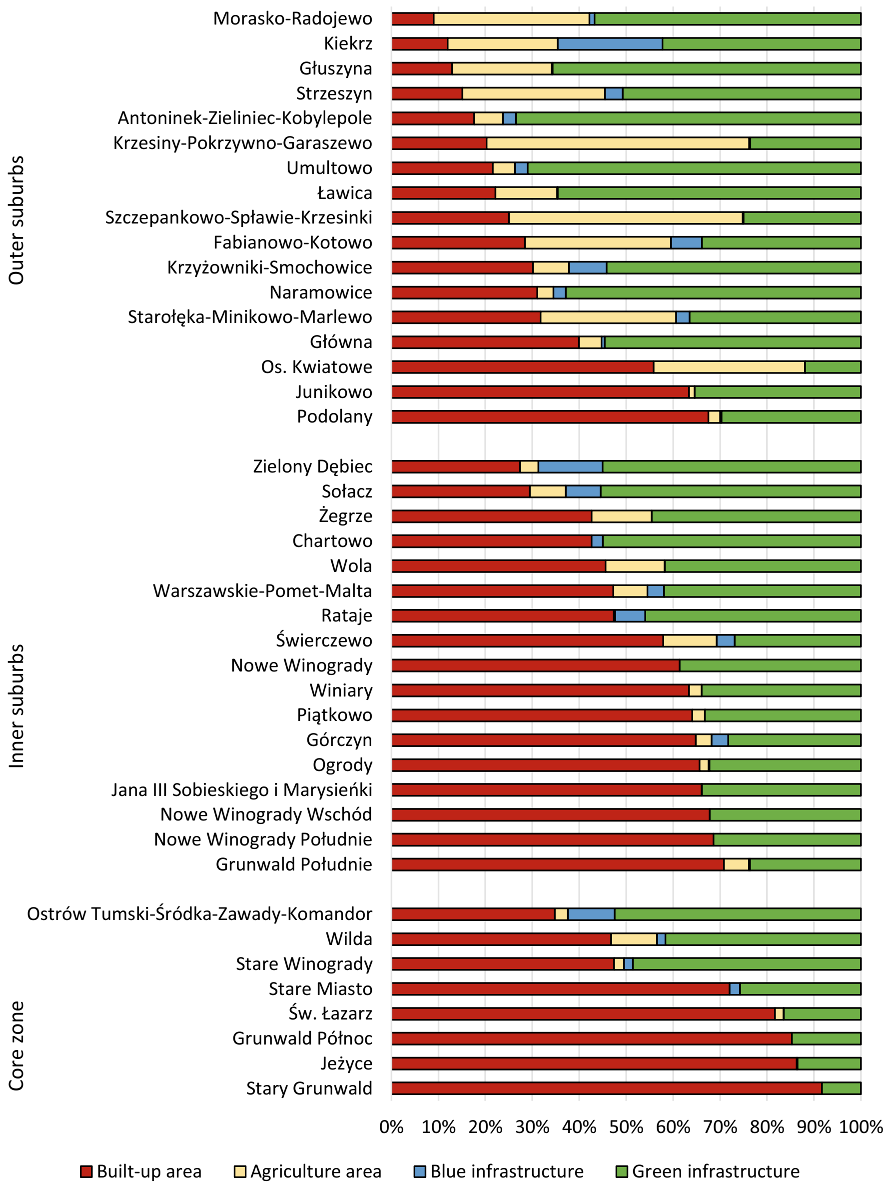

Fig. 18.2 Share of the main types of land use in basic administrative units by urban zones

Zepp et al. (2016), underlying connectivity of urban ecosystems and its richness in peripheral areas. The distribution of the main ecosystems forming wedge-ring system mirrors their crucial role in supplying regulating ES such as potential cooling effect at the city scale (Maes et al., 2016). However, more detailed view is needed to

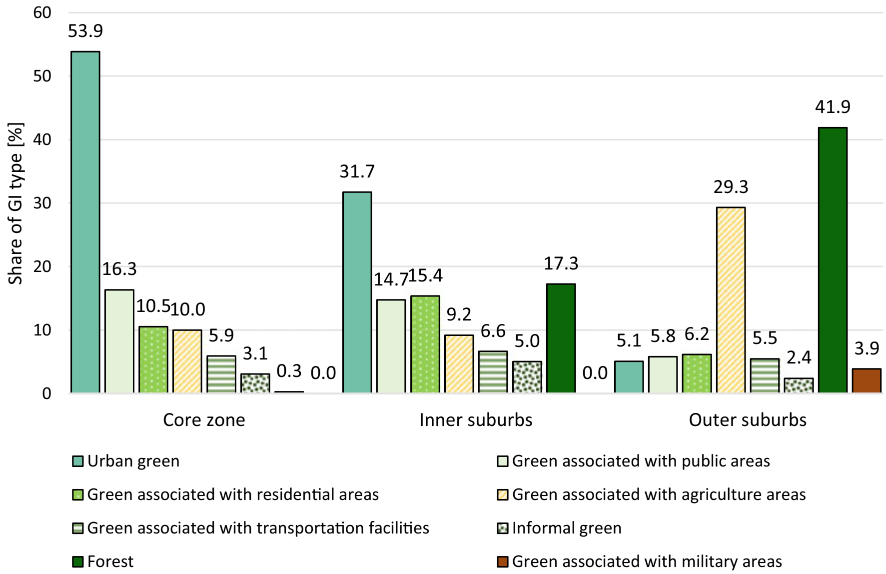

Fig. 18.3 Diversity of the green spaces and its distribution by urban zones

capture and assess the diversity of GI and its potential to deliver ES on the local level (Zwierzchowska et al., 2021).

Green infrastructure varies across the urban zones (Fig. 18.3). Urban green dominates in the core zone and is also the most abundant type in the inner suburbs. The core zone and the inner suburbs are also more rich in green spaces associated with public spaces and residential areas (multi-family estates). In contrast, forested areas are the most extensive type of GI in the outer suburbs, still present in the inner zone, but absent from the core zone. Different pattern is visible of the green spaces associated with the agriculture land. The largest share of this type of GI is in the outer zone, but thanks to the location of Warta river in the city centre it is also present in the form of a riverside grassy areas in the core and inner zones.

4.2 Social Perception of Green Infrastructure and Its Ecosystem Services

The surveys have showed that – regardless of the location of GI site in the urban tissue – their users attach the greatest importance to its cultural ES. Among the benefits of cultural ES, the most important were those related to outdoor recreation and aesthetic values of the landscape (Stępniewska, 2021; Stępniewska & Abramowicz, 2016; Stępniewska & Sobczak, 2017; Zwierzchowska et al., 2018). Findings for the cities around the world confirm the importance of cultural services of urban GI (e.g. Bertram & Rehdanz, 2015; Sirina et al., 2017; Swapan et al., 2017). The results of the surveys concerning GI and its ES in Poznań show that regulating ES are less obvious to the citizens (Stępniewska, 2021; Stępniewska & Abramowicz, 2016). In the case of Szachty – respondents perceived only improving the quality of air (Stępniewska & Abramowicz, 2016), while in Citadel Park – reduction of air pollution, improvement of acoustic climate and microclimate regulation, as well as provision of habitats for bats (Stępniewska, 2021).

As an important reason for choosing the urban GI as a place of rest and recreation, the respondents usually quoted its high accessibility. Direct vicinity of GI with housing estates, well-developed road network, including bike paths and the proximity of the public transport stops make urban green and blue spaces relatively easy to reach (Stępniewska & Abramowicz, 2016; Stępniewska & Sobczak, 2017). The accessibility to GI is inevitably a crucial factor that influences the flow of ES, however, the power to attract visitors vary among green spaces. These differences are visible between urban parks of inner suburbs. As much as 79.6% of respondents visiting B. Chrobrego Park (local park) came from the park's service zone of 800 m (Zwierzchowska et al., 2018). Warta Park is used mainly (62%) by visitors coming from a distance up to 900 m (Sławuta, 2019). However, in the case of the Sołacki Park (representative city park), 85.4% of respondents came from areas more distant than 800 m (Zwierzchowska et al., 2018). The proximity to green spaces encourages as much as 88.2% of visitors of Szachty in outer suburbs and only 16% of respondents visiting the Warta River Valley. Those results indicate that representative GI located in the core zone or inner zone is accessible not only for the local community but also for visitors from more distant areas, while GI of outer suburbs can be recognized as less accessible.

Ensuring sufficient green spaces is particularly challenging in the densely built-up city's core zone. The survey conducted among inhabitants of Old City revealed that the vast majority of the respondents notice the shortage of green spaces associated with housing and street-side greenery. That corresponds with a high (over 75%) percentage of build land development of the overall area and only several small public squares and green spaces associated with housing (lawns, trees, playgrounds, etc.) in the tenement backyards (Poniży et al., 2017). However, at the same time, 53% of respondents assess that there is a sufficient area of urban parks (which inhabitants use most) within a 800 m buffer zone (Poniży et al., 2017), which mirrors the location of elements of city's green wedge-ring system. Deficits in the quantity of GI in strongly urbanized core zone cause that even unspectacular blue-green spaces arouse a feeling of beauty and pleasure (Sławuta, 2019; Stępniewska & Sobczak, 2017) due to their perceived naturalness, the presence of greenery and wildlife. As it was highlighted by one of the visitors to the Warta River Valley in the centre of Poznań: 'Yeah, it's just a bit of water and greenery, but still it's in contrast to the overwhelming concrete' (Stępniewska & Sobczak, 2017).

Comparison of green space users' common activities (Table 18.2), shows that in general most frequent way of interacting in nature is walking (47.6%), meeting with other people (33.3%), getting sun or fresh air or passive rest in nature (30.1%), observing nature (23.9%), picnicking or barbequing (18.9%), and cycling,

Table 18.2 The most frequent activities reported by green space users

Urban zone	Case study[a]	N	Walking	Social meetings	Enjoying sun or fresh air/passive rest	Picnicking / barbequing	Nature observation	Cycling, rollerblading, skateboarding etc.	Site specific activity
			[%]						
Core zone	Warta River Valley – floodplain	231	*44.6*	*80.5*	*13.0*	*22.1*	11.3	*15.6*	
	Citadel – main city park	179	*63.1*	–	–	*63.7*	*16.2*	*21.1*[b]	
	Old City – parks	70	*50.0*	*17.0*	*56.0*	–	*36.0*	4.0	Visiting playground/ playing with children – *16.0*
	Old City – green associated with housing	70	*22.0*	*19.0*	*39.0*	–	*25.0*	0.0	Visiting playground/ playing with children – *13.0*
	Total	***410***	***58.4***	***44.0***	***20.1***	***34.4***	***20.4***	***8.1***	
Inner suburbs	B.Chrobrego – urban park	50	*58.0*	*16.0*	*46.0*	–	*38.0*	16.0	Mediate in nature – *28.0* Playing with children – *18.0*
	Sołacki – urban park	49	*61.2*	*18.4*	*57.1*	–	*44.9*	*18.4*	Mediate in nature – *40.8*
	Warta River Valley – urban park	100	*44.0*	*43.0*	*43.0*	–	*36.0*	*59.0*	
	Total	***199***	***51.8***	***30.2***	***47.2***	–	***38.7***	***38.2***	
Outer suburbs	Szachty – post-industrial revitalized area	204	*25.0*	11.0	*37.0*	–	*18.0*	11.0	Admiring landscape – *19.0* Inspiration of nature – *16.0*
	Total	***204***	***25.0***	***11.0***	***37.0***		***18.0***	***11.0***	

(continued)

Table 18.2 (continued)

Urban zone	Case study[a]	N	Walking	Social meetings	Enjoying sun or fresh air/passive rest	Picnicking / barbequing	Nature observation	Cycling, rollerblading, skateboarding etc.	Site specific activity
			[%]						

Note: The percentages in the table present the share of respondents who indicate one or more answers from the multiple-choice question, therefore the percentages do not sum up and can exceed 100%. In italics – most frequent answers in each case study

[a]Old City – activities conducted often; Warta River Valley – floodplain – 3 most frequently reported activities; Citadel Park – the most common purpose of visit; Wartą River Valley – Warta Park – activities reported as very frequent or frequent; B. Chrobrego Park and Sołacki Park– activities conducted always or often; Post-industrial area of Szachty – activities conducted at least several times a week;

[b]Sport in general

rollerblading, skateboarding, etc. (15.5%). In the core zone, there is a clear distinction between representative green spaces such as Citadel Park and Warta River Valley and local green spaces. The former is mostly used as places for a walk or social meetings with particularly popular picnicking or barbequing. For inhabitants of the old city, the green spaces in the core zone serve predominantly as a place for enjoying fresh air and walking. High engagement in children's outdoor activities is also characteristic. In comparison to other urban zones, visitors of green spaces from the inner zone more frequently appreciate passive rest as well as doing sports such as cycling, rollerblading, skateboarding, etc. They also put the highest attention to observe nature. In outer zone, Szachty are most frequently used for enjoying the fresh air and walks and valued for landscape and nature.

Anthropogenic contributions influence the possibility of interaction with ecosystems (Costanza et al., 2014). For this reason, the structure and level of ES do not depend only on natural capital, but also on the site arrangement. The results of the surveys from Poznań show preferences of citizens regarding GI development focus on improving the conditions for recreation. Insufficient infrastructure for leisure and recreation is one of the most important factors which according to the respondents limits the green space usage in each considered urban zone.

The value associated with experiencing cultural ES and the related use creates a strong pressure on the urban GI. The trade-offs between cultural and regulating ES are not perceived at all or are hardly perceived by citizens. Threats to GI related to the intensification of its recreational use concern not only sites located in core zone (Stępniewska & Sobczak, 2017), but also green spaces outside the city center (Abramowicz & Stępniewska, 2020).

5 Conclusions

Our findings highlight that although distribution and types of GI vary among the main urban zones, the inhabitants appreciate the GI and its CES regardless its location in the urban tissue. The common finding from the analyzed surveys on GI is the inhabitants' perception of mainly cultural ES and the expectation of further development of infrastructure enhancing recreational opportunities. That expresses the need for contact with nature despite its character and highlights the importance of accessibility to green spaces as well as need for enhancement of their recreational ES.

The composition and configuration of GI elements and its usage contribute to the complex trade-offs between cultural and regulating ES. Therefore, it is necessary to undertake a place-based analysis of the effects of various development scenarios, which will allow to optimize the decisions made in relation to individual GI sites.

Ensuring equality of accessibility to urban GI and its capacity for providing a bundle of ES requires ES-oriented planning. In Poland, planning arrangements made at the local level have the largest influence on spatial changes (Stępniewska et al., 2017). Therefore, the local government has basic tools that can be used for balancing land use decisions toward sustainable ES provision. However, the implementation of available tools is often voluntary, not imposed by law (Zwierzchowska et al., 2021). Shaping GI towards provisioning of a wide range of ES should take into account the diversity of its quality, spatial composition and configuration, as well as residents' demands and perception.

In the case of Poznań, the urban core zone is characterized by a limited number of small green spaces although they are relatively rich in urban recreation facilities. Therefore, the informal green spaces (especially along Warta River Valley) and parks in the core zone are of particular importance for inhabitants. In turn, in the inner suburbs there is a high potential in parks and neighbourhood green spaces. As for the outer suburbs – they are abundant in forests and agriculture areas, although not equally distributed.

The GI development in the dense urban core should include revitalization and multiplication of small-scale interventions such as nature-based solution (NBS) with the preferences to include trees in the urban fabric. Activities around GI in inner suburbs should focus on maintaining its existing resources (including avoidance of over-compaction) and improving its multifunctionality. With regard to outer suburbs, the combination of reasonable density of development with protection of existing green spaces and its connectivity from transformation is the key issue.

The findings of the study can provide valuable support in developing policies aimed at ensuring the continuous provision of all ES of GI that are key to the maintenance of resilience and vitality along gradient of core-peripheral urban areas.

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Chapter 19
Accessibility to and Fragmentation of Urban Green Infrastructure: Importance for Adaptation to Climate Change

Ieva Misiune and Justas Kazys

Significance Statement Urban green infrastructure (GI) is one of the key strategies to respond to environmental problems. It helps to support biodiversity, adaptation to climate change and ensure the provision of ecosystem services (ES). Scientific literature suggests that there are thresholds for minimum viable green area patch sizes. Besides the size, accessibility is another important factor for the supply of ES. This work assesses how demand and accessibility can be improved addressing fragmentation of GI in Vilnius, Lithuania. The analysis shows that climate adaptation policy should guide the development of GI addressing simultaneously the demand of ES and fragmentation of the GI, for instance, by reconnecting existing natural areas in this way increasing accessibility and reducing the risk of further habitat fragmentation.

Keywords Urban green infrastructure · Ecosystem services · Fragmentation · Accessibility · Climate change adaptation

1 Introduction

Healthy ecosystems can support biodiversity and provide a range of ecosystem services (ES) important for human well-being, enhance resilience and adaptation to climate change. It is especially important in urban environments as over half of the world population lives in the cities raising an enormous pressure on the natural environment (United Nations, 2019). Since urban population continues to grow, the pressures and the demand for healthy ecosystems and their services increase as well.

Urbanization causes environmental problems, such as urban heat island (UHI) effect, increased runoff due to impervious surfaces, change in biodiversity when non-native species change native species and the level of their diversity, and increased production of carbon dioxide (Bryant, 2006). Additionally, urbanization

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causes fragmentation and homogenization of the landscape's diversity and, thus, contributes to the decrease in habitat diversity (Antrop, 2004). Ultimately these problems contribute to more severe consequences of climate change and deteriorating quality of life.

Urban green infrastructure (GI) is one of the key strategies to respond to the pressures, including climate change, and to support biodiversity as well as ES provision in urbanized territories. GI is a network of (semi-) natural areas which can help in mitigating the impacts of urbanization and deliver different environmental, socio-cultural and economic benefits (EC, 2013). A number of documents at European level address the ecological problems in cities and the need to improve the quality of life of its citizens (EP, 2013/2663 (RSP)). GI is acknowledged as being an important strategy for the effective solutions and for the implementation of EU Biodiversity Strategy 2020.

Strategies for optimal design of GI could provide climate-related benefits such as microclimate regulation, air purification, reduction of carbon emissions, precipitation and runoff regulation. For UHI reduction trees are seen as the best microclimate regulation option (Venhari et al., 2017; Balany et al., 2020). Studies dealing with urban forest impacts on microclimate regulations found that older and larger trees have greater benefits for cooling and air pollution reduction. Venter et al. (2020) identified negative correlation between land surface temperatures to tree canopy cover and vegetation greenness in Oslo (Norway). Nastran et al. (2019) defined that higher proportion of forest, higher largest patch index and higher proportional landscape core are associated with a lower UHI in the cities of new EU members. Even very small parks that are heavily forested can produce greater cooling effects than parks or lawns with grass only (Jaganmohan et al., 2016). Although even small green spaces can decrease the temperature, most of the studies indicated that the larger the park (>3 ha), the stronger the effect (Venhari et al., 2017). Thus, the extent and type of GI areas are more important than the typology of urban development in which urban greening strategies are located (Jaganmohan et al., 2016).

For sustainable city planning it is important to know the demand of urban ES and if public urban green spaces (UGS) can meet it. At the same time, it is essential to ensure an effective planning of GI with healthy and resilient ecosystems that provide the key urban ES and can help adapting to and mitigating climate change effects. Thus, this analysis provides insights on how the demand can be addressed reducing the fragmentation of the major GI elements – urban forests and UGS – in Eastern European capital Vilnius, Lithuania. The work focuses on the social demand using population data and accessibility to GI using a spatial analysis approach. Further, fragmentation examination allows to identify the areas of GI that can address better the demand and at the same time has a high improvement potential. Some planning recommendations are provided at the end.

2 Materials and Methods

2.1 Study Area

Vilnius is the capital of Lithuania situated in the southeast of the country with over 561,000 inhabitants. It is the only growing city in the country with an intensive internal rural to urban migration. Regardless of an ongoing urban sprawl, a large share of the city is covered with green infrastructure. Public UGS, which are intensively used (having recreational infrastructure) and extensively used UGS (without infrastructure) cover over 3300 ha (8.25%) of the city. Urban forests cover over 13,450 ha (33.55%) and are open to people for recreational use. Altogether these elements of GI make up 16,758.66 ha (42%) of the city municipal area. Additionally, 2385 ha is covered by allotment gardens, agricultural areas and water bodies, which are the elements of GI. These territories, however, not always are accessible publicly, thus, were not included in the analysis. Nearly 39% of the territory is urbanized with 12% (4709 ha) having impervious surfaces (Fig. 19.1).

Neris, the second longest river in the country, flows over the whole town from its North to South. The richness of green spaces like urban parks, forests and protected areas as well as the water bodies provide a multitude of ES to the residents of Vilnius city. Based on GreenMatch's findings, however, the surface temperature in Lithuania has increased the most compared to other 31 European countries, with an increase of 0.325 °C per decade. Years 2019 and 2020 were the hottest throughout the instrumental measurements (since 1770). During the first two decades of the twenty-first century compared to the twentieth century, the average air temperature in winter and spring became warmer by 1.6 °C, in summer by 1.4 °C, and in autumn by 1.3 °C. No significant trends have been observed in the sequence of annual precipitation (since 1887), but in recent decades' precipitation has increased in the cold and decreased in the warm period. This is due to the prevailing marine air masses in warm winters and a more frequent recurrence of anticyclonic processes in summers (Bukantis & Kažys, 2020).

2.2 Dataset and Methods

The dataset of urban GI for the study area was prepared according to the latest Vilnius city master plan (V-Planas, 2020). Official municipal data on land use with 15 land use types, location and number of inhabitants was acquired from the city municipality.

The main components of urban GI in Vilnius are: intensively used UGS (having more recreational infrastructure, like benches, playgrounds and other), extensively used UGS (usually without recreational infrastructure), urban forests and water bodies, which only partly included in the analysis. Allotment gardens and agricultural areas are important for GI connectivity in the city, however, these territories are

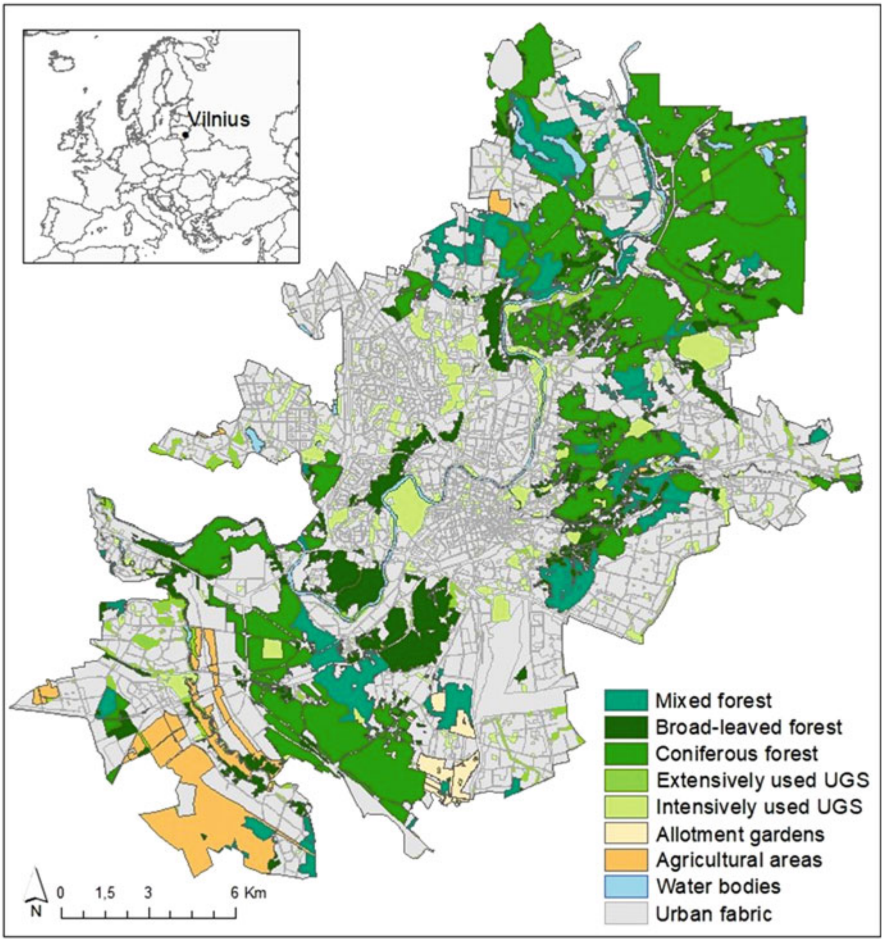

Fig. 19.1 Green Infrastructure of Vilnius city. Source: own elaboration based on the land use data from Vilnius municipal plan. (V-Planas, 2020)

not public and thus will not be included in further analysis. All mentioned green spaces compose a network of (semi-) natural areas which provide different ES and ultimately helps mitigating the impacts of urbanization, like air pollution, urban heat-island effect and others. Different urban GI areas can provide different ES, however, the size and the type of the green space is a decisive factor for the capacity of the ecosystem and its potential to adaptive climate change effects.

Scientific literature has a choice of indicators dealing with ES demand. Many approaches use comparative methods and define several indicators, based on provision or accessibility to GI. Social demand for urban ES was assessed using population data – inhabitant number living in each apartment building or private house within the city limits – and it was calculated using a kernel function.

In this study, we defined access a maximum 300 m linear distance to the boundary of urban green space of a minimum size of 1 hectare (10,000 m^2) as recommended default options for the indicator (Annerstedt van den Bosch et al., 2016). Distance of 300 m and the size of the green space are suggested to serve as a proxy measure for assessing public accessibility to urban green spaces.

Fragmentation of urban GI was assessed using The Landscape Fragmentation Tool (LFT), which provides a method to quantify landscape fragmentation (Parent & Hurd, 2008). The tool classifies a land cover type of interest (in this case urban GI) into four main categories:

- Perforated – GI pixels along the edge of an interior gap that are degraded by "edge effects".
- Edge – GI pixels along the exterior perimeter of a GI area that are degraded by the "edge effect".
- Patch – small isolated fragments of GI that are completely degraded by "edge effect".
- Core: GI pixels that are not degraded by "edge effects". They are further subdivided into: small core (smaller than 101 ha); medium core (between 101 and 202 ha); and large core (larger than 202 ha).

The classification of pixels is based on studies of forest ecology, which have found that the size of forest patch impacts its viability in terms of supporting wildlife. Larger areas are more likely to support greater numbers of interior species and as it was discussed in the Introduction it also helps to adapt to climate change more effectively. All geospatial and geostatistical analysis was performed using ArcMap 10.7.1.

3 Results and Discussion

3.1 Addressing the Demand by Fixing Fragmentation in the Study Area

The results of the assessment in Vilnius are presented in Figs. 19.2, 19.3, 19.4 and Tables 19.1 and 19.2. As one may see the highest demand of ES are in the center and the west of the city (Fig. 19.2). These territories have the highest number of people usually living in multistorey houses with no gardens or private backyards. It is important for them to have a good access to UGS so to avoid severe climate change effects or for recreational purposes.

The analysis shows a spatial disproportion of GI (Fig. 19.1) and demand of the UGS (Fig. 19.2) which is a serious issue for supplying ES in Vilnius. The demand for the UGS greatly correlates with the values of territorial index of matter artificiality found by Jukna (2014). Maximum values of this index are dominant in greatest matter artificiality core territories of cities with very high building density level.

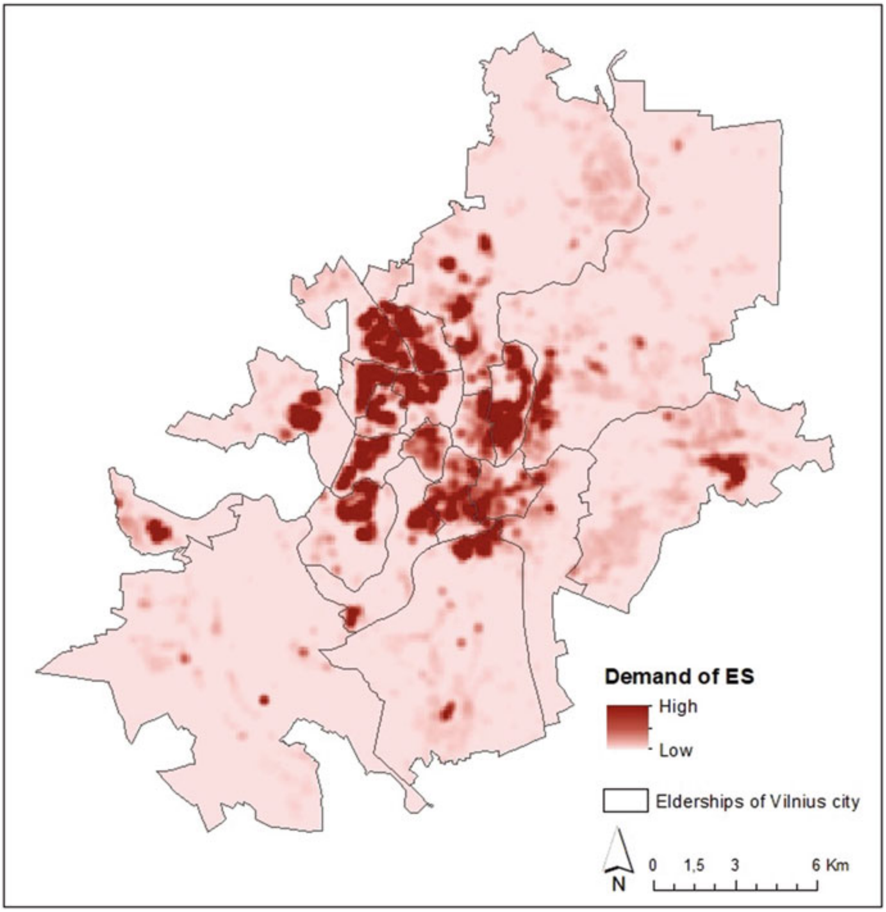

Fig. 19.2 Demand of the UGS in the study area based on inhabitants' location

Vilnius characterized by a greatest diversity of technogenisation area types, which can be seen through the whole city's structure, also in the center of it (Jukna, 2013). The areas of the highest demand of UGS are related to processes of massive industrialization and urbanization during the communist period, massive urban transitions in the post-1990 period and the changing occupational structure and an increase in social inequalities since 2001 (Valatka et al., 2015).

Geospatial analysis of urban GI shows gradient change in its fragmentation. This obviously depends on the dispersion of GI within the city limits. In the city center urban GI is most fragmented and has the smallest patches, which are scattered in the territory. Patch is considered a small isolated fragment of forest or other type of GI that are completely degraded by "edge effect". The core elements of GI increases with the distance from the city center as urban forests are mostly at the far north and south of the city. However, these core areas are affected by forest pixels along the edge of an interior gap in a forest ('Perforated' in Fig. 19.3) that are degraded by "edge effects".

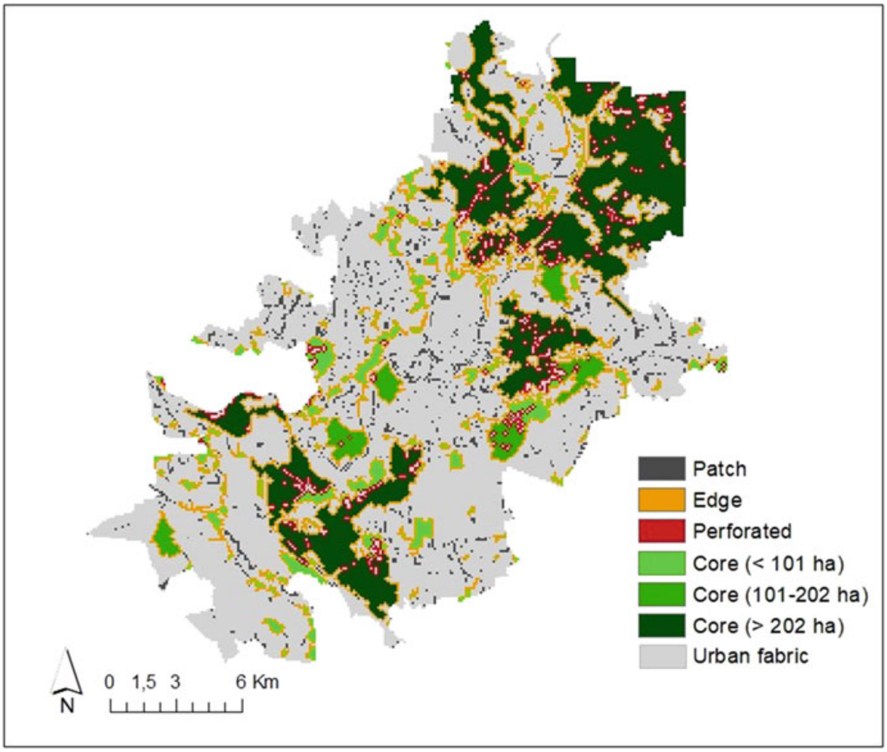

Fig. 19.3 Fragmentation of urban GI in the study area

Looking at the share of different fragmentation units of the GI one can see that core forest areas over 202 ha make up almost half of the GI in Vilnius (Table 19.1). These territories, however, are at the outskirts of the city and do not address the demand, which is concentrated in the city center. Another important insight is that one quarter of the GI territory is considered as degraded by the "edge effect" (Edge in Fig. 19.3).

Even though Vilnius has a lot of green spaces, fragmentation shows that ES related to the microclimatic and air quality are hardly accessible in most central parts and could become even less accessible in the future due to climate change higher average temperature and the higher magnitude and recurrence of extreme events such as heat waves. The probability of temperature extremes generally increases non-linearly with increasing global warming levels. The most recent research showed that, compared to the historical climate, warming will result in strong increases in heat wave area, duration, and magnitude. These changes are mostly due to the increase in mean seasonal temperature (Vogel et al., 2020). In Lithuania, the annual average temperature could increase from 1.5 to 5.1 °C (depending on different emission scenarios) until 2100 (Keršytė et al., 2015). The temperature changes could be slightly higher according to the newest CMIP6 project modelling results (Tebaldi et al., 2021). Moreover, future climate change could intensify UHI

Fig. 19.4 Accessibility to: (**a**) urban forest; (**b**) intensively used UGS having recreational infrastructure; (**c**) extensively used UGS without infrastructure

Table 19.1 Share of different fragmentation units of the green infrastructure in Vilnius

GI fragmentation units	Share of the units, %
Patch	8.03
Edge	25.28
Perforated	8.47
Core (<101 ha)	8.66
Core (101–202 ha)	2.27
Core (>202 ha)	47.29

Table 19.2 Number of people living 100 m and 300 m from the closest GI, including water bodies

	Forest	Intensively used UGS	Extensively use UGS	Water bodies
100 m	67,670 (11,98%)	242,516 (42,93%)	15,996 (2,83%)	10,173 (1,8%)
300 m	256,954 (45,49%)	418,309 (74,053%)	64,444 (11,4%)	74,007 (13,1%)

effect and warming will probably be equivalent to about half the warming caused by climate change by the year 2050 (Huang et al., 2019).

There is not a lot of evidence about UHI magnitude in Vilnius. However, some studies revealed the existence of this phenomena. Mažeikis (2013) used Enviro-HIRLAM numerical weather prediction model and found the differences in meteorological parameters (air temperature, wind speed, precipitation field) in the urbanized areas in Lithuania (Vilnius case study). Higher anthropogenic heat flux sums up to higher sensible heat flux and it means that the energy available for UHI formation near surface air is higher. Urbanavičiūtė and Bukaintis (2020) found that the average monthly air temperature (2012–2017) measured at Vilnius University meteorological station (located in the city center) at all times of the year were 0.8–1.54 °C higher than temperatures recorded in suburbs (Trakai Vokė and Civil Aviation meteorological stations). The highest UHI magnitude values are reached in warm season (May-September). In most cases, UHI effect persisted not only during the day, but also at night time.

The higher magnitude of recurrence of heat waves, UHI effect with a combination of air pollution (mostly of traffic) could cause serious health, social and other problems in central parts of Vilnius, which lacks GI. Venter et al. (2020) identify the increase of health risk threshold in Oslo (Norway) during the summer (>30 °C) while each city tree was replaced by the most common non-tree cover. In Vilnius, heat related mortality could increase from 7 deaths per year in 2015 up to 46 deaths in 2100 if there would no adaptation and reduction measures implemented (Martinez et al., 2018). Pfeifer et al. (2020) indicated that heat and heat waves lead to an increase in mortality in Nordic climatic region, despite these countries having low average temperatures, suggesting that relatively high temperatures as compared to more normal temperatures may be of importance.

Accessibility visualizations in Fig. 19.4 show the access to different types of GI. It is no surprising, that intensively used UGS having recreational infrastructure, like benches, lights or playgrounds (Fig. 19.4b) are concentrated in the areas with the highest demand (Fig. 19.2). However, these are usually small fragmented patches having low capacity to provide regulating ES related to climate adaptation. There are much less people that has access to the core areas of GI or other type of GI (Table 19.2).

The Fragmentation map of urban GI (Fig. 19.3) illustrates that the most core elements could not support ES functions, such as microclimatic regulation and air purification in the place with highest demand (Fig. 19.2); in Vilnius, the accessibility to forests (Fig. 19.4a), which could fully support these functions, are lower than 50% (Table 19.2). Moreover, the accessibility to water bodies, which could additionally improve microclimate regulations, is even more limited (Table 19.2).

The expansion of perforation zones (Perforated in Fig. 19.3) could be related to extensively used UGS without infrastructure (Fig. 19.4c). Even though now the accessibility to extensively use UGS is limited (Table 19.2), it could trigger the collapse of core components as a result of the growing demand of its usage in the future. Therefore, the situation in perforation zones should be monitored and maintained to prevent the loss of core elements in Vilnius.

3.2 GI Planning for Effective Adaptation to Climate Change

Urban green cover in Vilnius can be improved in different ways. First of all, improving connectivity between existing elements of urban GI by preservation of green corridors and connection of patches identified in the fragmentation analysis. This helps to counter fragmentation and increases ecological coherence. Identifying multifunctional zones is another effective technique for GI development. Territories that support healthy biodiverse ecosystems and at the same time encompass compatible land uses such as recreation, forestry or farming. Such territories should become a backbone of the urban GI from the city center to the outskirts. Nevertheless, there are two noticeable problems in the city: lack of core elements and over exploitation of them. Even though the percentage of accessibility to intensively used UGS is high (Table 19.2), most of these UGS are recognized as patches in Fragmentation map (Patch in Fig. 19.3). In the future, planners should include more core elements in the most demanding districts in Vilnius. Foremost larger GI elements would serve for climate adaptation. Second, it would benefit the city dwellers as they tend to look for larger green spaces to have longer and more diverse physical activities that the small parks and gardens even with recreational infrastructure cannot support. It means that the demand for larger spaces in central parts of the city (like Vingis park, Karoliniškės landscape reserve, Neris river embankments, etc.) will grow. It is even more important if the pandemic lockdown situation recurs in the future as now a lot of citizens spend their time in the biggest intensively used UGS in the city center. The overexploitation of these core elements could lead to a loss of the core functions in the future.

Urban GI is currently receiving growing attention from urban planners and policy makers as an important strategy to reduce heat related effects in the cities (Balany et al., 2020; Venter et al. 2020). From a policy standpoint, tree protection standards can greatly reduce UHI (Sung, 2013). Urban GI inclusion into urban spatial panning and policies are seen as a key to success. A proper identification of climate change risks and threats would allow effectively plan land use or operational regimes. Thus, the interest of city dwellers and the principles of climate change adaptation must be addressed in municipal spatial planning documents. However, there are limited policies for urban GI of climate mitigation and adaptation in Lithuania. Kilpys et al. (2017) provided the recommendations for climate change mitigation and adaptation for municipalities. Recent Vilnius city master plan (2021) briefly indicates several measures, including nature based solutions for climate change adaptation. The development of GI, therefore, especially in high demand areas, should be better addressed by policy makers and urban planners for effective adaptation policies.

4 Conclusions

The large part of Vilnius territory covered by GI and makes the City to be seen as "a green city". However, the largest part of the 'core' (>202 ha) vegetation areas, which are essential in securing ES supply (microclimatic regulation and air purification), are located in the outskirts of the city. The quarter of city area, instead of creating 'core' and 'patch' fragments, is indicated as 'edge' territories. This fragmentation and unequal distribution of urban GI affect the demand and accessibility of ES. Now there is a great dislocation of GI accessibility and areas with higher demand of UGS and so of ES in Vilnius City. The disproportion of demand and accessibility will raise due to climate change processes (e.g. UHI) and continuing fragmentation of GI. Moreover, the absence of proper climate change adaptation regulations could bring more severe challenges for the city in the future.

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Chapter 20
Social Demand for Urban Wilderness in Purgatory

Shadi Maleki, Jason P. Julian, Russell C. Weaver, Christina Lopez, and Mike Kraft

Significance Statement In a rapidly urbanizing world, urban wilderness areas offer unique opportunities to connect with raw nature. After examining social demand for urban wilderness in one of the fastest growing cities in the United States, we found that high levels of naturalness positively influence visitors' use and perception of natural areas. Age and youth experiences with nature were the most significant, positive correlates with perception of wildlife. Regardless of race/ethnicity, income, and education, visitors recognized the importance of wildlife in urban wilderness. Overall, this study found that social demand for urban wilderness is a multi-dimensional balance between natural amenities and cultural conveniences. This knowledge is useful to city planners to properly plan and protect the natural areas within urban environments.

Keywords Parks and protected places · Natural areas · Urban green space · Perceptions and preferences for wildlife · Cultural ecosystem services · Urban wilderness · Social demand

1 Introduction

Urban green spaces are vegetated lands within a city *designed* to improve public welfare. Wilderness areas, by contrast, are natural lands "where the earth and its community of life are untrammeled by [humans], where [a human is] a visitor who does not remain" (Wilderness Act, 1964). While there is no universally accepted

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definition for *urban wilderness*, it commonly refers to an undeveloped area (save natural surface trails) within city limits that is large enough where human activities are not seen or heard. With a minimum human imprint, urban wilderness areas offer unique opportunities for a proximal population to connect with raw nature and engage in primitive recreation (Nash, 2014).

While numerous studies have examined the effects of *urban green space* on physical and mental wellbeing, far fewer studies have explored social demand (i.e., use, perceptions, preferences, and values) for *urban wilderness*. This chapter presents a case study to assess the use, perceptions, preferences, life experiences, and sociodemographic characteristics of visitors to Purgatory Creek Natural Area (PCNA), a large urban wilderness with high levels of biodiversity and natural amenities located in San Marcos, Texas, USA (Fig. 20.1). Urban wilderness demand was explored, emphasizing users' perceptions of wildlife and solitude as elements of wilderness. The guiding research question of the study was: "What sociodemographic characteristics are associated with perceptions of and preferences for wildlife and amenities in PCNA?" Because experiencing "solitude and

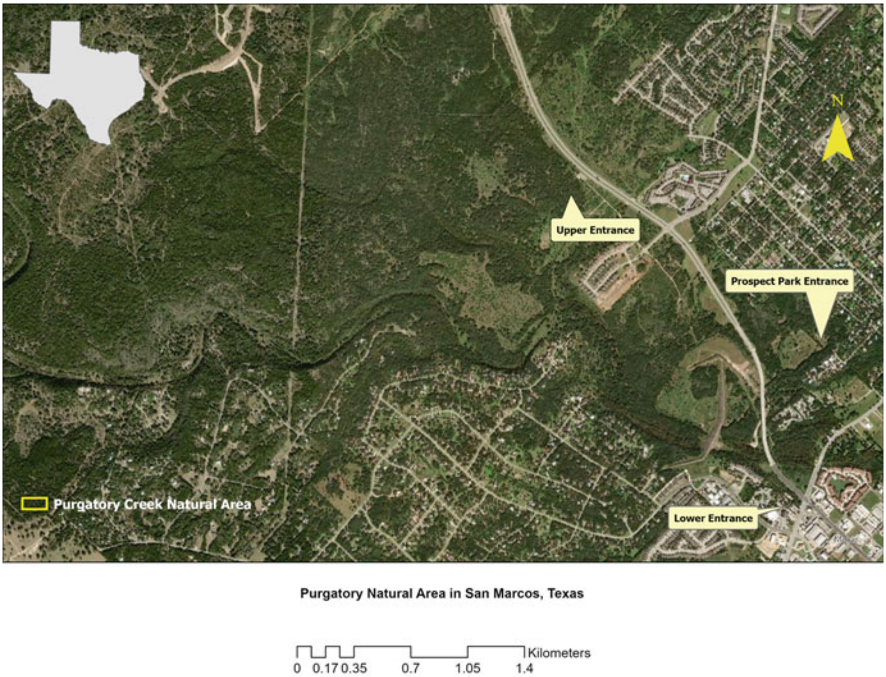


Fig. 20.1 Purgatory Creek Natural Area (PCNA) study area in San Marcos, Texas, USA. (Data for this map were obtained from the City of San Marcos, Texas Department of Transportation, and Esri base maps)

naturalness" are important aspects that distinguish wilderness from other types of urban green spaces (Nash, 2014), we set out to understand the extent to which users cite these characteristics as reasons for their use.

The benefits of urban wilderness and green spaces are wide-ranging and far-reaching. They benefit the environment on multiple fronts by mitigating the impacts of urbanization on climate and ecosystems (Kubiszewski et al., 2017). Cultural ecosystem services (CES)—non-material benefits such as environmental education, spirituality, recreation, aesthetics, and stress relief—stemming from nature-human interactions are also abundant in semi-natural areas within cities (Campbell et al., 2016). Following a positive feedback loop, CES encourages the use of and support for parks and natural areas; however, challenges remain for including these non-material benefits in the planning and management of urban natural areas (Dickinson & Hobbs, 2017). Perceived ecosystem services can vary based on the geography of place and different landscape settings. Educational background and professional roles have also been found to influence social demand. Individuals whose work is related to the environment are more likely to display a stronger preference for natural settings (Eriksson et al., 2012). Further, people with previous nature experiences, especially during youth, often show a higher preference for wild elements (Jay & Schraml, 2009).

People tend to relate CES to their individual wellbeing and, based on their perceptions and experiences, assign diverse aesthetic, social, and cultural values to green spaces (Ives et al., 2017). Most people agree that the value of a protected area increases with its naturalness level; however, discrepancies were found between actual preferences for wilderness among those with different cultures and environment-related attitudes and experiences (Buijs et al., 2009). Sociodemographic variables such as age, gender, race/ethnicity, income, and education are among the most studied factors that influence perception and preferences for natural landscapes within an urban setting (Misiune et al., 2021).

The main characteristics associated with wilderness tend to be the absence of human influence and economic exploitation. However, Bauer (2005) notes that (1) such spaces are difficult if not impossible to find in or adjacent to cities, and (2) users often express a desire for so-called *wilderness* areas to provide amenities (e.g., fireplaces, trash bins, benches, parking lots) that are at odds with the aforementioned conditions. In other words, while users' preferences for *wilderness* over the built environment are well-documented (McMahan & Josh, 2017; de Groot & van den Born, 2003), the dissonance between these preferences and the simultaneous demand for built amenities are not well understood. Our case study adds new insights into this balance by asking users of a unique urban wilderness area, among other things, why they choose to use the study area and what, if any, amenities they would like this area to offer. This knowledge is useful to city planners who may not be aware of visitors' preferences for and benefits of natural areas.

2 Methods

2.1 Study Area

The urban wilderness area we examined is the ~500-ha Purgatory Creek Natural Area (PCNA), located within the city limits of San Marcos, Texas, USA (Fig. 20.1). PCNA comprises three separately named tracts, but they are contiguous and thus treated as one natural area. At the time of our study, there were three main public entrances: Prospect Park (at the dead-end of a minor residential road), Upper Purgatory (at the dead-end of a service road along a tertiary road), and Lower Purgatory (at the intersection of two major secondary roads). Prospect Park is the original natural area developed in the 1990s, with additional contiguous parcels added later (San Marcos Greenbelt Alliance, 2017). PCNA contains approximately 17 km of natural surface trails that visitors use to engage in various activities such as walking/hiking, running, mountain biking, bird watching, and dog walking. Figure 20.2 shows natural landscape and the types of amenities present in PCNA. Purgatory Creek, a large ephemeral stream, runs through the natural area and recharges the Edwards Aquifer, one of Central Texas's major water resources. The fluvial ecosystem and its surrounding woodlands provide habitat for numerous species, including the apex predator mountain lion and the federally-protected

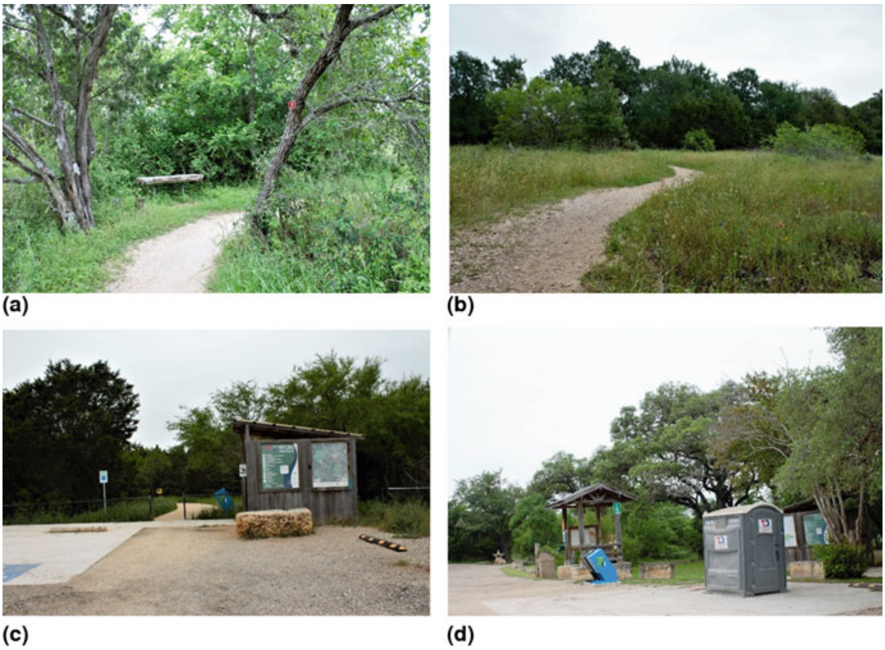


Fig. 20.2 Purgatory Creek Natural Area (PCNA) landscape. (Photos **a**, **b**, **c**, **d** show the natural landscape and the types of amenities present in PCNA. All photos were taken by C. Lopez)

Golden-cheeked Warbler (Duarte et al., 2016; Groce et al., 2010). PCNA is co-managed by the City of San Marcos (CoSM) and the nonprofit San Marcos Greenbelt Alliance (SMGA).

San Marcos is a college town and rapidly growing city (2017 population of 65,000) located along the Interstate-35 corridor between Austin and San Antonio, two of the fastest-growing large cities in the USA. San Marcos is also a tourist destination. Each year, approximately 14 million people visit the San Marcos Premium and Tanger Factory Outlets shopping center, and over 100,000 flock to the San Marcos River's recreation areas (Greater San Marcos Partnership 2020). Because PCNA is embedded in a dynamic and urbanizing region, its relative absence of human influence and extensive spatial footprint make it unique within the region and place it in high demand.

2.2 Survey Instrument

The survey design was based on the authors' previous studies on social demand for ecosystem services in natural areas (Castro et al., 2016; Julian et al., 2018), which were an expansion of the social preference framework of Martin-Lopez et al. (2012). Surveys were conducted at the three public entrance/exit points from June 2016 to April 2017, during different days of the week and over the full range of daylight hours to have a sample that represented the full suite of users and uses of the natural area. Visitors who appeared to be 18 years or older and who were leaving the area were approached and invited to participate in a brief survey about their use, preferences, and perceptions of PCNA. Participants completed a 22-question survey in 10 min or less. No incentives were offered for participation in the survey.

The survey instrument used a combination of multiple-choice, Likert-scale, and open-ended questions to collect information about natural area use, access, childhood nature experiences, sociodemographics, and the primary focus of this research: perceptions of nature and wildlife. To evaluate the perception of wildlife, the survey asked participants to rate the statement: "having birds and wildlife in the parks I use is important" on a five-level Likert scale from "strongly disagree" to "strongly agree." The survey instrument contained two other Likert-scale questions to further explore participants' preferences for nature: (1) their preferred amount of people in the park when visiting and (2) the likelihood they would visit the park if it became crowded (Manning et al., 2009).

Moreover, following Kaplan (1985), this study analyzed nature preference/perception by examining how the environment is experienced. For this purpose, the survey included two open-ended questions. The first such question asked participants to name the amenities they wished to see added to PCNA. The second question sought information on participants' motivations to visit PCNA. To further explore human-environment relationships, our survey included two questions on childhood nature experiences related to environment raised (urban, suburban, rural) and time spent outdoors (regularly, occasionally, rarely, never). The survey also collected sociodemographic information on age, gender, race/ethnicity, education, income, occupation, and student status.

Demand for green spaces and nature, more broadly, beyond PCNA, was examined through multiple questions about general park use and preferences. The survey respondents were asked how often they visit any natural area and why. Proximity-related questions asked participants about their current residence and mode of transportation. Finally, visitors were asked a close-ended question, on a scale from "strongly disagree" to "strongly agree," on whether park space and trails in their city/town meet their current needs.

2.3 Data Analyses

The survey instrument was designed to include a mix of closed- and open-ended questions. The analysis was performed in three steps. The first step was exploratory and summarized the descriptive statistics of respondents' characteristics. In the second step, non-parametric Kruskal-Wallis tests and post hoc pairwise Wilcoxon tests (when required) were employed to test hypotheses related to respondents' perception of nature and wildlife. Finally, we engaged with responses to two open-ended questions that explored motivations for visiting PCNA (*Why did you come to this park today instead of others?*), and their preference for any further amenities in the park (*What other amenities, if any, would you like to see added to this park?*).

3 Results and Discussion

3.1 Visitor Sociodemographics

A total of 391 surveys were collected from visitors to PCNA, mostly at the Lower Purgatory entrance ($n = 304$), which is the most popular among the three entry/exit points, followed by Upper Purgatory ($n = 66$), and Prospect Park ($n = 21$). Most visitors were current Texas State University students (65.5%), followed by former students (27.4%). The strong presence of university students and graduates largely explains visitors' age makeup, as more than half of respondents were under 25 years old (50.3%) while another quarter was between the ages of 25 and 34 years old (24.9%). More than 7% of the visitors were over 55 years old. A majority of respondents were white (66.1%) and male (54.6%), with a significant fraction of visitors (22.9%) reporting Hispanic/Latino ethnicity. Most visitors were raised in a suburban environment (58.7%), while 30% were raised in a rural environment and only 11% in an urban environment. The vast majority of the respondents had regular outdoor activity during childhood (86.9%). Only 2.1% reported never or rarely spending time enjoying outdoor activities during childhood and adolescence.

3.2 Natural Area Use

More than half of the respondents said that they visit PCNA one or more times per month: 29.4% make one to three visits per month, while 24.6% visit the park weekly (Table 20.1). Another 26% of respondents reported making between two and eleven visits to PCNA per year, while the remaining 17.1% visit once per year or less frequently. With respect to any natural area (i.e., other than the PCNA), park, or trail, a large majority of respondents (71.7%) claimed to visit such places on at least a monthly (29.2%) or weekly (42.5%) basis. This park/natural area visitation frequency is comparable to a similar study in Vilnius, Lithuania (Misiune et al., 2021). In the second half of Table 20.1, observe that the majority of survey respondents agree (69%) or strongly agree (6.2%) that the parks in their city or town meet the current level demand therein. However, 11.4% disagree, and 2.3% strongly disagree with this statement.

Table 20.1 Visitors' use of Purgatory Creek Natural Area (PCNA)

Question	Answer	Distribution (%)
Visit PCNA	Once a year or less	17.1
	A few times a year (2–4 times a year)	13.8
	Several times a year (5–11 times a year)	13.0
	1–3 times a month	29.4
	Weekly	24.6
	Daily	2.0
Visit any natural area, park, or trail	Once a year or less	1.0
	A few times a year (2–4 times a year)	9.7
	Several times a year (5–11 times a year)	7.4
	1–3 times a month	29.2
	Weekly	42.5
	Daily	9.2
Parks meets current demand	Strongly disagree	2.3
	Disagree	11.4
	Neither agree nor disagree	11.1
	Agree	69.0
	Strongly agree	6.2
Activities in the park today	Hiking, walking, running, or other exercise	93.9
	Biking	5.9
	Bird watching or other nature experience	5.4
	Dog walking	20.2
	Social outing	7.9
	Stress release	6.6
	Other	6.9

3.3 Urban Wilderness Perception

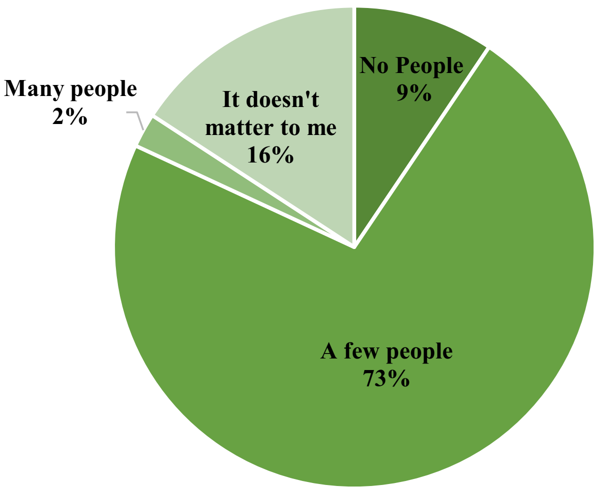
While we can debate the definition of urban wilderness, it is generally accepted that it provides favorable habitat for wildlife (Nash, 2014). Almost all of our survey respondents (95.6%) agreed that having birds and wildlife in PCNA is important. An urban wilderness is also perceived as a refuge to find alone time, experience restoration, and recover from the stresses and fatigue associated with an urban lifestyle (Campbell et al., 2016; Stigsdotter & Grahn, 2011). Accordingly, this study found that most respondents wished to experience nature in relative solitude. Indeed, 82.4% preferred to see no or only a few people in the natural area during their visit (Fig. 20.3), and almost half (44.3%) would stop visiting PCNA if it became crowded. On the other hand, almost half (44.6%) would visit PCNA even if it became crowded (Fig. 20.4).

Using the non-parametric Kruskal-Wallis test in conjunction with posthoc Wilcoxon pairwise tests, sociodemographic data (independent variables) were tested against respondents' perceptions of birds and wildlife (dependent variable) to understand the importance of characteristics that might speak to PCNA's wilderness qualities to different users (Table 20.2). Before unpacking these results, observe that we were forced to combine some groups due to low observed frequencies in some categories.

3.3.1 Age

Kruskal-Wallis tests revealed significant differences in the importance of birds and wildlife to respondents by age group ($p = 0.026$). While the median rank for all age groups was 5 (indicating high importance of birds and wildlife to all groups), post

Fig. 20.3 Preference for the amount of people in PCNA showing how many people respondents prefer to see when visiting PCNA



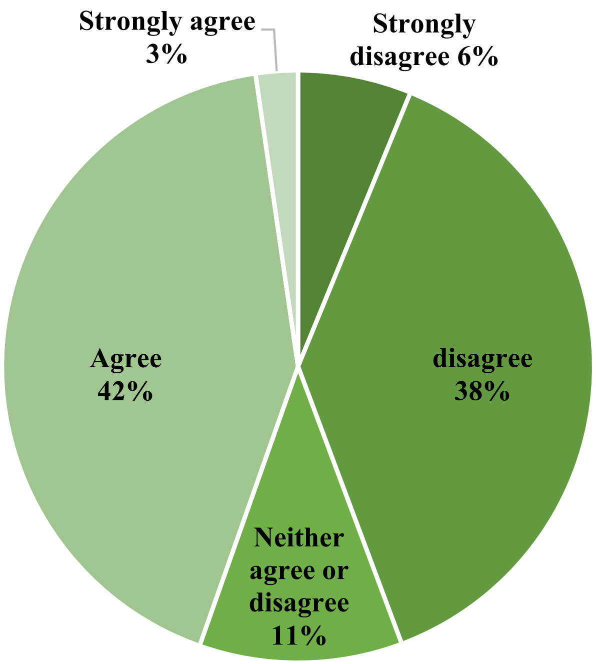


Fig. 20.4 Respondents' answers to whether they would still use and enjoy PCNA if it becomes crowded

hoc Wilcoxon pairwise tests suggested that the distributions of responses differed for younger and older visitors. Specifically, visitors 45 years and older placed higher importance on having birds and wildlife in the park relative to younger respondents. The mean ranks for persons aged 45–54 and 55+ were both 4.81. These values were significantly higher than the mean rank of 4.51 for persons 25 years and younger.

3.3.2 Environment Raised and Childhood Outdoor Activity

Youth experiences in nature-based activities have been shown to have a positive relationship with adult environmental attitudes (Jim & Shan, 2013; Julian et al., 2018). From our study, we also found that regular childhood outdoor activity positively influenced the perception of wildlife. Perceived importance of birds and wildlife to the PCNA differed significantly by the amount of childhood outdoor activity ($p = 0.020$) and marginally significant ($p = 0.068$) by type of environment (urban, suburban, rural) in which a respondent was raised. The median rank of 4 among respondents who "occasionally" engaged in outdoor activities during childhood was significantly lower than the median rank of 5 for those who regularly experienced an outdoor activity as a child.

With respect to youth environment, at a 90% level of confidence, visitors who grew up in an urban environment placed significantly less importance on the

Table 20.2 Relationships between sociodemographic variables and perception of wildlife ("Having birds and wildlife in the parks I visit is important")

Grouping variable	Groups	Group median	Group mean	n
Age	Under 25	5	4.51	196
Chi Square = 11.05 (p = 0.026)	25–34	5	4.49	96
	35–44	5	4.62	37
	45–54	5	4.81	32
	Over 55	5	4.81	27
Environment raised	Urban	4	4.40	42
Chi Square = 5.36 (p = 0.068)	Suburban	5	4.58	224
	Rural	5	4.59	116
Childhood outdoor activity	Regularly	5	4.60	332
Chi Square = 7.78 (p = 0.020)	Occasionally	4	4.30	42
	Rarely or never	5	4.50	8
Income	<$20,000	5	4.53	114
Chi Square = 5.58 (p = 0.134)	$20,000–$40,000	5	4.45	92
	$40,000–$60,000	5	4.69	66
	>$60,000	5	4.58	68
Education	High school and above	5	4.61	31
Chi Square = 1.01 (p = 0.77)	Some college, but no degree	5	4.53	172
	Associate or technical degree	5	4.59	22
	Bachelor's or above	5	4.58	158
Race/ethnicity/origin	Hispanic or Latino or Spanish	5	4.52	88
Chi Square = 7.03 (p = 0.07)	Black or African American	5	4.50	12
	White or Anglo	5	4.61	256

presence of birds and wildlife in a natural area (median = 4) compared to persons who hailed from suburban and rural communities (median = 5 for both groups).

3.3.3 Education, Income, Race/Ethnicity/Origin

Unlike previous studies, which found that use of and preferences for green space varied among people from different racial/ethnic groups (Payne et al., 2002), and with different levels of education and income (Jim & Shan, 2013), this study did not find any significant differences in how people perceive the importance of wildlife-based on their race/ethnicity/origin, educational level, and income class. Regardless of any of these factors, the survey respondents positively valued the existence of wildlife and other nature elements in wilderness areas.

One difference that our study did show was that age could influence the perception of wildlife, as younger visitors demonstrated lower awareness compared to older visitors. This finding supports a previous study that found age to be an influential factor in nature perception, where older people assign greater importance to experiencing wildlife in urban green spaces (Sang et al., 2016).

3.4 Motivations for Natural Area Usage

As in previous studies (Paul & Nagendra, 2017; Campbell et al., 2016; Misiune et al., 2021), proximity to the green space was the most frequently mentioned factor (n = 127) that motivated respondents' visits to PCNA (Fig. 20.5). Indeed, most of the survey respondents lived in San Marcos or came from nearby towns. Some participants cited the size and quality of trails (61) as reasons for using PCNA rather than other nearby parks. Some respondents mentioned that they visit the park to engage in activities such as walking, running, biking (46), or walking their dogs (14).

Two main themes emerged from survey responses, which provided insight into respondents' perceptions of natural and anthropogenic amenities. The first concept was "naturalness" (12), expressed with various terminologies such as "natural," "raw nature," "natural landscape," "rugged," and other statements used to describe their preference for a more natural landscape. Respondents also used "scenery" (6) through various expressions to show their appreciation for naturalness's aesthetic value. The second theme that arose from survey responses was "solitude" (19), expressed through words such as "quietness" and "secluded."

3.5 Preference for Amenities

Despite a strong consensus on the importance of having wilderness elements in natural areas, our qualitative results indicated what visitors wanted to see in wilderness areas (e.g., trash bins, benches, camp-fire places) is not well-matched with

Fig. 20.5 Visitors' motivations for visiting Purgatory Creek Natural Area (PCNA). (This word cloud was generated using Wordle.net)

Fig. 20.6 The most desired amenities by visitors in Purgatory Creek Natural Area (PCNA)

typical characteristics of a wilderness (Bauer, 2005). The interpretive analysis of 102 total comments identified several amenities that survey participants most desired (Fig. 20.6). Trashcans were at the top of the list (n = 72), followed by water fountains (63), improved signage (53), better trails (42), and benches (13). Some people asked for picnic areas (3), and only two people asked for a larger parking lot. Many asked for dog water fountains and waste bags (23). Several respondents stated that they like the park as is and did not desire any changes. In these 16 comments, respondents said either they "loved" the park or it was their favorite.

4 Conclusions

The Purgatory Creek Natural Area (PCNA) case study shed light on the complex social demand for urban wilderness, including how that wilderness is used, perceived, preferred, and valued. The findings buttressed the widely accepted notion that high levels of naturalness—rare within urban settings—positively influence visitors' use and perception of natural areas in cities. Age and youth experiences with nature were the most significant, positive correlates with perception of wildlife and nature in PCNA.

Our study also showed that visitors from different races/ethnicities, income, and education levels agreed on the importance of wildlife and relative solitude in the selected urban wilderness. However, there were some mismatches between what visitors valued of urban wilderness (i.e., raw nature) and what amenities they desired for that same urban wilderness (e.g., trash bins, signage, benches). To obtain a more comprehensive understanding of visitors' perception and preferences of urban wilderness, there is a need for further studies that involve participants with more diverse sociodemographic characteristics. Understanding users' perception of urban wilderness is essential for managing and protecting these unique spaces as well as increasing awareness about the importance of wilderness areas within urban settings.

Overall, this study found that social demand for urban wilderness is a multi-dimensional balance between natural amenities and cultural conveniences. While in Purgatory, we want to be cleansed (of urban stresses), but we do not want to suffer too much in the process. Place-based studies, like this one, in a wider variety of environments are needed to shed more light on social demand for urban wilderness to promote a healthy balance between people and nature in an ever-urbanizing world.

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Chapter 21
The Role of Allotment Gardens for Connecting Nature and People

Petra Schneider and Tino Fauk

Significance Statement Allotment gardens (AG) are valuable elements of communities that provide substantial ecosystem services. An AG as a type of community garden is a plot of land made available for individual, non-commercial gardening or growing food plants. Beside the provision of urban ecosystem services, AG's deliver an ecological potential to habitat connectivity in the urban realm as well a substantial contribution to human health. The role of AG's in the frame of urban ecosystems is manifold and multifunctional. Beside their purpose for food production and recreation, AG's offer crucial benefits for public health and wellbeing, social inclusion, environment, and as cultural archive. Their intrinsic purpose is connectivity, for habitats, people, ecosystem services and circular flux management. The contribution is based on a literature review supported by a field survey that was performed in the period 2017–2020 in Ecuador, Germany, Sweden, Uganda, and Vietnam.

Keywords Urban gardening · Green infrastructure · Habitat connectivity

1 Introduction

Allotment gardens (AG) have a long tradition. Nowadays an AG is considered as a type of community garden, a plot of land made available for individual, non-commercial gardening or growing food plants. In countries under development they are conceived as "gardens for the poor", as an important motivation was self-sufficiency through the cultivation of fruits and vegetables (Gusted, 2017). In any

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case, AG are a location of social interaction, and increasingly are recognised as biodiversity hubs in Green Infrastructure (GI). GI describes a strategically planned network of natural and near-natural areas with different natural features on different scales. In this respect, the GI represents a new planning approach for landscape architecture, which is based on a comprehensive and sustainable view of nature and the landscape. In addition to ecological, socio-cultural, aesthetic and economic aspects, diverse socio-political goals such as climate change, biodiversity or social cohesion are integrated into the concept. These biotope networks are intended to preserve biodiversity on the one hand and to strengthen and regenerate ecosystem functions and the potential for providing ecosystem services based on them on the other. The main aim of this contribution is to have a look at AG and their GI potential. This concerns several questions, like in which way AG might be part of urban biodiversity networks, their contribution in terms of ecosystem services and which role AG may play in nature conservation, restoration and habitat connectivity in the long term.

2 Materials and Methods

The present research is based on a qualitative literature review through the Web of Science and other scientific research platforms like Scopus and Google Scholar supported by field survey evidence. The literature review focused on AG's as such, their history and traditional role for food supply for the poor, and their recently transformed role as GI element including. The field survey was performed during excursions with collection of qualitative information in the period 2017–2020 in Ecuador, Germany, Sweden, Uganda, and Vietnam (countries in alphabetic order). Several types of stakeholders where consulted during the field surveys, particularly random AG gardeners from the mentioned countries, complemented with information from local communal and academic stakeholders. Interviews with gardeners comprised the topics of garden size, mode of cultivation, role of biodiversity, role of environment and health, as well as their opinion on the role of AG's as GI. The survey included from five (Sweden, Uganda) to ten (Ecuador, Germany, Vietnam) stakeholders per country. Literature review focused on a qualitative approach, quantitative data from the literature were used to support the drawn conclusions.

3 The Role of Allotment Gardens Around the World

3.1 Dimension and Purpose of Allotment Gardens

Having a look on the dimension and purpose of AG's, country specific diversity becomes already obvious. The Cost Action TU1201 defined AG's as '*small plots of urban land allocated by local authorities to households who are interested in* *producing their own vegetables*' (Veen, 2014). Veen (2014) underlined that the international termination differs in terms of the AG characteristics, and they are different from community gardens where people do not have individual plots. According to Guitart et al. (2012) community gardens refer to green spaces for mainly horticultural uses, which are run by local communities in urban areas including communally and individually managed or rented plots of land. AG's are also different from urban agriculture, which is practised on larger scale and commercially. As documented by Veen (2014), a Norwegian dictionary defined AG as a "*collection of small garden plots, 150–300 square meters, outside the owner's domicile, usually on rented, most often municipal land*". Sovova and Veen (2020) investigated Dutch and Czech AG's and found an AG size in The Netherlands of 100–500 m^2, as well as in Czech Republic of 200 and 240 m^2. In Germany, the size is limited to 400 m^2, and the only permanent building in the AG may be a bower that is not used for living. Also, the Polish Allotment Garden Act contains restrictions regarding the bower (Moskalonek et al., 2020). The AG dimensions were confirmed in the field surveys.

In the Global North, importance and function of urban AG has repeatedly undergone major changes, particularly in the last decades. As a place with an existential and health promoting function more than 200 years ago, AG's were transformed recently into the main leisure and recreational facility in the urban realm that serves social interaction (Moskalonek et al., 2020). AG's became substantial GI part, representing harnessed nature that is used infrastructurally (Benedict & McMahon, 2012). Meanwhile, particularly in European cities, their leisure and recreational value is more important than an economic benefit (Moskalonek et al., 2020).

However, the AG history shows, that in economically difficult times the practical use becomes more important. This is also the case in developing countries where AG's still have a crucial food security function and serve families with low incomes (Khalil et al., 2017; Singh & Singh, 2017), as is illustrated in the example from Uganda (Fig. 21.1). Khalil et al. (2017) defined small-scale food producers as smallholders and summarised that they are taking the bottom 40% of the (i) operated land size, (ii) the Tropical Livestock Units and (iii) the distribution of

Fig. 21.1 AG's in Uganda. (Photo: Petra Schneider)

revenues. Particularly in economically less developed countries of the Global South, AG's are usually used by individuals or families, even families might support each other (Singh & Singh, 2017). In a later stage of development, there is a trend of transition from cooperation to cooperatives, as was illustrated in an investigation in Benin by Houessou et al. (2019). Do to the extreme climate in Africa, AG's are often practised as agroforestry in order optimise the water balance and to protect the soil from evaporation in a hot climate (Lorenz & Lal, 2018) (Fig. 21.1, left).

Water retention systems, trees for shadow, or frost protection systems are typical AG elements differing according to climate and biogeographical zones. Furthermore, urbanisation, growing population and community development have an impact on AG's structure and size. Roberts and Shackleton (2018) found a clear decline in most community food garden attributes in South Africa between the 1980s and 2000s, which refers to the number of gardens per town, the total area of all gardens combined and the mean size per garden with a maximum garden size loss in King Williams Town by 77%. Trembecka and Kwartnik-Pruc (2018) argued that also in European countries the number of AG's is decreasing due to increasing property prices, except Austria and Germany where the AG's are located on municipal land and are under special protection.

3.2 Allotment Gardens for Health and Wellbeing

Soga et al. (2017) quantified the health benefits of urban allotment gardening in Tokyo, Japan, and underlined the improved physical and psychological wellbeing through a questionnaire survey and comparison between gardeners and non-gardeners and concluded a substantially better general health, mental health and social cohesion. The authors proofed that the moderate intensity of AG physical activity promotes people's physical fitness and health, and caused additional psychological health benefits. Furthermore, AG's are likely to increase people's vegetable consumption. Also, Wood et al. (2015) performed a study on the quantification of AG health and well-paired t-tests revealed a significant improvement in self-esteem and mood as a result of one allotment session, being valid for the time spent on the allotment as well as the time after up to 7 days. Furthermore, the results proofed that allotment gardeners experience less depression and fatigue and more vigour. In that investigation, the participants identified six main themes for enjoyment of allotment gardening, that is being outdoors and having contact with nature (70%), sense of achievement derived from allotment gardening (50%), opportunity for restoration and stress relief (35%), enjoying social interaction (31%), growing and eating the produce (19%), and the opportunities to be active (11%). Comparable results were found by Egerer et al. (2018). Furthermore, nice AG's provide a positive visual impact (Fig. 21.2) and enjoy people (Borysiak & Mizgajski, 2016). Working people recover from work stress (Young & Hofman, 2020). Moreover, AG open up a new field of activity for the unemployed. Retirees are discovering a meaningful leisure activity that they can do as often as they want, even on a small budget. In the

Fig. 21.2 AG's in Visby, Gotland, Sweden. (Photo: Petra Schneider)

Global South AG's serve intrinsically public health and wellbeing through the contribution to local food security and ensuring livelihood of local people.

3.3 Ecosystem Services of Allotment Gardens

Ecosystem services (ES) are nature's services for humans, which they obtain through habitats and living beings such as animals and plants. They are divided into four categories according to the nature of the benefits to humans:

provisional services: products that are obtained from ecosystems; regulatory services: benefits arising from the ecosystems regulation; supporting services: services that are required for the production of all other ecosystem services; as well as cultural services: non-material benefits obtained through ecosystems, such as the fulfilment of aesthetic, spiritual and intellectual needs, recreation, and cultural heritage. AG's are considered as substantial green resource for the provision of urban ecosystem services (Gómez-Baggethun & Barton, 2013; Speak et al., 2015). AGs are part of Nature-based Solutions, supporting ecosystem services including people and habitat connectivity.

Due to their closeness to the city, AGs can therefore help to reduce urban traffic. Like all green spaces, they reduce air pollution as they eliminate dust and form an urban heat buffer (Rost et al., 2020; Mancebo, 2018). Rost et al. (2020) found that on average in Berlin (Germany), the assessed AG nocturnal air temperatures were 2.7 Kelvin cooler than the remaining urban realm. This benefits the city's microclimate and water balance. Furthermore, AG's are locations of a circular material management and the promotion of closed water and nutrient cycles, particularly in dry regions. Common practices everywhere in the world are roof water harvesting and water retention. AGs are also used to recycle garden waste on site as a substructure for the soil layer and in this way to create micro-habitats.

AG's are an excellent example for a multifunctional land use type delivering ecosystem services like food provision, nutrient cycling, air purification, heat buffer, biodiversity, as well as physical as well as social wellbeing and benefits

Fig. 21.3 Multifunctional land use of AG's in Hoa Binh, Vietnam. (Photo: Petra Schneider)

(Langemeyer et al., 2018). Figure 21.3 shows the multifunctional land use of AG's in Hoa Binh, Vietnam, that are used for food provision, while the land is used in parallel for water retention in the flood case. Furthermore, the gardens in Fig. 21.3 have a linear shape along the river that promotes biotope network structures for fauna migration.

The biotope function of urban gardens relates to the function of species and habitats. Gardens can then provide biotopes for non-domesticated species and support undesired overgrowth of crops and domestic animals. This has a supportive effect for biodiversity. In addition, AGs act as a buffer zone between natural and urban habitats, so that the location of allotment gardens on the outskirts has a favourable effect, as they act as link to the town centre, but also to the agricultural landscape. At the same time, in addition to their function as a retreat, they also make a contribution to the protection of the local flora and fauna. Moreover, they represent valuable islands for plants, animals and people. The wealth of structures that can be found in different forms from garden to garden and is of particular importance. There are niches in AGs for numerous plants and animals due to the diverse mosaic-like garden structures, including the different culturally and individually determined farming methods and care intensities. Exemplarily, the Polish Allotment Garden Act illustrates the upgraded role of AGs in terms of nature protection and habitat connectivity (Moskalonek et al., 2020). The Polish Act defines new AG functions going beyond the traditional ones, like restoring degraded areas to the community and nature, protection of the environment and nature, acting the improvement in ecological conditions of municipalities and shaping a healthy human environment. If they are a connecting element to other urban green spaces, they take on important tasks for the biotope network and are therefore an indispensable prerequisite for biodiversity. In addition to being places of retreat for flora and fauna, they also fulfil a biotope function to protect native animal and plant species in "mini biotopes" (Meyer-Rebentisch, 2013).

Nowadays AG's also fulfil an important function as a reservoir of genetic diversity: often gardeners cultivate old useful and cultivated plants that are no longer cultivated in commercial agriculture and are therefore often threatened with extinction. Furthermore, pollination bees find habitats, and this concerns domestic bees as well as wild bees which are observed in AG's (Egerer et al., 2020).

AG gives a possibility to grow own food. One of the AG characteristic is that berry bushes and fruit trees, summer flowers and ornamental plants, vegetables of all kinds, medicinal plants and aromatic herbs grow side by side, in type depending on the climate zone. Those who care for them in the AG at the same time are making a contribution to biodiversity. The types of grown fruits and vegetables depend on the climatic zone, the geographical conditions, and the preference of the gardeners, the volume of the harvest mainly from the AG size. However, there is a difference between the Global North and South as the percentage of self-sufficiency use of the harvest is higher in the Global South, which underlines the priority of food provision. For instance, the average results of Sovová and Veen (2020) indicate that 70% of the harvest are used for self-sufficiency in Dutch and 52% in Czech AG's. Roberts and Shackleton (2018) made investigations on South African gardens and concluded that 84% of the gardeners used the harvest for home consumption but also sold any excess to provide some income, while 16% reported gardening solely for the purpose of selling the harvest.

4 Show Case Allotment Gardens of the Allotment Garden Association Schnarsleben e.V. in Saxony-Anhalt, Germany

The following show case illustrates the role of allotment gardens for connecting nature and people, and might be considered one way of AG future, particularly in the Global North. It refers to a typical German AG, that can be found in a similar version across Europe, and shows the transitional development potential from a historically priority relevant food producing space to a regionally important place of habitat connectivity. The planned nature conservation measures are currently under approval by the local planning authority and shall be implemented starting from 2022.

The Allotment Garden Association (AGA) Schnarsleben e.V. has its origins in the 1930s. It is located in Niederndodeleben in the Hohe Börde landscape protection area. The garden area has currently a good usage share. 71 of 104 garden parcels are currently in typical allotment use. On the one hand, the Covid-19 pandemic is the reason; on the other hand, the trend towards self-sufficiency with fruit and vegetables has been increasingly popular in recent years. AGA Schnarsleben e.V. has now reached a crucial point in its history and intends to combine nature protection, species conservation and urban gardening through a Nature Conservation Strategy. With its location in the hilly landscape of the Hohe Börde region, the location offers the possibility to develop a green corridor as a symbiotic use of allotment gardening and stepping stone patch biotopes (Saura et al., 2014). The connections between the anthropogenic use and the degradation of natural or important anthropogenic ecosystems have prompted AGA Schnarsleben e.V. to take actions for the preservation and increase of biodiversity by reallocating unused garden parcels for ecosystem restoration. The measures comprise restoration of the fruit garden as orchard meadow, establishment of bird promotion areas, and herb gardens (Fig. 21.4). In addition, targeted species protection measures, e.g. through a semi-active habitat construction for species are also foreseen. The strategy for a green infrastructure in suburban and urban gardens is intended to consolidate biological diversity in the long term. In addition, the strategy was developed in a way that future land use models for the sustainable development of peri- and urban areas can be established, taking into account an appropriate scale and the given conditions. Figure 21.4 shows how the planned nature conservation measures shall form an ecological corridor for habitat connectivity. This biotope network needs an interdisciplinary cooperation of different actors. Most of the biotope network area is currently in intensive agricultural use.

To analyse the implementation possibilities of the biotope network, the AGA Schnarsleben e.V. started stakeholder involvement with the local agricultural company and the community of Niederndodeleben. On the parcels not anymore in use the grassing of sheeps and goats already began. The sample for habitat connectivity

Fig. 21.4 Overview on the gardens of the Allotment Garden Association Schnarsleben e.V. – Planned nature conservation measures. (Author: Tino Fauk)

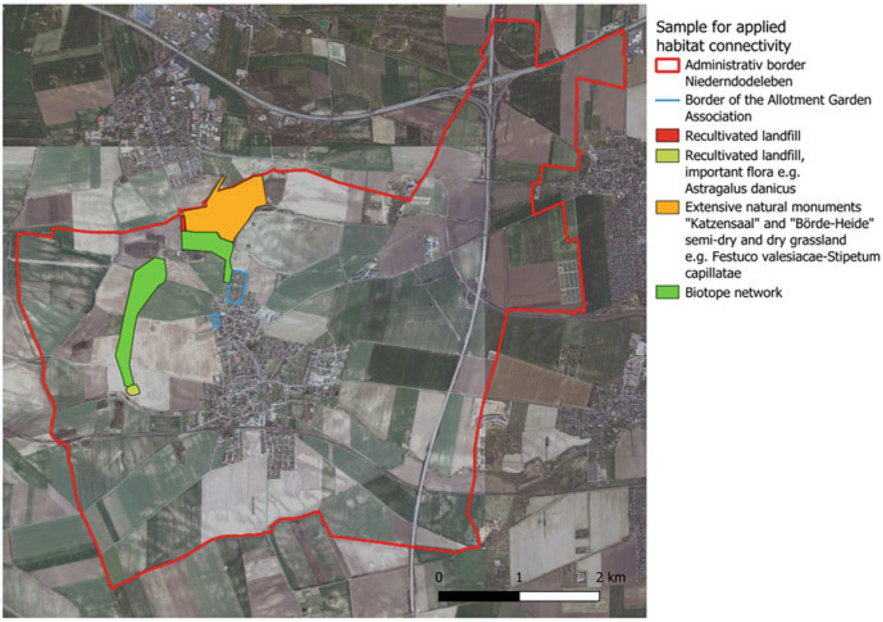

Fig. 21.5 Planned nature conservation measures of the Allotment Garden Association Schnarsleben e.V. – Sample for applied habitat connectivity. (Author: Tino Fauk)

in Fig. 21.5. Further action of AGA Schnarsleben e.V. is e.g. optimizing natural habitats for fauna and flora.

Environmental education is equated with species and nature conservation. Furthermore, it is planned to gain long-term scientific knowledge about the population development of the native flora and fauna in times of climate change and increasing urbanization. In addition, it is important to attract the interest of the next generations in the local nature, which almost no longer occurs in this agro-industrial landscape of the Hohe Börde. The motto is “Experience nature in community”.

5 Conclusions

AG’s in the urban environment are an indispensable part of urban quality of life. It is precisely the diversity of cultivated plants and their mostly vital and healthy condition that allotment gardens contribute significantly to improving the quality of life. By cultivating old cultivated plant species and varieties that are no longer used in horticulture today, as well as knowing about their cultivation and processing, cultural assets can be locally preserved and preserved. The value of AG’s as a form of green spaces close to residential areas is particularly evident for the majority of urban families with children and the elderly. An increase in the quality of life through AG's within city districts is achieved precisely through the human and social coexistence of different social classes with common interests. AG's have great potential for integrating people.

In addition to the various social and economic functions, urban gardens also fulfil important ecological functions. The balancing effect on the inner-city climate and in particular its potential for strengthening biodiversity should be emphasized here. Due to the different structural characteristics, AG's have different meanings for species protection and the habitats of plants and animals. However, it should be noted that in some regions there still might be undesirable legacies from the past where sometimes artificial fertilizers have been applied by the gardeners.

As illustrated in the contribution, AG's fulfil a variety of functions that have a positive effect on human health and quality of life. The social importance of allotment gardening has proven, in addition to the ecological and economic components. The preservation of traditional garden knowledge and an independent garden culture, AG's enable the preservation of this cultural knowledge through their diverse social functions and opportunities for interaction.

Generally, AG's are valuable elements of communities and GI that provide substantial ecosystem services. Important is to preserve them and to integrate the allotment requirement plans in urban, regional and special planning, as well as in urban-rural concepts. Therefore, the development of holistic concepts for connecting urban green spaces and landscaped areas, including allotment gardening should be fostered. However, the practice shows that planners are often not yet familiar with the GI concept and the design principles and therefore might not acknowledge in a sufficient way the AG benefits in the urban and regional planning concepts. Therefore, potential threats for AG in the future might comprise their elimination in order to obtain land for housing construction, as already happened in Germany. For that reason, it is necessary to create more awareness about the environmental benefits of AG's. In this regard, the personal AG experience will contribute to further awareness. Experience might comprise allotment hikes and cycle paths or art trails, as well as leisure infrastructure taking into account the needs. The promotion of AG's in the vicinity of residential areas will lead to their further acknowledgment. Abandoned AG's are of crucial importance for nature conservation and restoration.

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Chapter 22
Green Spaces and Their Social Functions: Specific Challenges in Urban Spaces of Arrival

Annegret Haase

Significance Statement Urban green spaces fulfil multiple functions. Next to their function as areas for leisure, recreation, perception of nature or improvement of physical and mental health, they are also operating as spaces of social contact, encounter, communication and interaction. This social function of urban green spaces becomes a challenge in heterogeneous neighbourhoods where many different groups of residents having different backgrounds of origin, socialization and social daily routines and practices live together and use the same public space. This chapter looks at the social functions of urban green spaces in heterogeneous urban areas, so-called urban spaces of arrival how we find them in many European cities, with a focus on encounter, communication and interaction.

Keywords Social functions of urban green spaces · Urban spaces of arrival · Encounter · Challenges · European cities

1 Introduction

Urban green spaces fulfil multiple functions. Next to their function as areas for leisure, recreation, perception of nature or improvement of physical and mental health, they are also operating as spaces of social contact, encounter, communication and interaction. With such functions, urban green spaces contribute considerably to social cohesion in densely populated and built neighbourhoods. This social function of urban green spaces becomes a real challenge in heterogeneous neighbourhoods where many different groups of residents having different backgrounds of origin, socialization and social daily routines and practices live together and use the same public space.

Set against this background, this short chapter looks at chances and challenges of social functions of urban green spaces in heterogeneous urban areas. It analyses the

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social functions of urban green spaces in heterogeneous urban areas with a focus on encounter, communication and interaction. It discusses specific challenges for these functions that may appear in heterogeneous urban environments, so-called urban spaces of arrival how we find them in many European cities. In doing so, it refers to an emerging discourse on the interconnections between social heterogeneity in cities and its impacts on green space use/green regeneration. Due to its limited word account, the chapter may only shortly address a bundle of important aspects. It starts with a short reflection on the social roles and functions of urban green spaces, especially with respect to encounter, communication and interaction. Then it discusses specific challenges for these functions that may appear in heterogeneous urban environments, so-called urban spaces of arrival that can be found in many European cities and that are characterized by a highly heterogeneous population and a high representation of people with international background (Haase et al., 2020; Hans et al., 2019). Within this context, urban green spaces are being discussed as spaces of contact and conflict, of coping with difference and as places of social experience, learning and cooperation. Finally, an outlook is being given on open questions and needs for future research are being identified.

2 Materials and Methods

This chapter is based on research experience and results from different international and national research projects in which the author has been involved such as Divercities (EU 7 FP, 2013–2017) that dealt with the analysis and governance of urban diversity in 14 European cities, KoopLab (BMBF, 2018–2021) focusing on cooperative development of green spaces in arrival neighbourhoods in 3 German cities and MigraChance (BMBF, 2018–2021) researching the role of social conflicts for urban transformation and institutional change in cities. The chapter, thus, does not represent an empirical case study as such but operates at a more general level as a reflection that uses knowledge from both literature and empirical analysis and examples from the mentioned projects as illustration.

3 Urban Green Spaces as Spaces of Encounter, Communication and Interaction

When this chapter refers to urban green spaces, they are meant to be publicly owned and/or accessible. The focus is on green spaces being located in or close to residential areas, mainly being neighbourhood parks or smaller green spaces that are used by the residential population, mostly from the adjacent/surrounding neighbourhood. The focus here is less on larger, more forest-like green spaces as they can be found in the outskirts of many cities or centrally-located green spaces that are used by residents of different parts of the city.

There is a number of perspectives how urban green spaces can be analysed. In the following, I will focus on the social roles and functions of urban green spaces, in particular with respect to their importance as places for encounter, communication and interaction[1] between their users. Why does this focus matter? Since encounter, communication and interaction have the potential to strengthen social cohesion between people using the same green space, and, at the neighbourhood level, they can create a more cohesive atmosphere in the area; especially in today's cities always more heterogeneous urban environments being characterized by increasingly different housing and living conditions, socialization and cultural backgrounds and social resp. socio-economic differences, high quality green spaces as a factor of residential environment quality have got more into the focus. In this context, green spaces may serve as "spaces of encounter" (Fincher & Iveson, 2008) to enable getting to know each other, learn about each other, negotiate interests etc. (Berding & Karow-Kluge, 2017; Peters, 2010; Peters et al., 2010). They represent places where the heterogeneous urban society becomes visible, perceivable, a place where coping strategies with heterogeneity, contact and conflict are being practiced and tested. Potentially, urban green spaces operate as places of "inclusive openness" (Neal et al., 2015: 474).

Due to their very nature as freely accessible places, public urban green spaces are relevant zones of encounter. There are very different assessments on the question whether, to what extent or under which conditions urban green spaces as zones of encounter, communication and interaction support social cohesion (Räuchle & Berding, 2020). Urban spaces may foster cohesion and consolidate contacts, or they can represent problematic places that are avoided, neglected or even feared (e.g. Neal et al., 2015: 465–66). In extreme cases, urban green spaces can represent places of social injustice and exclusion as a result of social power relations, or they are perceived as unsecure spaces, places of conflict or danger (Neal et al., 2015: 474; Budnik et al., 2017: 97–98). Often, factors like design and care (illumination, clear or unclear arrangement, waste disposal) or differing ideas of activities, noise and speed play a decisive role for the perception of a green space as a pleasant and safe space or not. Not least, social norms and values are important as well as expectations concerning the behaviour of others or the conditions of co-existence or co-activities in a green environment (Tessin, 2012: 27). Shape and design of green spaces may as well either favour cohesive co-existence, support interaction or minimize the risks of conflicts (e.g. Peters et al., 2010: 96–97). The appropriation of a green space by one social group and the examination of social power relations may lead to the exclusion of another social group/other social groups in terms of accession and/or interactional injustice (Low, 2013). Exclusion includes cases where it is represented by the non-visibility or absence of people e.g. in a park or other green space as a result of discrimination or feared/experienced rejection.

[1] While encounter refers to any form of meaningful contact, communication focuses on the exchange of information through talk; interaction, finally, includes also common activities.

Encounter incudes different things such as the simple visibility of other people, i.e. simultaneous presence, but also interaction, i.e. various forms of action and reaction (Fugmann et al., 2017). Encounter can be differentiated due to the places where they happen, the fact whether they represent daily routines or specifically planned activities, whether deliberate appropriation forms part of the interaction or whether the encounter (analytically seen) represents a specific setting or may be generalized in a way. Additionally, encounters may, when they exceed a purely simultaneous presence, be shaped along a continuum from cohesive to conflict-prone.

Green spaces may represent places that people go to in order to be alone or even to deliberately flee from social conflicts (Dangschat, 2011; Peters et al., 2010). At the same time, green spaces operate as places where people spend time with relatives and friends and meet others, mostly people that are already known to somebody. Not least, green spaces also allow for unplanned, spontaneous meetings with hitherto unknown people. Peters et al. (2010: 98) underline that in the majority of cases, unplanned meetings/interactions with people someone does not know are short, superficial talks being pushed by external stimuli such as weather conditions or the observed/perceived behaviour e.g. of children or dogs. Similar to other studies (e.g. Dines & Cattell, 2006) they conclude that well-being in parks and a feeling of relaxation increase with the number of such spontaneous, even if short and superficial, meetings. The probability of non-superficial encounter and interaction increases when the green space is being used mainly by local people and users represent a manageable group of largely the same people following the same routines (e.g. walking a dog, using a playground, sitting on a bench). Several physical characteristics of green spaces such as size, clarity, density of vegetation or diversity of design (e.g. existence or lack of distinct sub-areas, areas for more communality or seclusion) also determine to what extent and how such a place becomes a space of encounter (e.g. Vierikko et al., 2020).

Green spaces are thus an “ambivalent terrain” (Berding & Karow-Kluge, 2017: 2) since it is in particular the vagueness and anonymity of public spaces that demand a high level of behavioural security by the users. The question if and under which conditions green spaces will become places of social encounter or even of social cohesion depends on a variety of factors and their interaction (Fugmann et al., 2017: 51). Important are prerequisites such as a basic trust and knowledge about the places and the availability of amenities and infrastructures that make the place attractive as a place to be and to make use of (Dines & Cattell, 2006). In this sense, green spaces are not just spaces of encounter and interaction but also places where different interests and perceptions are co-existing and possibly being negotiated (ibid.: 38).

4 Specific Challenges for Green Spaces and Their Design, Use and Appropriation in Urban Spaces of Arrival

Looking at urban green spaces and their social functions in so-called urban spaces of arrival, some additional specifics have to be considered. As mentioned above, urban spaces of arrival are areas with a highly heterogeneous population including high shares of people with an international biography and high shares of migrants. Arrival, thus, relates much to international arrival although not exclusively. Taking the term a little more generally, one ca say that urban spaces of arrival are characterized by high fluctuation in terms of people coming to and leaving the area. The debate on such spaces in cities was pushed e.g. by Dan Saunders' book "Arrival city" (2010); the perspective of arrival first and foremost looks at the potentials and prospects for settling and social mobility that an urban space provides for newcomers. Spaces of arrival, subsequently, emerge/develop due to a number of factors that make them attractive for newcomers: availability of affordable and accessible housing, supportive infrastructures and networks and, if they are inner-city neighbourhoods, a good location (Hans et al., 2019; Saunders, 2011; Schillebeeckx et al., 2019). Such spaces are to be found either in inner-city, former working class areas or in large housing estates at the fringes of cities. International migration and the increased heterogeneity of urban population across Europe made urban spaces of arrival becoming an always more frequent phenomenon that can be found all over Europe (Oosterlynck et al., 2019). Their heterogeneity and dynamics of in- and outgoing people make social cohesion being a specific challenge in these areas. Crowded and underprivileged housing conditions, density and high shares of income-poor households are additional factors that aggravate the situation (Großmann et al., 2019).

Urban spaces of arrival are, as we e.g. learnt in a cross-European study on arrival areas in the EU 7FP project Divercities, often densely built neighbourhoods which are, particularly when situated in inner-city locations, under-equipped with high-quality green spaces (Fig. 22.1). They are, at the same time, very much in need of such places due to the above described challenging living and housing conditions of the majority of their residents. Therefore, the topic of green space equipment and greening in heterogeneous urban environments such as spaces of arrival has become more and more an issue of urban planning and theoretical debates (e.g. Elands et al., 2020; Kabisch & Haase, 2014 for Berlin). As well, there has risen the awareness among urban green scholars that the increasing diversity of urban population matters when it comes to the (recreational) use of green spaces and related wants and needs, the perception of urban nature among people with diverse lifeworld backgrounds and potential implications for planning (Kloek, 2015) but with respect to the shaping and organization of participatory development of such spaces as well as engagement and stewardship (Elands et al., 2020).

Fig. 22.1 Urban space of arrival: Leipzig's inner east. (Photo: UFZ in 2016)

5 Encounter in Urban Spaces of Arrival: Opportunities, Conflicts, Ambivalences

The social functions of urban green spaces, i.e. as spaces for encounter, communication and interaction, are particularly important for heterogeneous urban environments such a spaces of arrival. At the same time, there are many specific challenges that arise from the diversity and also precariousness of those spaces for the use and for benefitting from green spaces by the residents. The debate itself has provided ambivalent evidence (Räuchle & Berding, 2020: 2–3; Elands et al., 2020). Here, an interesting parallel can be observed in comparison with the debate on social difference and diversity and the coping with them in daily practices and living together. This debate, on the one hand, focuses on the potential of urban spaces of arrival (i.e. as enabling spaces for settling, making oneself familiar with the new place and basis for social upward mobility, diversity as chance for the place itself) and on the other hand with the challenges, problems and conflicts of increased heterogeneity (e.g. marginalized spaces, exclusion or the emergence of so-called parallel societies). When looking through this lens, we can clearly see that long-term optimism concerning integrative urban policies has been questioned by existing and growing levels of conflict, intolerance and even violence (Bannister & Kearns, 2013; Valentine, 2013). But it is also inequalities, injustices and precariousness that challenge cohesion, tolerance and a peaceful living together (Amin, 2002; Low, 2013).

Valentine (2013: 8–9) states that contact within a context of social difference does not necessarily results in respect for this difference and that meeting another person is not equitable with meaningful contact or even a positive outcome. Public (green) spaces might be also spaces where prejudices and hostile attitudes towards others might be confirmed or even strengthened through contact. They are perceived by some people as a place of rejection. Valentine underlines that meaningful contact might have a positive effect for more social cohesion but not necessarily for a long time or in a sustainable way. Other studies distinguish between different types of (intercultural) encounter; those include deliberate acknowledgement of the other, i.e. more than a superficial acceptance, passive tolerance up to rejection to a lesser or larger degree (Bannister & Kearns, 2013). Hoekstra and Dahlivk (2017) show for the cases of Vienna and Amsterdam what Granovetter (1973) called "the strength of weak ties": i.e. that even superficial meetings are crucial for the daily life of residents whereas urban policy prioritizes meaningful encounter as a mean to strengthen social cohesion in a diverse urban society.

Wiesemann (2014) ascribes to encounter both affirmative and destabilizing impacts on prejudices and stereotypes towards "others". Moments or actions that affirm prejudices and stereotypes are e.g. "territorial injuries" such as when someone does not step aside or the consideration of someone else with depreciatory views, deliberate ignorance or absence of response e.g. to a greeting. In a similar way, encounter may also destabilize or even counteract prejudices and stereotypes e.g. through "moments of civility" such as response to a greeting, giving information or spontaneous help. Those moments might of course have only a temporary effect or might be perceived as exceptions that do not affect existing prejudices too much (ibid.: 151). Particularly important are so-called "moments of sociability" (Fincher & Iveson, 2008) where predominating differentiations e.g. referring to where someone comes from or how somebody looks like loose importance for the moment/common activity etc. This is for heterogeneous contexts very important since it could have a generally integrating impulse, at best reaching beyond the precise occasion where it happened. Sometimes such moments of sociability have the power to question predominating attitudes produced through mass media or public discourse (Wiesemann, 2014: 174). The same applies to personal differentiations or categorizations that become less important or have to "communicate" with the new impressions that emerged through the social contact and common activities (ibid.: 191).

Social encounter may result in contact and cohesion but also in rejection and conflict – this is what research on contact through encounter and its impacts on cohesion and conflict tell us (e.g. Hewstone & Brown, 1986). It is always a bundle of factors and their interplay that determine and drive whether, when and to what extent encounter develops to be the first or second, or whether the results are ambivalent. Conflicts through encounter and interaction do not play just a negative role. Instead, they operate often also as trigger or catalyst of necessary change. They show shortcomings of co-existence and living together in a heterogeneous neighbourhood/environment. This brings about the chance for negotiation, e.g. of different wants and needs and interest of different groups of people with respect to how to use a green space. In the recent scholarly debate on migration and an internationalizing society, the understanding of productive functions of conflict as trigger for change or indicator of problems that have to be dealt with has become important for the assessment of the quality of integration/inclusiveness. Interestingly, this new knowledge is much in line with older knowledge e.g. from the social conflict theory or theories of radical democracy. Here, an interdisciplinary approach including knowledges from different research strands might be helpful to understand better the complicated and highly ambivalent “grammar” of social contact, encounter, communication and interaction in socially diverse environments.

6 Urban Green Spaces as Areas of Social Experience, Learning and Cooperation

It is what Berding and Kluge (2017: 2) call “spatially or socially based partial publics” or what Amin (2002: 2) called “micro publics” that bring about a higher level of liability. Such specific publics may be less accessible since they are related to certain thresholds to enter them. But within those publics, common interests and rules of mutual understanding may be easier to be communicated. Thus, a higher level of cohesion between the participants may be generated which results in a larger trust in common actions. Amin (ibid.) and Fugmann et al. (2017: 49) suggest those micro publics to be excellent places to negotiate diversity. Partial or micro publics can also take the form of open or green spaces that are not accessible for everyone and gather people with diverse lifeworld backgrounds but with a minimum of shared interests that form the basis of common activities.

Green spaces operate also as spaces of social experience. Here, urban green scholarship provides a rich body of evidence (e.g. Peters et al., 2010; Elands et al., 2020; Cocks & Shackleton, 2020). This literature, among others, makes clear that a consideration of ambivalence and context dependency are indispensable to identify which role an open/green space plays for social cohesion or for different (potential) user groups. It is also crucial to understand that a romantization and celebration of green spaces as solution for many problems does not meet reality (Räuchle & Berding, 2020: 2). The availability and accessibility of green spaces are no solution e.g. for bad housing conditions in the neighbourhood or may mitigate easily challenges such as racist or discriminatory behaviour or the exclusion of others by appropriation (Low, 2013: interactional justice). In heterogeneous urban environments such as urban spaces of arrival, there exists an intersection of marginalization and underprivileged living circumstances that cannot be facilitated or tackled by green regeneration/improvements (alone).

In heterogeneous urban environments, it is also crucial which prerequisites with respect to meet others, coping with difference, speak in front of others etc. people bring into encounters (Räuchle & Berding, 2020: 3). Such capabilities and resources decide on whether encounter is being experienced as beneficial, harmful or threatening. This issue is being often too little considered when encounter, communication and interaction are being organized in heterogeneous environments. Nevertheless, stepwise, it enters debates that deal with the equipment, accessibility, use and social function of urban green spaces (Vierikko et al., 2020; Elands et al., 2018). Planning processes are increasingly based on multicultural experience of cities/

Fig. 22.2 Co-development of park futures in arrival contexts in Leipzig, Germany. (Photos: Haase, A. in 2019)

neighbourhoods, participation including different groups and deliberately include forms of co-development with diverse participation and different knowledges and capacities existing among the residents of heterogeneous areas as transdisciplinary research e.g. in different German cities show (www.kooplab.de, Fig. 22.2).

7 Open Questions and Needs for Further Research

The topic of the role of urban green spaces in heterogeneous environments is a comparatively new topic. Although in the last years, an increasing body of knowledge has been developed, there is still a lot of untouched questions and lack of evidence.

Often, studies differentiate between people with or without migrant status/immigration background. Here, a more intersectional differentiation referring to multiple characteristics of people including education, income, probability of being discriminated etc. would be helpful to better understand the chances, interests, wants and needs but also barriers and constraints of people for accessing and making use of and benefitting from an urban green space. To realize such a more differentiated view, the debates on green space use and on coping with social difference should be brought into a closer communication. Another topic that deserves more attention is the ambivalence of encounter in green spaces, and the factors that determine whether and to what extent encounter may end up in more cohesion or conflict. Conflict itself may be looked at also as a matter of negotiation and as an indicator and catalyst of necessary change as social conflict theory suggests already for a long time. Also here, a stronger interdisciplinary view of urban social, ecological and planning perspectives might represent a fruitful future research avenue.

In the discussion on cooperative open/green space development, perspectives of migrants or the explicit consideration of social difference play a rather second-rank role in the hitherto debate. The same is true for demands for a participation of marginalized or hitherto underrepresented people, not regarding at calls for a needed broader participation that deliberately includes diverse opinions and groups of people, multilingualism and so-called easy language for those who are not familiar e.g. with planning vocabulary. Another largely un-discovered field is the inclusion of diverse knowledges of the use of urban nature, green spaces etc. that migrants or newcomers bring with them to a new place. Little is also known about the existing resources in terms of time, interest, knowledge etc. among people who are under- or not represented in ordinary participation processes but that could be brought into co-development when considered. Here, a relation to justice questions becomes obvious as e.g. Elands et al. (2020: 216) state: "Moreover, it is crucial to consider not just diversity, but also its interaction with equity issues to ensure that benefits are equitably shared and distributed. Equity does not come automatically with urban green engagement but needs to be deliberately included as a target into planning". In the recent debates urban green spaces, justice issues have got increasing attention (Kronenberg et al., 2020; Langemeyer & Conolly, 2020; Pineda-Pinto et al., 2021). While in social sciences, there has developed a debate that looks at the interconnections between diversity/difference and justice, such knowledge still largely waits for being "weaved" into urban green space debates on a larger scale. Justice questions, again, operate often closely together with questions of discrimination and rejection leading to exclusion as a form of injustice. At this point, the urban green space debate even touches the arenas of right-to-the-city or political ecology debates dealing with the power contexts in which urban green spaces, their development, design and use are being incorporated and depending on as well as the struggle that is being fought for equal rights to urban nature under the condition of contested, crowded or overused green spaces.

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Chapter 23
The Link Between Urban Green Space Planning Tools and Distributive, Procedural and Recognition Justice

Helena I. Hanson and Johanna Alkan Olsson

Significant Statement Climate change and an increasing urbanisation create pressure on cities in terms of extreme weather events, deteriorated public health and wellbeing and a loss of biodiversity. Urban green spaces, such as parks and street trees, can help to reduce vulnerability and improve living conditions. Planning tools can support decisions on where, what and how much urban green space to save or implement. If used appropriately, planning tools can capture citizens' needs and foster a more just planning and implementation of urban green spaces. This demands knowledge about the tools, their efficiency and appropriate application, as well as knowledge about the ecosystem and human needs. It also demands adequate technical, time and economic resources, as well as organisational and communication structures that can include citizens in the planning process.

Keywords Urban planning · Green space · Planning tools · Environmental justice · Ecosystem services

1 Introduction

Climate change and urbanisation put pressure on cities in terms of extreme weather events, deteriorated public health and wellbeing as well as loss of biodiversity (UN, 2015). Urban green and blue space (hereafter UGS) can provide many benefits (i.e. ecosystem services (ES)) to people (MEA, 2005), and 'greening' initiatives are considered as an important pathway to develop more sustainable cities (EC, 2015). Within urban planning, there has been an increased interest in greening initiatives, narrated through the uptake of a variety of so-called green space governance concepts (Hanson et al., 2020), including ES (Hansen et al., 2015; Nordin et al., 2017) and nature-based solutions (NBS) (Hanson et al., 2020). This uptake has been paralleled by an increasing attention from both science and practice towards

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UGS planning tools and frameworks (hereafter we only use UGS planning tools) (ranging from simple scoring tools, to infrastructures for big data collection) (Knobel et al., 2019) aiming to facilitate decisions in relation to where, what and how much UGS to preserve or create. Utilizing such UGS planning tools is relevant as researchers have highlighted the citizens' UGS demand and provision (e.g. accessibility and quality of public green space) can be unevenly distributed in relation to socio-economic factors (Hughey et al., 2016; Sister et al., 2010). However, even though UGS planning tools can facilitate the inclusion of UGS in the planning process, they can also have potential implications for justice. This includes the risk that e.g. data availability, economic resources, and knowledge will steer the planning process towards certain types of UGS and/or ES provisioning (Grêt-Regamey et al., 2017; Jacobs et al., 2016; Olsson et al., 2020).

The aim of this study is to understand the link between UGS planning tools and environmental justice in relation to the distribution of UGS and urban ES. We define UGS planning tools as devises used to facilitate the assessment and implementation of UGS in the planning and building process. We use Sweden as a case, focusing on the city of Malmö and its neighbouring municipalities. Swedish municipalities have through the Swedish Planning and Building Act (2010:900) a 'planning monopoly', which gives them right to define its spatial planning unless appealed. The Planning and Building Act ensures that different perspectives are considered, including the interests of different societal groups, through a certain degree of public participation (consultation).

2 Theoretical Approach

The theoretical approach is grounded in the field of environmental justice, which has been described as "the intertwining of environment and social difference" (Walker, 2012, p. 14). Initially, environmental justice research focused on health impacts, caused by waste and industrial sites, on low-income and minority people (Downey & Hawkins, 2008; Schlosberg, 2004). Today, environmental justice research has a broader approach also including an unequal distribution of UGS and ES demand and provision (Wolch et al., 2014; Wüstemann et al., 2017).

Tools and frameworks used to assess the planning context can facilitate a more equal distribution of resources/ES by identifying areas/societal groups lacking them. However, imprudent assessments can render justice issues, for instance, when focussing on assessing nature only, potential social consequences may be overlooked. To analyse which potential justice issues may arise when tools are introduced in UGS planning, we adopted a three-dimensional justice structure, developed by, e.g., Alexander and Ruderman (1987) and Schlosberg (2004), and contextualized in relation to green space by, e.g., Low (2013) and Ernstson (2013). The first dimension, *distributive justice*, concerns the benefits or incurred costs and risks; whether material or non-material, objective or subjective, in a society (Walker, 2012). In relation to UGS planning, this justice dimension concerns the distribution of UGS and ES (quantity and quality) in relation to different societal groups (especially those categorised vulnerable). The second dimension, *procedural justice* concerns the fairness and inclusiveness of the processes used by those in power to reach specific outcomes or decisions (Thibaut & Walker, 1975; Tyler, 1988). In relation to UGS planning, this justice dimension concerns how different stakeholders are included in decision-making processes on green space development. The third dimension, *recognition justice*, concerns the recognition given to different social and cultural values or identities, and to the societal groups who hold them, and has both a normative and a psychological dimension (Alexander & Lara, 1996; Honneth, 2004). In relation to UGS planning, this dimension concerns the acknowledgement of UGS and ES demands from all societal groups in the UGS planning process.

3 Methods

To answer our research aim, we collected data from semi-structured interviews and stakeholder workshops with actors involved in UGS planning and implementation, in Sweden. The data were collected over a time of 3 years from 2017 to 2020. Some stakeholders were both interviewees and workshop participants. Some stakeholders participated in multiple workshops. In total, the study included data from 32 individual stakeholders.

3.1 Semi-structured Interviews

Semi-structured interviews (Bryman, 2016) were conducted with the aim to gain more insight into the use of UGS planning tools in urban development projects. Twelve stakeholders were interviewed, representing three different departments in the city of Malmö (7), two consultancy firms (2), one construction company (1) and the National Board of Housing and Building (2). The interviews followed an interview guide with four broad themes: (i) which tools and frameworks are used, (ii) and when in the planning process, (iii) what works and doesn't work well and (iv) what is the future role of tools in urban development. Follow-up questions were employed to clarify or dig deeper into specific issues. The interviews were conducted in September and October 2018, and lasted about 60 min each. Most interviews were recorded and transcribed. For those not recorded, detailed notes were taken and compiled directly afterwards.

3.2 Workshops

In addition to the interviews, data were collected from four workshops, covering four different research projects, all within the frame of UGS planning. The first workshop (December 2017) focused on urban water retention modelling and the use of blue-green solutions. Ten stakeholders participated, representing two municipalities, the local water and sewage service company and two consultancy firms. The second workshop (April 2018) focused on UGS planning tools used in urban planning in Sweden. Seven stakeholders participated, representing five municipalities and one consultancy firm. The third workshop (September 2018) focused on identifying indicators of UGS planning tools. Eleven stakeholders participated, representing the city of Malmö, five consultancy firms, one construction company, and the Swedish Geological Institute. The fourth workshop (November 2020) focused on the need for UGS planning tools in urban planning. Five stakeholders participated, representing four municipalities and the Region of Skåne. From each workshop detailed notes were taken.

3.3 Data Analysis

Interview transcriptions and detailed workshop notes were coded in relation to the research aim. We first classified the mentioned UGS planning tools into three broad groups, based on our previous understanding of urban planning. (1) Process tools – tools used to structure and facilitate the municipal planning process. This included tools used within the municipal organisation, and tools used to engage with external actors (e.g. construction companies, citizens etc.). (2) Strategic plans – UGS/ES provision and demand analysis used as guidance in the planning process. (3) Counting tools – tools that provide numbers/values on how much and what type of UGS to implement. The tools presented in this chapter should be seen as examples of UGS planning tools used in a Swedish context, and not an exhaustive list. As a second step, we sorted the comments about the tools and analysed these findings in relation to the three dimensions of environmental justice: distributive, procedural and recognition justice. Based on this, we identified a number of key issues that may either hamper or foster a just distribution of UGS and ES. In the result and discussion section, we present and reflect on these issues.

4 Results and Discussion

In the first section, we present the identified UGS planning tools used in municipal planning and building processes. Where necessary, we briefly explain the tool. In the second section, we use the three-dimensional justice framework and discuss how

Table 23.1 A brief description of how the three types of UGS planning tools may facilitate or hamper a just UGS provision in relation to the three-dimensional justice perspectives

UGS planning tools	Three-dimensional justice[a]		
	Distributive	Procedural	Recognition
Process tools	(+) Provide input on UGS demand and balance implications across societal groups (−) Time-consuming and costly, potential influence of individual champions	(+) Facilitate stakeholder interactions to improve participation (−) Lack of knowledge and lack of organisational structures for participation	(+) Facilitate stakeholder interactions to capture diverse values (−) Lack of knowledge and organisational and communication structures
Strategic plans	(+) Provide analysis of UGS provision and demand across geographical and administrative levels (−) Highly dependent on data and other resources	(+) Facilitate citizen engagement in urban planning (−) Time and biased towards quantitative values, lack of knowledge between stakeholders	(+) Provides publicly available maps on UGS provision and demand (−) Biased towards quantitative values
Counting tools	(+) Provide values on how much and which type of UGS to implement (−) Lack of complexity, focus on smaller scales	(+) Provide easy to overview basis for participatory interaction (−) Biased towards quantitative values, lack of knowledge about the tool, lack of transparency	(+) Facilitate municipal – developer interactions (−) Risk favouring easy-to-implement UGS structures, without acknowledging local and societal needs

[a]For each 'UGS planning tool – justice couple' a brief note is given about how the tool may contribute to improved justice within the dimension (+), and which potential justice issue it may lead to (−)

UGS planning tools may facilitate or hamper a just UGS and urban ES provision by providing examples (based on the empirical data) (Table 23.1).

4.1 Tools Used in Urban Green Space Planning

The results of the study demonstrate that Swedish municipalities and businesses use a variety of UGS planning tools. The tools are used at different stages in the planning and building process and are grounded in different UGS planning ideas and principles (ES, environmental compensation, sustainable development etc.).

A majority of the respondents mentioned various types of *process tools*, including structures for, cross-departmental and municipal collaboration, municipal-developed checklists, guidelines used in the planning process, and lists of best practices. Also, present were formalised dialogue structures used to facilitate interactions between municipalities and construction companies, which included participatory approaches to explore the implications of new plans on the quality and quantity of UGS. Some actors also mentioned tools used to improve and facilitate stakeholder engagement, such as online GIS based-planning tools (e.g. CityPlanner) and surveys. These tools were mainly mentioned by municipalities, except for digital tools developed to facilitate stakeholder dialogues, which were mentioned by both municipalities and consultancy firms. Another type of tools used in municipal planning is *strategic plans* (e.g. the comprehensive plan and green-, tree-, biodiversity conservation and climate adaptation plans) used to guide the urban development process and to facilitate the development of detailed development plans. Strategic plans usually include different types of large-scale provision and demand analysis of e.g. the number of citizens within a certain distance to a park, the amount of green space per capita, or the capability to handle excess storm-water. These plans also include maps focusing on the spatial distribution of different types of UGS (trees, parks, urban gardens etc.). Strategic plans are developed by the municipalities, but consultancy firms are often involved in the development. The third type of tools, used by both municipalities and consultancy firms, is *counting tools*, used to provide fixed values on how much and what types of UGS to implement, often within a detailed development plan or a building plot. An example of such a tool, used by municipalities, is the mitigation hierarchy used to restore/compensate UGS/biodiversity/ES in relation to exploitation. Another example is the Biotope Area Factor, developed in Berlin, Germany in 1994, used to set a fixed amount of green space to be implemented in a given detailed development plan. A last example is, different types of ‘green point systems’ that summarize green space/ES loss and gains due to development, that are used in land allocation competitions between developers in order to improve greening and sustainability outcomes. Examples of counting tools used by developers and consultancy firms include the BREEM sustainability assessment method used to certify development projects and buildings, and different types of ES and biodiversity assessment methods developed by the individual consultancy firms. The Swedish housing company Riksbyggen point system (the ‘ecosystem service tool’) was also mentioned, which is used to balance the negative impacts on ES provision caused by exploitation. In relation to counting tools, several respondents mentioned interactions and involvements with transdisciplinary (research) projects, aiming at developing new ES/NBS mapping and assessment tools. For example, the ‘Urban Nature Navigator’ developed by the Horizon 2020 project NATURVATION, the ‘Eko-geokalkyl’ developed by the Swedish Geotechnical Institute, the Biotope Area Factor developed for public green space by the C/O City association and the ‘Alnarp tree model’ developed in a series of research projects conducted at the Swedish University of Agricultural Science.

4.2 Environmental Justice Issues

4.2.1 Distributive Justice

Distributive justice issues relate to the distribution of benefits or incurred costs and risks in the society. *Strategic plans* include UGS assessments and maps, but our findings from both workshops and interviews suggest that data availability, knowledge about how to perform an ES assessment, technical issues and economic and time resources influence the content and the depth of the plan. UGS analyses are often based on Geographical Information System (GIS) data, providing data on, for example, proximity and accessibility to UGS. However, to assess distributional differences, UGS analysis also needs to consider accessibility, quantity and quality across different socio-economic as well as vulnerable groups (e.g., minorities, children, teenagers, elderly as well as disabled persons) (Kabisch & Haase, 2014; Rigolon, 2017), which are more data and resource consuming assessments. Moreover, many *counting tools* identified in our study target green space development of smaller areas (e.g. detailed development plans or building plots), with limited acknowledgement of surrounding areas. However, any development will most likely have consequences outside a building plot. Such consequences could for instance be increased pressure on neighbouring green spaces or reduced access to green space due to road or building constructions. Greening as a part of urban regeneration projects can also spur gentrification processes, where the original population is replaced by more affluent inhabitants (Checker, 2011; Quastel, 2009). To counteract distributive injustice, we argue that there is a need to assess and compare the needs of different citizens' groups. However, such assessments can easily become time-consuming and costly, as the data must cover the real needs and not only the presumed needs of an average citizen. One potential pathway is to work with process tools. Our empirical data suggest that municipalities to some extent use of different types or *process tools*, including dialogues with developers, to study plan implications in relation to sociocultural factors, as well as online GIS tools that facilitate citizens' input in urban development projects. However, the use of process tools seems to rely on the engagement of individual champions that are willing/eager to test new methods. Such unstructured, non-mainstreamed work will most likely influence the result of the process, as it opens up for sincere influence by the individual civil servant.

4.2.2 Procedural Justice

Procedural justice issues relate to discrepancies regarding who is and who is not included in the decision-making process. The development of *strategic plans*, facilitates citizen engagement as it enables assessments across geographical and administrative levels, which opens up for citizens' comments on how the plan can be improved to better meet personal or community needs. However, in relation to stakeholder engagement there are several procedural justice issues. One relates to the problem of getting stakeholder input at the 'right stage'; i.e. at a stage where it is easier/possible to consider the input in the decision-making process. Another to the problem of reaching a diverse mix of stakeholders. From the interviews/workshops, it is clear that individual planners' or project groups' are testing new approaches to engage with stakeholders. Examples include both the use of online GIS-based planning tools aiming to facilitate citizen's input on early planning stages, and developer dialogues. Such *process tools* have the potential to be an important support for more inclusive planning processes, even though previous research have shown that there is a lack of municipal understanding and organisational structures on how to organise participation (Olsson et al., 2020; Wamsler et al., 2019), that goes beyond "technocratic compromises" (Checker, 2011). Another procedural justice issue that concerns both *strategic plans* and *counting tools* relate to methodological constraints, which may influence which stakeholders/values that are included in decision-making processes, and which are not. Required tool input data are usually quantitative, or a combination of quantitative or qualitative data, which means that those that work with, or demand values/services assessed by qualitative methods (for example cultural ES), risk to be excluded or under-prioritized in decision making processes (Grêt-Regamey et al., 2017). Another methodological constrain relates to the understanding of the tool and who has knowledge about the methodological approach, and who has not. Indeed, the more complex a tool is, the higher is the risk that only a few will actually understand it, and hence able to identify and question potentially biased or erroneous results. This is especially the case for tools related to water modelling, which are mainly used by consultancy firms performing assessments for municipalities or urban developers in relation to *strategic plans*. For *counting tools* developed by consultancy firms, the problem may not necessarily be solely related to the complexity of the tool, but also to a lack of transparency (unwillingness to share the underlying assumptions and logic of the tool) due to business interests, making it difficult to question the results. A reflection that can be made in relation to the willingness to test new ideas is that it could increase the risk that *counting tool* developers with good connections and negotiation skills may disproportionately influence the outcomes of the planning processes, albeit within the public procurement rules. One of the interviewed planners with a long experience in urban planning argued that "they are just tools"; however, a planner with less experience or a planner in a municipality with less knowledge and lack of economic power may become compromised by tool developers.

4.2.3 Recognition Justice

Recognition justice issues relate to whose needs, rights and preferences that are included, or excluded, which is governed by internal and external power relations, as well as data, knowledge and resource availability (economic, personal, time). The study respondents' indicated that different types of *process tools* are used to facilitate interactions between stakeholders involved in and/or affected by the planning process, increasing the potential that multiple perspective are considered in the decision-making process. Using *strategic plans* is another pathway to better include multiple perspectives over time as it contributes to a common understanding about whose needs and perspectives that are captured in the analysis. However, the increasing interest in *counting tools*, pose a risk that UGS planning becomes more in terms of as a 'ticking the nature box', with little consideration of creating a diverse

UGS. Many of the respondents mentioned simple *counting tools* focusing on meeting fixed green targets (e.g. the Green Biotope Factor) and argued that these tools are easy to use in the practical planning context and in dialogues with developers. These tools, however, risk favouring simpler UGS structures that are 'easy-to implement' and/or economically favourable (in the developer's point of view) over UGS structures that claims more surface or/and cost more (e.g. larger inner yards), but with higher qualities both for both nature and people living in the area. To reduce the risk of producing new development areas with a deficiency of qualitative UGS, any results delivered by a tool need to be interpreted in relation to local and societal needs. Nevertheless, the use of *counting tools* could also help to improve the planning process as it provides values/numbers that can help to facilitate discussions between, for example, planners and developers.

5 Conclusion

UGS planning tools come in a great diversity. Some may support distributive, procedural and recognition justice in relation to UGS planning and implementation, others may not. Process tools can facilitate stakeholder interactions to improve participation and capture plurality, but that implies organisational and communication structures that can handle the work, and capture the values. Strategic plans provide UGS and ES analysis across geographical and administrative level, but their quality depends on data availability knowledge, and capacity to make the assessments. Counting tools may facilitate dialogues with developers by providing value on how much green space to implement, but can also lead to UGS planning mainly focusing on fixed-targets overlooking local and societal needs. We argue that UGS planning tools can help to guide a just, diverse and sustainable UGS planning and implementation. However, for this to happen, we need data, knowledge about nature (ecosystem) and its processes, time and economic resources, as well as organisational structures enabling long-term stakeholder interactions.

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Part IV
Coastal-Marine Systems

Chapter 24
Can Local Knowledge of Small-Scale Fishers Be Used to Monitor and Assess Changes in Marine Ecosystems in a European Context?

Cristina Piñeiro-Corbeira, Sara Barrientos, Rodolfo Barreiro, Shankar Aswani, José J. Pascual-Fernández, and Raquel De la Cruz-Modino

Significance Statement In the last decades, many coastal areas have observed dramatic changes in marine ecosystems, due to anthropogenic and environmental alterations. The general absence of long-term data sets in the marine environment and, more specifically, on benthic and demersal communities represents a severe issue for management and conservation. We propose to incorporate the small-scale fishers' knowledge and science for better policy recommendations, both in terms of fisheries optimization and resource conservation. Based on two different cases of study with diverse ecosystems, we explore the combination of quantitative and qualitative tools, and participative techniques used to incorporate fishers' local ecological knowledge. The results highlight fishers' capacity to identify coastal and marine landscapes resources and changes, reinforcing and complementing the scientific assessment.

Keywords Fisher's knowledge · Small-scale fisheries · Participatory mapping · Marine recovery

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1 Introduction

In recent decades there has been a push to use Local Ecological Knowledge (LEK hereafter) in the design and participatory monitoring and management of Marine protected Areas (MPAs hereafter) worldwide. While many of these studies have occurred in indigenous areas or small coastal communities in developing nations (e. g. Silvano & Begossi, 2012; Mellado et al., 2014), there is a growing effort to include LEK in the design of MPA areas and their monitoring and management in developing nations too (e. g. Scholz et al., 2004; Davies et al., 2018). In the context of Europe, these efforts are still limited, and a few proposals have incorporated LEK into MPA design and monitoring (Burns et al., 2020), despite there being an increasing interest to enhance local participation and compliance (Higgins et al., 2008). This investigation expands on these efforts by examining the use of LEK to monitor and manage European MPAs. In this regard, we consider the incorporation of small-scale fishers' LEK as a value-added for coastal fisheries research, monitoring, and management with the assumption that fishers' LEK can be an essential component in collaborative strategies and community-based management schemes (Gerhardinger et al., 2009), particularly in the monitoring of short and long-term changes in MPAs in Spain. In this study, we explore the fishers' perception of abundance for different species and fishers' behavior and effort displacement in two different contexts where the severe reduction of different benthic populations is being studied due to natural and anthropogenic changes. In the first case, after a volcano eruption affecting an MPA, we were interested in detecting any fishing displacement, leading to an increase in operational costs. Considering the ecosystem-services provided by this MPA (Roncin et al., 2008), we also wanted to know the level of fishing usage of the MPA and the main species target around it and associated LEK. In the second case, we explore the potential of fishers' knowledge to assess long-term-changes in crucial marine habitats. Kelp forests are essential to maintaining the local fleet's small-scale fisheries around the MPA, but there is a lack of information about kelp forest changes in this MPA and areas nearby. Here, we looked for their historical distribution and regression and their associated central fisheries.

1.1 Case of Study Characterization

This study was carried out in two MPAs in Spain: (1) The Marine Reserve (MR hereafter) of Punta de la Restinga and Sea of Calms (El Hierro, Canary Islands) and (2) the Islas Atlánticas de Galicia National Park (IANP hereafter). There are several MPA designations in Spain, including MR, National Park (NP hereafter), Protected Biotopes, and Fishing Reserves, among others with different stakeholder involvement degrees (De la Cruz Modino & Pascual-Fernández, 2013). MPAs also be established for various purposes (Jentoft et al., 2011), including fishing sustainability and allowing for some forms of small-scale fisheries within the protected areas. In this regard, in some MPAs, small-scale fishers participate in the MPAs management and maintenance through their *cofradías*[1] or fisher organisations (Bavinck et al., 2015) with the State and regional officials.

The case of Punta de la Restinga and Sea of Calms MR is an example of how small-scale fishers may participate in the design and monitoring/management of MPAs' from *step zero* (Jentoft et al., 2012), thus increasing their governability as well as the MR's role in stakeholder's synergy building and fostering community development (Pascual-Fernández et al., 2018). The Sea of Calms is historically the main fishing area for the small-scale fishers from La Restinga village, and the MR implementation helped protect this sensitive area where small-local-fishing boats can fish year-round (De la Cruz Modino, 2012). In October 2011, the submarine volcano *Tagoro* erupted on El Hierro Island's Southwest coast, just in La Restinga coast – see Fig. 24.1. The Sea of Calms was heavily affected, and fishing activities were completely officially banned for almost a year. Since then, only a few studies have researched the role of the MR in the recovery, except by Mendoza et al. (2020), who argued that the no-take zone showed more resilience than the buffer and fished zones in the MR. This research suggests that no-take zones are crucial in the recovery process after catastrophic events (Mendoza et al., 2020).

A possible displacement of the fishing effort and changes in small-scale fishers' behavior could indicate the volcano's effects on the benthic communities, and the fishing concentration efforts around the MR may support Mendoza's conclusions. In this regard, a mapping process was initiated with fishermen's collaboration, under the premise that local knowledge was accurate enough and possibly complementary to scientific knowledge, as daily fishers' experience updates it. Participatory mapping (Aswani & Lauer, 2006) was not only considered as an affordable tool for assessing the fisheries recovery because it provides practical information on the status of fishing areas after the volcano's eruption, but also because it can help to evaluate the role of local monitoring of the MPA in this context. This technique was also chosen to further the involvement of fishers and other local stakeholders in the area's different projects after the eruption.

In the other case study, similarly Galician *cofradía*s have historically participated in the dialogue between fishers, scientists, and decision-makers, facing important community initiatives for guaranteeing fishing activity, resource management, and the viability of the small-scale fishery in the long term (Frangoudes et al., 2008; Perez de Oliveira, 2013). Kelp forests are one of the main habitats in temperate coastal ecosystems that provide essential ecological and socio-economic ecosystem services to local small-scale fisheries. However, their decline has been reported worldwide in the last decades (Vergés & Campbell, 2020); NW Spain (Barrientos

[1] *Cofradías* are non-profit public corporations, the most important fisher organizations in Spain, which represent this sector and take roles of consultation and cooperation for the administration, while undertaking economic, administrative, and commercial management tasks (Bavinck et al., 2015; Pascual-Fernández, 1999). They have played an important role in the implementation of Marine Reserves in Spain.

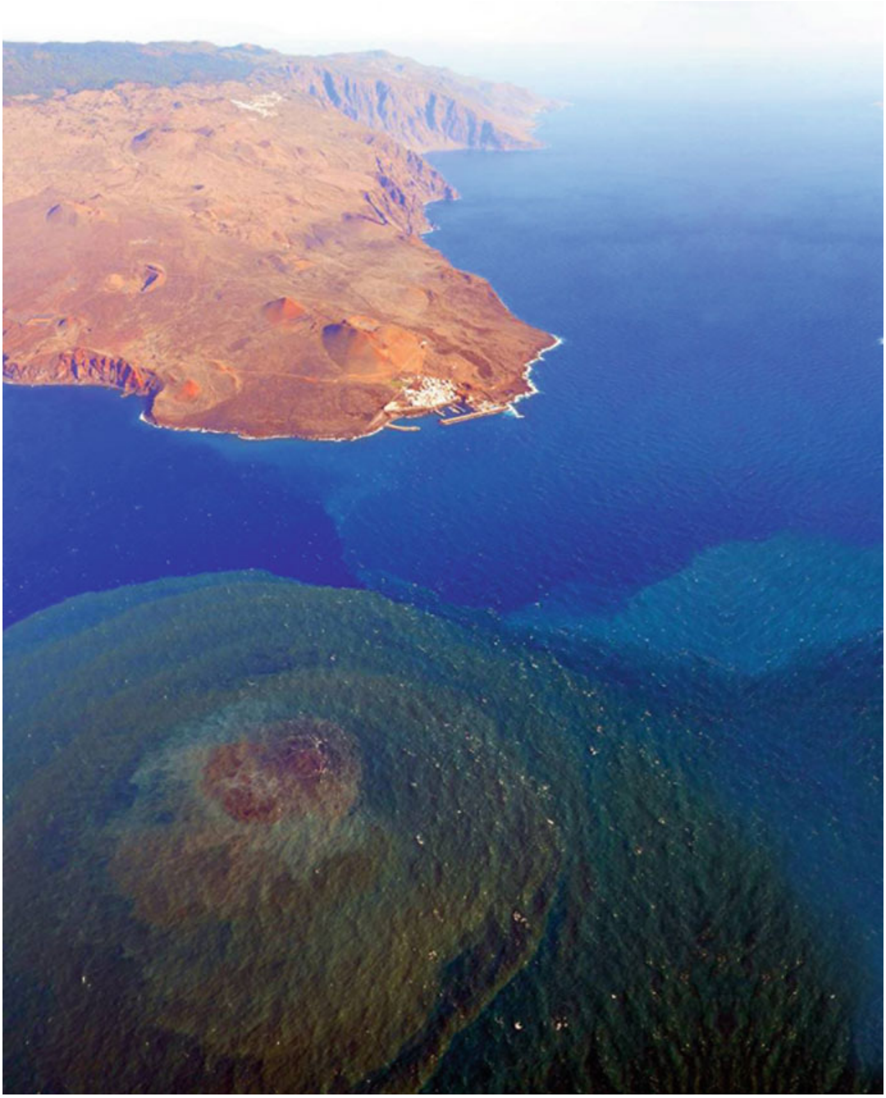

Fig. 24.1 Tagoro volcano eruption in La Restinga coast, 2011. (Photo: Antonio Márquez, Instituto Volcanológico de Canarias (INVOLCAN))

et al., 2020). In the case of the IANP, kelp forests[2] have disappeared in recent decades for causes still unclear, although recent evidence suggests that their failure

[2] The main foundation species of kelp forest in NW Spain are *Laminaria ochroleuca* and *Laminaria hyperborea* (Pérez-Ruzafa et al., 2003).

to recover is possibly due to increasing herbivory pressure.[3] The consequences of the loss of these kelp forests for coastal ecosystem services have remained unassessed, and one of the significant challenges of any assessment is the lack of long-term data sets. In this regard, we assumed in this study that fishers often know far more about the locations of critical habitats and the distribution of marine resources than scientists do (Johannes et al., 2000). Therefore, older fishers and seaweed harvesters are an asset to map past and present distributions of kelp forests, the central fisheries linked with this habitat, and any displacement of fisheries linked to the disappearance of kelp.

In both contexts, we assumed that stakeholder involvement is a source of useful information for scientists and decision-makers and considered community-based management's role in strengthening conservation and management initiatives. Small-scale fishers' knowledge of seasonal variations in marine fish behavior and movements, marine habitat composition changes, and stock assessment (Brown et al., 2018; Johannes et al., 2000; Teixeira et al., 2013) can potentially improve marine governance and monitoring in the face of environmental uncertainty. Furthermore, how this uncertainty is handled "with the people" can influence the perception that local people share (Chuenpagdee et al., 2020; Jentoft et al., 2010) in marine governance and monitoring initiatives, besides potentially increasing their compliance with the norms if these are the result of rules they have collaborated to develop. In sum, we consider that small-scale fishers' collaboration and short- and long-term environmental monitoring are essential for studying environmental change and marine resource recovery after environmental disturbances.

2 Methods

Between 2018 and 2020, a multidisciplinary research team researched El Hierro and Galicia (see Fig. 24.2) within the framework of various collaborative and local stakeholder-centered research projects. Most of the Spanish small-scale fisheries fleets are in Galicia (57.37%), Andalucía (12.85%), and the Canary Islands (9.88%) (Pascual-Fernández et al., 2020a, b). In El Hierro, fieldwork was mainly conducted in La Restinga's population, the main fishing village, and the home of the only *cofradía* on the island. Throughout the year, fishers use the same gear and boats to combine benthic and demersal fisheries, e.g., parrotfish (*Sparisoma cretense*) and alfonsino (*Beryx splendens*), with pelagic oceanic fisheries, mainly tuna.

In the case of the IANP in Galicia, fishing is mostly conducted by fishers from three *cofradías* (Vigo, Cangas, Baiona) located in Ría de Vigo, the southernmost ría

[3] The reasons for this phenomenon are currently being studied within the framework of the project HERBIKELP financially supported by Biodiversity Foundation of the Ministry for Ecological Transition and Demographic Challenge (Spain) to 2021, and results have published during 2022 (Barrientos et al. 2022a, b).

Fig. 24.2 Study areas around the two North Atlantic Spanish MPAs

of Galicia, as well as by fishers from another *cofradía* further away (Bueu; Ría de Pontevedra). For various logistical reasons, only fishers from Cangas participated[4] in this research, and these are stakeholders who usually fish within the IANP year-round, trapping several fish and shellfish species on the seaweed-beds with small traps. Spider crab (*Maja brachydactyla*), octopus (*Octopus vulgaris*), and velvet swimming crab (*Necora puber*) are the most profitable fisheries of the area, being Galicia the most popular region in Spain in terms of octopuses' landings (Pascual-Fernández et al. 2020a, b).

In both case studies, the first step was a mapping exercise with key informants, chosen by their relation to the fishing area and the MPA, and this led to the formulation of general maps representing the seascape of each area – see an example in Fig. 24.5. Specifically, semi-structured *face-to-face* interviews were held in El Hierro with retired fishers and MR employees involved in surveillance tasks. In Galicia, local scientists, and divers with knowledge of the kelp areas and who had been working around the IANP for a long time were interviewed. A second interview-phase was carried out from a non-probabilistic sampling approach, combining semi-structured *face-to-face* interviews on a written questionnaire completed

[4] At this stage, we only have few interviews, and from one *cofradía* due to the COVID pandemic, thus these are preliminary results, and more interviews are expected.

by the interviewer and a draft-mapping to be drawn by each participant. Each interview (0.45–1.5 h) started with an introduction to the topic, followed by a nautical chart orientation.

In La Restinga, we wanted to know if fishers had returned to their traditional grounds, if they fished in the same way, and how they perceived the Sea of Calms' status five years after the total fishing ban; so, questions were divided into four different sections in the questionnaire. The first part included basic questions about the fishing productive unit organization (e.g., number of boats and crew) and the characteristics of their main activities (e.g., central fisheries and fishing traps, fishing distance, and depth-range). The second part included questions about the level of use of the MR, with inquiries about the time of fishing in the buffer zone and fisheries associated with the MR, among others. A third part comprised the main operational cost of the general fishing activity, and finally, the questionnaire included some questions about changes suffered after the volcano's eruption and the fishers' perception about the level of fishing recovery. The questionnaire was useful to obtain additional information about fishers' beliefs about the MR's role in this process. In this study area, we identified 25 small-scale fishing productive units (Pascual-Fernández, 1991) working regularly and authorized to fish inside the MR. Considering some differences among the fishing productive units (e.g., fishing experience, boat length, and crew size), we tried to cover different profiles choosing the interviewers with the help of the *cofradía* and its President. Finally, all participants ($n = 13$) were asked to mark on the map the areas where they regularly fished, considering their main target species.

In Galicia, we wanted to detect long-term changes in kelp forest areas and fisheries associated with this habitat using a questionnaire, which was also divided into different sections. The first part included basic questions about Cangas fishermen's main fishing activity, identifying if this activity included seaweed harvesting and, in the case of just fishing, if the activity was carried out in kelp forest areas. A second part included questions about their general small-scale fishing activity and target species on kelp forests, changes detected in the kelp forests (both on target species and kelps), their perception about these changes, and how changes had affected their activity. Specifically, fishers were asked about the presence and increase of some fish species (*Sarpa salpa*) that may be responsible for the *herbivorism* pressure on kelps. Finally, we asked about the specific fishing areas in both National Park and inner Ría de Vigo, target species, and the presence/absence of kelp forest in those areas. The latter are those areas being studied as part of the HERBIKELP project.

In Cangas, participants ($n = 10$) were asked to mark on the map the areas where they fished, the location of kelp forests, and sites where kelp have disappeared. The *cofradía* had a critical facilitating role in identifying the most experienced fishers that usually work on kelp forest areas. Two fishing units that harvest seaweeds (*Laminaria ochroleuca* and *L. hyperborea*) in Ría de Vigo were extensively interviewed. Besides, small-scale fishers ($n = 8$) who harvest target species associated with these kelp forests in Ría de Vigo and IANP were likewise interviewed.

The purposive sampling of fishers and local users at each area seemed adequate to generate a map incorporating LEK with the help of members of each *cofradía*. In both case studies, a nautical chart 1:42000-scale of the study area was provided to participants and fine-tipped colored pens to mark local information regarding the change in marine ecosystems, pictures, and bathymetric maps. Finally, additional actions were performed such as boat trips with fishers along the drawn coast in La Restinga, visiting different fishing areas and critical grounds along the Sea of Calms, and diving surveys to assess the status of kelp forest areas within and outside the IANP in Galicia (Ría de Vigo).

Map produced by fishers (see Fig. 24.3) and information provided during the questionnaire-led interviews were digitized and georeferenced into a GIS using a polygon, line, or point shape files as needed with the help of QGIS 3.16-Hannover. Digitized LEK maps were combined into a single map to visualize similarities and differences in participants' spatial information. Concerning La Restinga fishing areas, a final map with an amalgamation of the most frequently occurring classifications through the union of individual LEK maps followed by a count of individual data points where the overlapping layers intersected was made. Key informants and stakeholders reviewed final maps to ensure that all information had been correctly digitized.

3 Results

3.1 Monitoring the Small-Scale Fisheries Areas and Fishers' Behavior After a Submarine Volcano Eruption

From the information gathered jointly with fishers, we produced a set of maps of La Restinga and the Sea of Calms representing the main small-scale fishing areas and fishing grounds, taking into consideration the combination of multiple fisheries, the transition from inshore to deep-water fisheries in the studied area, and the differences within the local small-scale fishing group. Maps show how fishers have come back to their main fishing area around the MR and the Sea of Calms and distribute various small-scale fisheries around the MR and the volcano eruption area, including their traditional fisheries (see Fig. 24.4). According to the questionnaire results, fishers interviewed recognized hand-line fishing gear usage in general (97.7%). After the submarine eruption, most fishers affirmed that the MR and the temporary fishing closure helped recover the fisheries, mainly parrotfish (*Sparisoma cretens*e). This map also highlights the diversity of the small-scale fishing activities concentrated on the MR's buffer zones, on the edges of the no-take zone, and in the shallowest areas. Besides, Fig. 24.4 reflects the concentration of the shrimp traps around the volcano. This fishery is in the same area where it was conducted before the catastrophe, revealing the fishing usage recovery level in the area closest to the eruption, even though fishers who fish for shrimp talked about some bottom instability in the area.

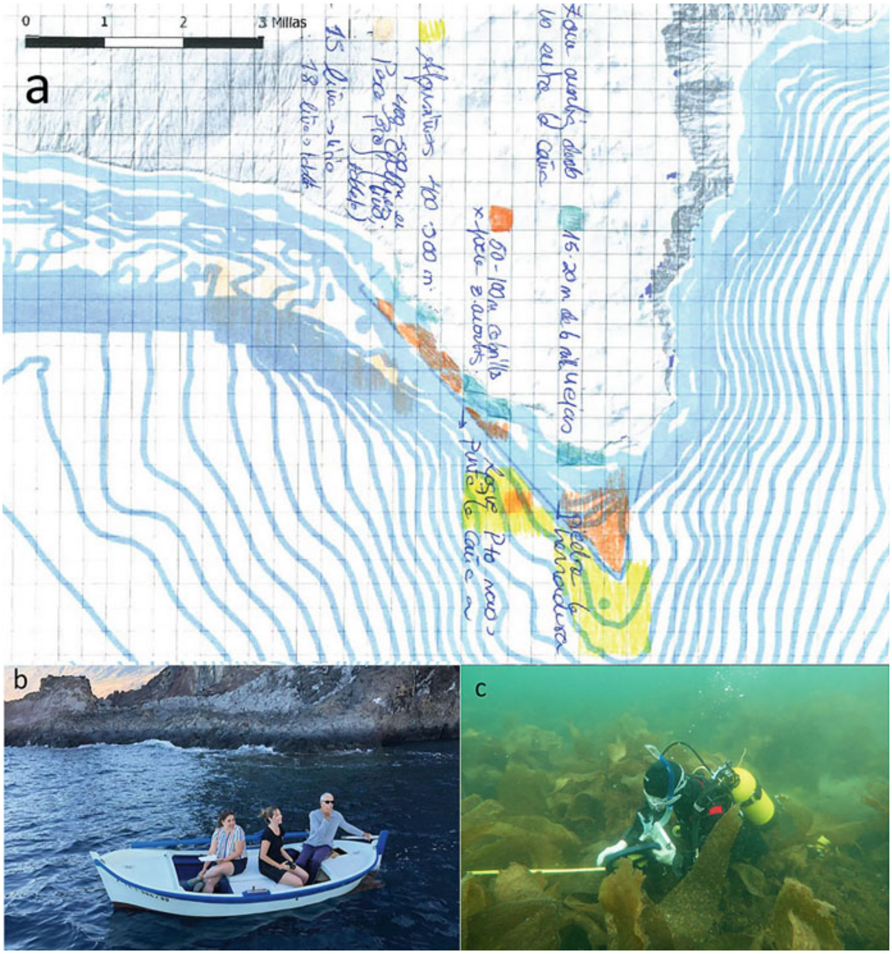

Fig. 24.3 Example of participatory maps results (**a**) and complementary activities carried out in El Hierro (**b**) and Galicia (**c**). (Source: Authors)

Finally, Fig. 24.5 compares fishing strategies for small-scale fishers using boats <10 meters in length and between fishers with wildly different experience levels. These maps revealed essential differences in fishers' behavior, preferences, and ability to access the various fishing grounds, linked to their experience and ecological knowledge, and not by the volcano eruption effects. We found that the most experienced fishers (e.g., boat 3, 6, 5, 9 in Fig. 24.5) could access far away fishing grounds, even when fishing alone in small boats. These experienced and old fishermen were specialized in costly but profitable fisheries such as the blacktail scomber (*Serranus atricauda*) and fisheries over 300 and 700 meters and more in-depth, as alfonsino (*Beryx decadactylus*), stout beardfish (*Polymixia nobilis*),

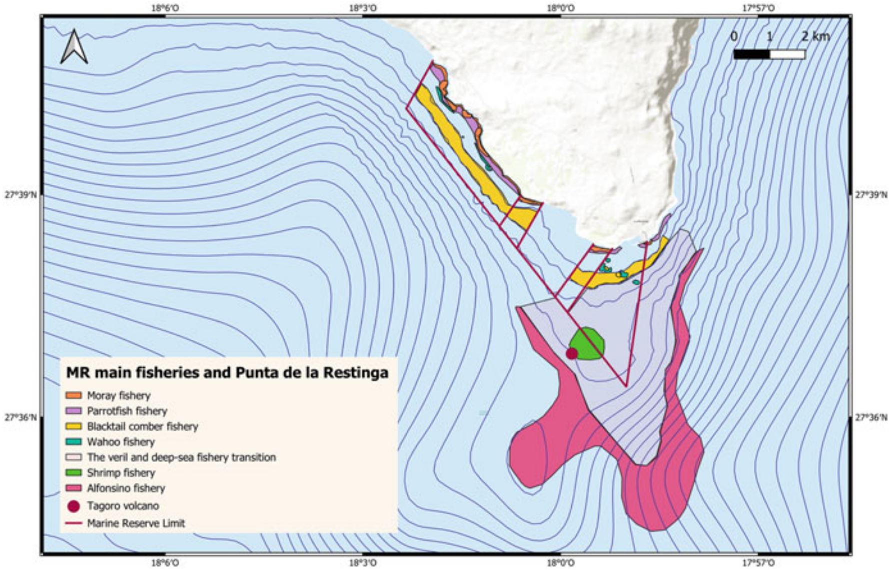

Fig. 24.4 MR main fisheries at Punta de La Restinga

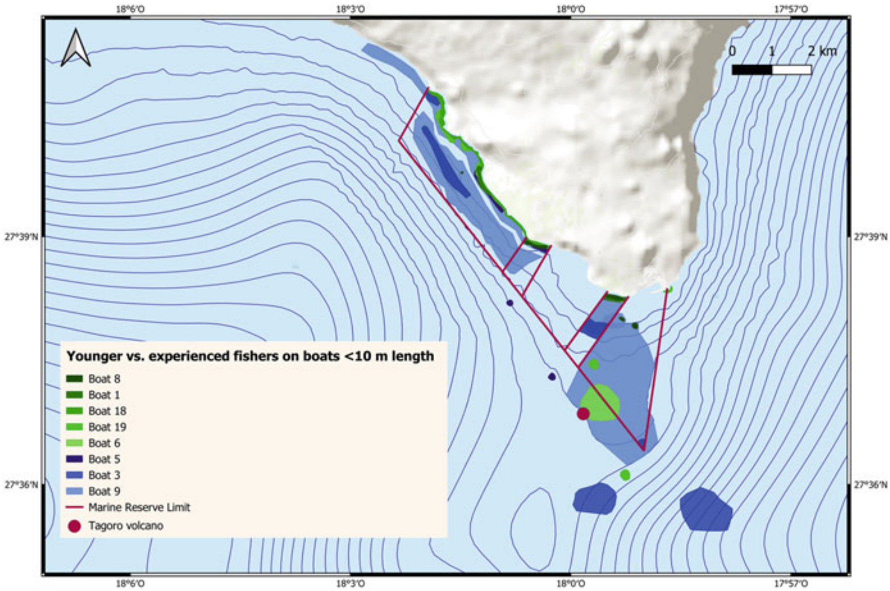

Fig. 24.5 Younger vs. experienced fishers on boats <10 m length at La Restinga fishing village

and oilfish (*Ruvettus pretiosus*) among other targeted species. Variability in LEK was high between experienced and younger fishers, and the inclusion of younger fishers without adequate knowledge may influence fishing strategies around the Sea of Calms. Maps revealed that less experienced fishers (e.g., boats 1 and 8 in Fig. 24.5) might choose simple, effective, low-cost, and practical solutions and strategies to reduce uncertainty by concentrating their fishing efforts on benthic communities closer to shore and the MR.

3.2 Integrating Fisher Folk Knowledge to Assess Kelp Forest Loss

In Galicia, data obtained in this first collaborative-study with small-scale fishers in Ría de Vigo-IANP allowed the construction of an initial set of maps showing the main areas where kelp forests have disappeared and where they are still present (Fig. 24.6), as the most relevant fisheries linked to these habitats (Fig. 24.7).

All interviewed fishers agreed that the species *Laminaria ochroleuca* and *L. hyperborea* have disappeared in recent decades, and most of them pointed out their loss in the coastline of the IANP and the outermost areas of Ría de Vigo. At the same time, all agreed that kelp forests are still present inside the Ría de Vigo and some IANP areas. Working with local fishers, we were able to identify where kelp forests are still present: four areas in the northern side of the Ría (From Rande to

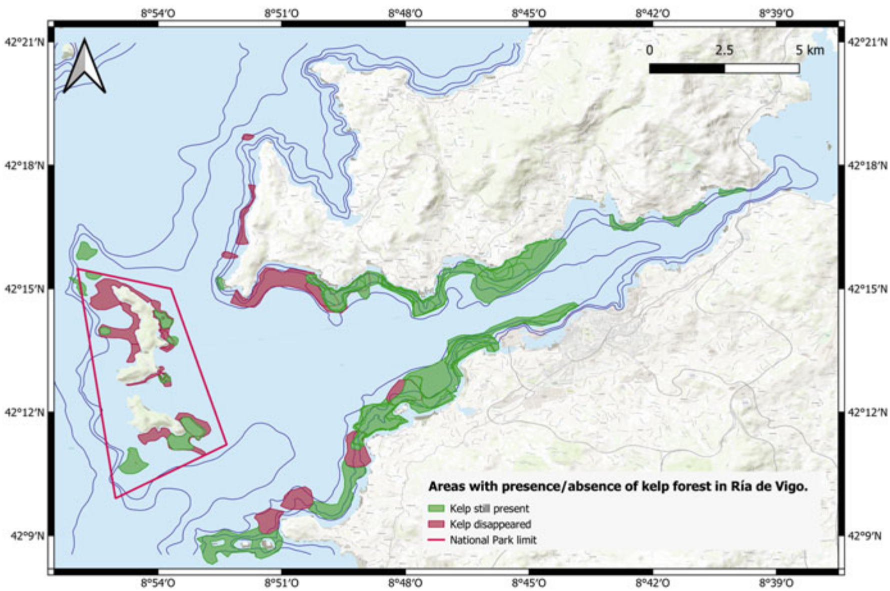

Fig. 24.6 Different areas with presence and absence of kelp forest in Ría de Vigo

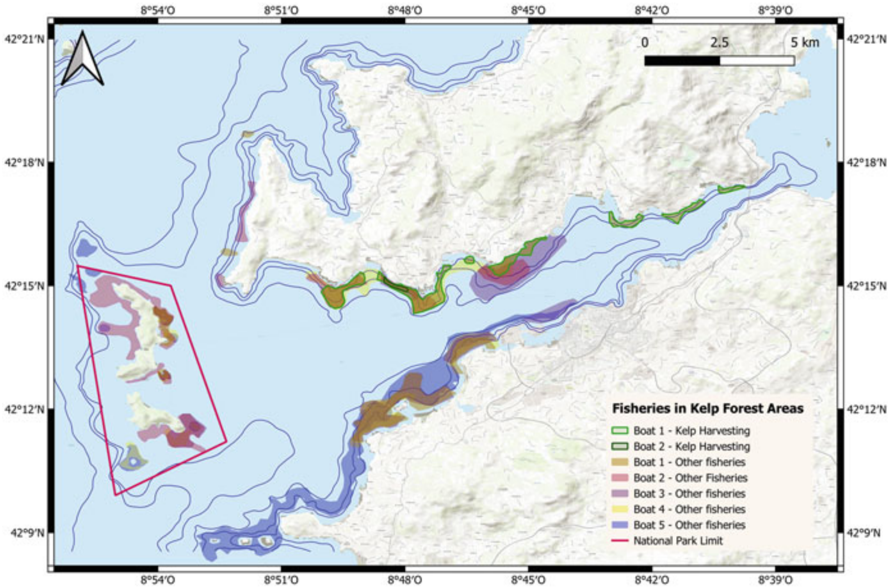

Fig. 24.7 Different Small-scale fisheries linked to kelp forests

Nerga beach), three on the southern side (from Vigo to Estai Cape), and nine small areas in the IANP (Fig. 24.6). On the other hand, fishers highlighted a loss of kelp from most of the IANP shore, from four small areas in the southern side of the Ría (north of Toralla, south of Estai Cape and Punta Meda), and four sites on the northern side (between Nerga and Home Cape).

Results allowed identifying the principal fisheries associated with kelp forest in this region for the first time, highlighting the octopus, spider crab, velvet swimming crab, or the European lobster (*Homarus gammarus*) as the most important commercial fisheries in this Ría. Fishers also identified fishes such as the white seabream (*Diplodus sargus*) and ballan wrasse (*Labrus bergylta*) as target species linked to kelp forest areas (Fig. 24.7). Fishing areas shown by fishers for these species were always the same, only changing the fishing period and the fishing gear. Parallel to kelp retreat, fishers perceived changes in their central fisheries, and many described a decrease in catches in areas where *L. ochroleuca* and *L. hyperborea* have disappeared. The presence of other canopy-forming species, such as the annual *Saccorhiza polyschides* or the pseudo-perennial fucoids *Gongolaria baccata* and *G. usneoides,* could explain why these fisheries have not wholly disappeared from these areas. Finally, both fishers and seaweed collectors agreed on an increase in Sarpa salpa catches in the last decades, supporting the idea that *herbivorism* could be behind the non-recovery of kelps around the IANP.

In Galicia, this is the first-time that fishers' knowledge is used to assess long-term kelp changes in forests and target species. Understanding the link between the kelp forest loss and fishing activities changes is essential to develop better management practices on these socio-ecological resources on which small-scale fisheries depend. In this regard, our results represent a first step to increase the scientific knowledge about the loss of kelp forests in Galicia considering a major scale than specific areas that are typically studied in ecological research. It also shows how this loss is linked to changes in associated fisheries, affecting the local small-scale fleet.

4 Discussion and Conclusions

During the last decade, social and marine sciences have paid increasing attention to global marine environmental changes and their consequences on small-scale fisheries that have increased their vulnerability and economic uncertainty (Kolding & van Zwieten, 2014). In this context, the general absence of long-term data sets even in a European context represents a serious issue, and some authors have argued for the need to incorporate small-scale fishers' knowledge and science for better policy recommendations, both in terms of fisheries optimization and resource conservation (Kolding & van Zwieten, 2014). LEK represents a suitable and cost-efficient approach for small-scale fisheries when conventional sampling methods are difficult or expensive to implement. Using fishers' knowledge, combining quantitative and qualitative tools can allow for ways to design and implement natural resources management and conservation policies locally (Aswani, 2019) under the increasing global change.

Fishers have detailed knowledge of their resource's environment and their fishing practices (Neis et al., 1999). This approach's benefits extend beyond filling gaps in scientific knowledge, promoting fishers' confidence and engagement with research activities linked with the conservation and monitoring of MPAs. Working together on building common objectives (Chuenpagdee et al., 2020) and sharing perceptions and information about the environmental and economic problems among stakeholders may be an agreed better approach for lasting solutions (Kolding & van Zwieten, 2014). Diversity in ecosystems and local cultures makes it difficult to develop a standardized method to use LEK. However, triangulation with other data sources and comparative techniques can strengthen research results, including the collaboration between researchers with interdisciplinary backgrounds and specialists in social and ecological sciences (Mellado et al., 2014).

Small-scale fishing communities often possess a high level of knowledge regarding fish populations and marine ecology (Scholz et al., 2004). For example, in Galicia, results agree with previous studies that showed a retreat of kelp species in Galicia (Barrientos et al., 2020). In La Restinga, our study reinforced the no-take zone's value in the recovery of small-scale fisheries after the volcano was pointed out (Mendoza et al., 2020), such as the recovery of some target species as *S. Cretense*. In this regard, our study exemplifies the high reliability of small-scale fisher's information and its value facing the challenges of ecosystem management in subtropical and temperate regions that are especially vulnerable to changes due to disasters or global warming, such as the increasing warm-affinity species (Vergés &

Campbell, 2020). The body of information held by fishers has a vital role in fisheries and benthic communities' assessment. Our research results support the research methodology and highlight the interdisciplinary approach's success and suitability in both case studies. Nevertheless, going one step further, when the information is built jointly with fishers it remains consistent and the uncertainty is reduced, turning the scientific research and assessments more convincing to these resource users (Neis et al., 1999) and local communities. For all the above reasons, the integration of LEK in a European marine management context, considering its variations among fishing groups and its role in maintaining traditional small-scale fisheries, seems a good and reliable source of information for assessing and monitoring marine environmental sustainability.

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Chapter 25
Marine Ecological Democracy: Participatory Marine Planning in Indigenous Marine Areas in Chile

Jeremy Anbleyth-Evans

Significance Statement Globally, marine ecosystems and indigenous cultures continue to collapse, prompting a need for a paradigm shift in conservation and marine planning. While top-down processes of marine and cultural conservation have widely been shown to be unsuccessful, this chapter shows how to carry out participatory methods for marine conservation planning, through eliciting traditional ecological knowledge and mapping with fisheries communities. Drawing on work in Manquemapu and Caulin Indigenous Marine Areas located in Chile, it considers how different communities identify ecological threats from overfishing and aquaculture, and how researchers can advance the integration of their evidence through participatory GIS. The chapter explores how different valuations of nature are expressed, specifically in Mapuche -Huichille first nation culture and conservation science; and how they can work together.

Keywords Participatory mapping · Conservation · Marine ecology · Democracy · Indigenous communities

1 Introduction

Globally, fishers from indigenous communities have different world views to conservation scientists, particularly in their approach to ecosystems, however there are overlapping valuations of nature (Muraca, 2011). In this context of these overlapping valuations of nature, some authors argue that these different knowledge systems of ecological observation, can be integrated, whilst ensuring that the co-evolution of their respective approaches are fully respected (Tengö et al., 2014).

While many indigenous approaches to ecosystems based on cosmo-visions (a combination of philosophical approach and belief system), are under threat, they can provide alternative paradigms to conservation of ecosystems (Gould et al., 2019). These indigenous 'cosmovisions', approach conservation based on a

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belief in the importance of humans being part of the ecosystem. In Mapuche-Huichille culture, the concept Itrofil Mogen, not only celebrates biodiversity, but celebrates local nature and humans within it as sacred, connected to all the elements of the local territory (Ñanculef-Huaiquinao, 2016).

This work defines Traditional Ecological Knowledge TEK, as those observations generated by those interacting continually with local ecosystems, such as farmers, hunters, and fishers, who can be aware of important environmental details missed by scientists and power over ecological decision making (Anbleyth-Evans, 2018). It is a system of knowledge defined by its cultural transmission down the generations, such as in indigenous communities. Other forms of ecological knowledge such as those of fishers, farmers and others working in ecosystems, may not have this culture dimension (Berkes, 2017). Thus, TEK involvement can improve ecological monitoring, build trust, fill knowledge gaps that scientists cannot reach, and improve understanding of potential environmental impacts from human effects on ecosystems such as port development, aquaculture industry or commercial fishing and its implications for the wider coastal community (Wilson et al., 2006; Garcia-Quijano, 2007; Johannes et al., 2000). This comes together to support the development of marine ecological democracy. This means a system where decisions and planning can be made where the ecosystems are valued most, and impacts most strongly felt, and where local monitoring continues through TEK (Anbleyth-Evans et al., 2020).

Nevertheless, understanding the differences between these value systems is useful in developing collaboration. For instance, indigenous connection to local place and cultural practices is different to scientists who normally seek generalisability and abstraction from place, to increase the significance of their research (Anbleyth-Evans, 2018). This relates to the importance of the values generated by community relations entwined with local nature, which are not always well understood. This premise is firstly based on conserving the relationship between biological, linguistic, and cultural diversity, or bio-cultural diversity (Davidson-Hunt et al., 2012). This can be protected by recognising indigenous rights to marine indigenous territories, and for indigenous people to enact their own conservation (Rozzi et al., 2006).

This chapter examines two contrasting case studies in Indigenous Marine Areas (IMAs) in Chile. It does this through semi-structured interviews, and, through participatory mapping through workshops. It aims to demonstrate how to carry out participatory methods to support conservation planning, to show that indigenous and scientific value systems can be complimentary, what was successful, and how different systems of knowing can collaborate in the future.

2 Methods

2.1 Case Studies

The two coastal indigenous coastal villages are mapped below in Fig. 25.1. Manquemapu, in Los Lagos region shows an example of a mixed traditional/modern

Fig. 25.1 Two case study sites: Manquemapu on the west coast of Los Lagos region and Caulin on the north coast of Chiloe island

conservation system which links to the traditional Mapuche normative/ethical framework of Az-Mapu. Az-Mapu provides guidance over governance, laws, and ethics regarding harvesting from nature such as fishing. While this has been successful so far there are still some challenges including integrating the artisanal fishing community into the process, and future aquaculture developments.

The second case study in Caulin Chiloe, shows the challenges of developing community management of seaweed aquaculture and fisheries, achievable by integrating TEK by artisanal indigenous fisher into the process. These cases show there is an opportunity to build new relational values for participatory conservation planning in the future and connect people across ecosystems and landscapes.

Figures 25.2 and 25.3 provide an overview of the coastal areas of Manquemapu and Caulin Chiloe respectively.

2.2 Semi-structured Interviews

The first step within the participatory mapping approach was the development of semi-structured interviews for the case study areas. Semi-structured interviews are useful firstly to understand the local context, allow for free-flowing dialogue where

Fig. 25.2 Coastal area of Manquemapu case study. (Source: Author)

Fig. 25.3 Coastal area of Caulin case study, north end of small island. (Source: Author)

Table 25.1 Interview themes, descriptions and questions

Theme	Description	Semi structured interview questions
Ecological conservation planning of local community impacts	Examining historic habitat overexploitation	Are there areas, such as natural shellfish banks or seaweed forests that have been overexploited in the past, and need to be protected?
Marine management/planning of external impacts on local ecosystems	Ongoing threats from aquaculture, industrial fishing and other developments	How do you propose to limit industrial aquaculture, industrial fishing, litter, and port development impacts?
Ecological endangered species conservation planning	Threats to endangered species	Are there marine mammals, birds and similar species in the area that need to be protected? If so how?
Ecological cultural dimensions	Influence of culture	How does Mapuche culture and its rules influence interaction and exploitation of nature e.g. Itrofil Mogen

the participants might need to explain something previously not considered, such as the bio-cultural context and different value systems.

20 semi-structured interviews with community activists, leaders those working in different governmental institutions, NGOs and aquaculture related businesses were carried out (Longhurst, 2003). Interview data was ordered through an inductive approach to thematic analysis supported by the software NVivo 10 (Clarke & Braun, 2013). The interviews were structured into themes (Table 25.1) with the aim to address: Perceived impacts on the local environment, how traditional management systems can adapt and manage these threats, loss of species, the value system, access to decision making and participation, and how stakeholders felt the current IMA system could resolve these issues in the future.

2.3 *Participatory Mapping and Focus Group*

Participatory mapping started with sketching on printed maps, ecological shapes, and other important and environmental and socio-economic features of the case study area. The sketching activity was performed through focus groups with up to 10 people. It is important to define what are the ecological elements to be mapped, such as what is most important to protect, such as habitats and sessile species such as shellfish seaweed forests, and their threats, including aquaculture contamination and overfishing. Maps were printed out in A1 or A2, so people could draw on them with colours representing different species, habitats, and other features. Results were digitalized using QGIS open-source software.

Participatory sketch maps are the most accessible to share LEK as they transcend language, cultural and power barriers (Anbleyth-Evans & Lacy, 2019). They do not require technical skills for the participants, and the challenges can be more easily visualised. Focus groups are meetings with multiple people from the community come together to carry out an exercise such as mapping, where semi structured interviews are normally one on one. They are participatory as they aim to identify the key marine ecological challenges with the community.

Counter-mapping refers to attempts to map against dominant power structures, to further seemingly progressive goals (Peluso, 1995). Those involved in the generation of Public Participation in Geographical Information Systems have worked to decentralise power of from the hands of the cartographic elite to support marginalised knowledges (Sieber, 2006). In this study, it was used in the context of imposed industrial aquaculture.

3 Results

3.1 Case Study 1: Manquemapu

Manquemapu is part of the Mapu Lahual territory, a heavily forested Mapuche-Huilliche area. Manquemapu is at least 81% ethnically Mapuche-Huilliche, and part of the former Füta Willi Mapu confederation, a political organisation of communities. A rural road connects the series of deep valleys that lead to the bay of the IMA, meaning there is a growing push for development, and the hills are scarred with new housing projects.

One of the primary challenges in the area has been the activities of artisanal fisher divers overexploiting benthic species, which were identified as needing conservation strategies in the mapping. One of the challenges is collaborating with non Mapuche-Huichille, Spanish-Chilean artisanal fishers. Artisanal fishers interviewed indicated that:

They would like to get more involved in the management committee, but there is no specific initiation ritual to become Mapuche-Huichille. However, to improve participation of all sectors it would make sense to find a way to allow them to feel part of the culture, so that all fishing activities could be understood.

At the same time, many of the indigenous group are part of the artisanal fisher's union, Marino Fuentealba, as well as part of the IMA managing committee. There are 117 registered artisanal fishers, out of a population of 180 people, a high percentage of the total community population. This means they are influenced by the commercial culture of artisanal fishing, and the need to keep expanding profit.

Because of the open access nature of the area, and as part of an ecological study and management plan, two zones were developed to understand the population dynamics. They were proposed to limit fishing, being approximately 13,32%, of the IMA. These areas reach a joint area of approximately 89.25 ha (Costa Humboldt, 2017). These are in the north west and south east (Fig. 25.4) and the other proposed management areas such as silent zones for cetaceans.

The community aims to restore natural conditions and protect from overexploitation several species located in the study area (see Fig. 25.4), such as

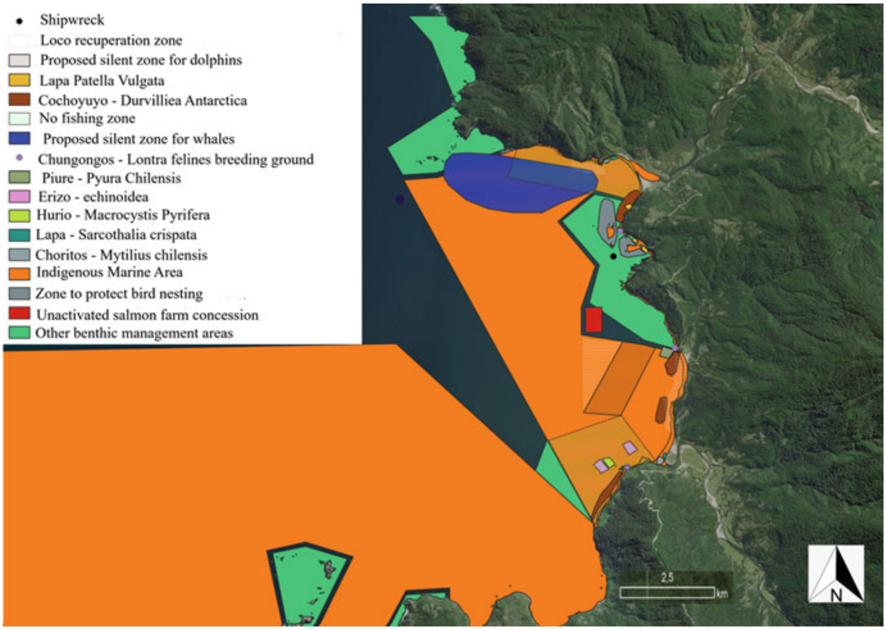

Fig. 25.4 Results of participatory mapping with Manquemapu community

the shellfish called Loco, or *Conchelapas conchelapas*, Lapa *Fissurella cumingi*, the sea urchin Erizo, *Loxechinus albus* and the seaweeds Cochayuyo *Durvillaea antárctica* and Luga roja *Gigartina skottsbergii*. They aim to develop a monitoring system of where they species and habitats are, and their health, whilst maintaining a level of subsistence fishing. At the same time, they plan to ensure that they expand their knowledge and skills through co-production of monitoring and conservation plans.

The administrative plan gives the objective "3.1 To safeguard and protect the marine space for conservation of marine biodiversity together with maintaining traditional practices balancing development" (Costa Humboldt, 2017). Relating to this, a discussion arose during the participatory mapping on how the community could develop biodiversity conservation. As seen in Fig. 25.4 next to the no fishing area with white and green hashed lines, there is also a traditional cultural site, the rock stack formation (Fig. 25.5), where the ancestors are ritually remembered. The Lonko, the traditional leader, explained that this related to the cultural traditions of the Mapuche Huichilles. This is also a hotspot for bird and sea otter nesting. Furthermore, that the community were against the activation of the salmon farm planned in the rectangle identified in Fig. 25.4 in red. The community want to develop concrete zoning for conservation of these habitats and species as services to the ecosystem. The idea of protecting whales and dolphins was also thought to have merit. Co-production of two silent zone free from acoustic pollution, as well as potential future aquaculture contamination, were drawn out on the map. There is

Fig. 25.5 Sacred rock stack in Manquemapu. (Source: Author)

concern that the aquaculture concession near to the rock stack cultural site could be activated where the birds nest.

While the community has made progress by getting their own enforcement boat to patrol the area to limit overfishing, this would be more complicated if their attempts to stop the private aquaculture rectangle from being activated. Overall, the strategic elements identified show how Manquemapu can evolve to support conservation of biodiversity, an example of a low impact anthrome.

3.2 Case Study 2: Caulin in Chiloe

Caulin is another Mapuche Huichille community in the north of the island of Chiloe. It is currently the largest IMA with its management plan recognised. A comprehensive strategy has been developed with the community to realise a multi-species fisheries management plan, integrating TEK alongside ecological and scientific information. Over 15 indigenous, fisherman and social organizations took part of focus groups, participatory mapping, and field sampling. The fishing management plan includes 8 commercial fisheries and 11 subsistence fisheries with a total of 19 marine species (6 algae and 13 invertebrates), along with the creation of 1,490,000 m^2 of no-take zones with clear conservation goals.

Diverse management tools have been developed, including no-take zones, fishing quotas, seasonal closures, size limits, and harvest guidelines. These proved to be necessary for achieving the multi species management. One of the biggest challenges has been to control the runaway Peillo *Gracilaria Chilensis* seaweed, and its aquaculture. A community leader explained that the Peillo seaweed had overgrown the farm areas and been difficult to control as it spread. The management plan supported a strategy to help this.

While native, the extent of the cultivation has overrun other ecosystems. Further to this challenge, the fisheries management plan has involved the development of a no take area, and a shellfish management area. Earlier to this, the first area created specifically for conservation of birds was to protect nesting. However, there hasn't been any strategy realised so far, as they were not thought to be at risk. Threatened bird species according to IUCN lists include Martin Pescador (*Megaceryle torquata*); Yegua (*Fardela Negra*) and Magallenic Penguin (*Sphenisus magellanicus*), however here there is an opportunity for monitoring from the school directly in front.

Additionally, to the species conservation, but integrated is the challenge bio-cultural conservation challenge. Another community leader explained that while the conservation strategy is moving forward, they would like to bring back the Mapuche Huichille culture, and restart the traditional calendar. Part of this is the revival of the use of ritual and space of the Guillatuns, thanking the guardian spirits of nature, identified in Fig. 25.6 above produced through participatory mapping.

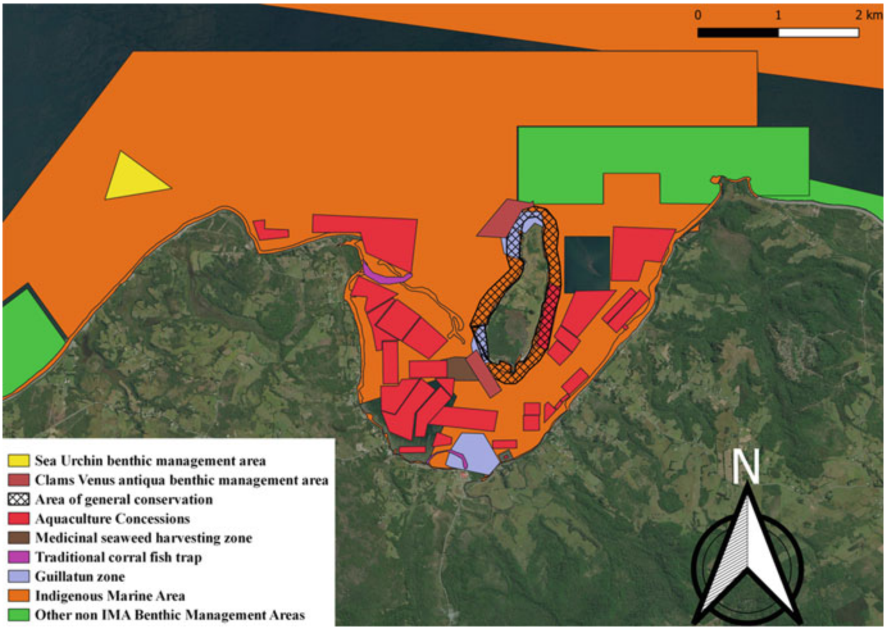

Fig. 25.6 Results of participatory GIS mapping from workshop with Manquemapu community. The red area is the benthic management of Almejas/clams Venus antiqua. The yellow area refers to sea Urchin benthic management sites. The green area is a general area of conservation

This can support the celebration of the Ngen, the local guardian spirits of the sea and land, such as the island, supporting use of the language, which has mainly been lost as well as using the plants for traditional medicine.

Reconnecting with the Mapuche-Huichille culture can enhance the connections with species and habitats in the future. As the community recuperates these dimensions of language, and local ecological mythological connections to place such as the north end of the small island, where a Ngen guardian spirit is thought to live, bio-cultural conservation can emerge.

4 Discussion

The value systems of conservation scientists and indigenous nations are different but can be complimentary. The Mapuche-Huichille values of marine and other ecosystems connects to conservation behaviour, firstly through traditional culture norms, for example by excluding fisheries and other harvesting around the rock stack in Manquemapu (Fig. 25.5), informing TEK. In a complimentary fashion, they have been collaborating with marine scientists to develop fisheries management plans to avoid overexploitation.

The value systems of marine scientists and Mapuche-Huichilles can be shown to be complimentary working towards the same goals of ecological conservation. Their traditional relational values with nature have created systems which are effective, thanks to the geographically remote nature of the areas where the Mapuches-Huichilles communities remain the main population. However, these traditional cultural systems are breaking down, with the push from the Chilean government to develop artisanal fisheries profits over the last 30 years, alongside the pressures of industrial aquaculture to expand into new areas. In other parts of the coast nearby, TEK informs that contamination from salmon aquaculture is substantial enough to suggest that aquaculture farmers operate according to a different value system. The salmon farm value system ensures that all effort is focused upon profit, and therefore without proper enforcement, are ready to profit in private, whilst passing on the impacts onto ecosystems and the communities in common (Anbleyth-Evans et al., 2020). These different value systems of Mapuche-Huichilles, scientists and aquaculture workers are summarised in Table 25.2 below.

Aquaculture workers and commercial fishers with their focus on short term profit, have a different value system, and therefore knowledge system to the other two looking to improve conservation planning. They contrast with Mapuche Huichilles and conservation scientists, in their focus on private profit and single species, that means they do not normally identify their own impacts or see the whole ecosystem during their extraction of nature. The Mapuche Huichille cosmovision also contrasts with conservation scientists who often tend to seek generalisability in their research, over local context.

In the wider political and ecological context this is relevant to what Temper (2019) calls decolonial environmental justice, that is allowing for indigenous

Table 25.2 Overview of contrasting values and knowledge systems of the Mapuche-Huichilles ethnic group, conservation scientists and Aquaculture/artisanal fishing workers

Mapuche-Huichille cosmovision/ knowledge values	Conservation scientists epistemic approach/values	Aquaculture/ Artisanal fisher epistemic approach
Place based/biocultural	Species/ecosystem based, seeking decontextualization/ generalisability	Profit based
Observation of species/cultural change	Scientific measurement of threatened species	Measurement of single species health
Bio-cultural approach	Ecosystem approach	Focus on exploitation
Local to global focus, with more focus on local context or Itrofil Mogen/realising the good life conserving biodiversity	Local to global world citizen with more focus on generalisability	Local profit-based approach with some variation

autonomy over governance to carry out ecological management for environmental justice. In this way, there is potential for greater application of TEK, and indigenous values to support the rights of stateless nations. For instance, Lofmarck and Lidskog (2017) identify that International policy Panel on Biodiversity and Ecosystem Services avoids contested and conflict-laden issues, including what counts as valid knowledge when working across knowledge systems. This needs deeper exploration with more stateless nations, such as in the context of the project of Nature's Contribution to People coined by IPBES (Diaz et al., 2018).

Developing co-production of research for marine bio-cultural conservation, is a way to bring together the scientific conservation value system and TEK systems. This means using mixed social and natural science approaches to address the challenges of multiple users developing marine coastal spaces. The increasing pressures of aquaculture, alongside historic overfishing, mean it is important to seek collaborations across different groups and worldviews to create a consensus.

5 Conclusion

This chapter introduced two IMA case studies where participatory conservation is slowly being realised. These introduce methods to move towards the protection of species and habitats, through initiatives to fish sustainably, with no take zones and limited aquaculture development. We deepened the planning through participatory mapping, co-producing a potential plan for future zones for cetacean and bird conservation, acoustic impact free zones, in Manquemapu, and areas to control fishing effort and bird conservation in Caulin. Further, areas that can be culturally recuperated in terms of their local connections to ecosystems were proposed. By identifying where cultures of conservation and their mechanisms exist, behaviour supporting conservation can be better supported.

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Chapter 26
The Socio-Ecological Dimension of Ocean Multi-Use Platforms

Daniel Depellegrin, Sander van den Burg, Maximillian Felix Schupp, and Lars Johanning

Significance Statement A Multi-Use Platform can integrate different maritime activities into a single sea area. We propose an analytical framework to investigate the socio-ecological benefits and impacts of potential Multi-Use Platforms designs in the Mediterranean and North Sea. The framework uses a marine ecosystem services matrix that has the aim to facilitate knowledge sharing on the ecosystem goods and services a Multi-Use Platform can potentially support and interact with. The results highlight that Multi-Use Platforms provide multiple opportunities for energy generation, food provisioning (e.g. recreational fishing, extractive aquaculture) and cultural services (e.g. coastal recreation, diving, research and monitoring). Further research suggests application of quantitative socio-ecological analysis techniques to measure potential synergies and trade-offs among the multiple activities of the platform.

Keywords Ecosystem services · Blue growth · Offshore wind energy · Aquaculture · Tourism

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1 Introduction

The last two decades have seen substantial progress by the scientific community in the development of classifiers for marine ecosystem services (MES) to provide to decision-makers, planners and practitioners common standards for categorization and quantification of the ecosystem goods and services provided by the marine environment (CICES, 2018; MA, 2005). MES classification experienced a further development with the progressive implementation of the MSP Directive in European Seas starting since 2014. A stronger focus was given to the integration of the MES concept into MSP-oriented analysis (Ivarsson et al., 2017), with the aim to facilitate the integration of socio-ecological notions as sustainability principle into the planning process and the need to increase awareness of MES benefits to coastal communities and the maritime sectors commercially benefitting from MES flows (Friedrich et al., 2020). This resulted into a more diversified approaches oriented to understand the maritime sectors' benefits and trade-offs from MES, such as in relation to coastal tourism (Depellegrin et al., 2017), aquaculture (Gentry et al., 2020) or offshore wind energy (Hooper et al., 2017). Moreover, the need to enforce ecosystem-based management (EBM) into MSP, as integrated management approach to take into account full interactions within ecosystems, including humans, contributed to the evolvement of conceptual and practical techniques for the incorporation of MES into Maritime Strategy Framework Directive (MSFD) pressure assessment (Menegon et al., 2018). Most recently the EU Blue Economy Report 2020 (EC, 2020) reviewing the economic performance of Europe's Blue Economy has highlighted the need to incorporate MES notions into maritime sector analysis in order to make the Blue Economy more sustainable and resilient.

A promising development to foster Blue Growth in European Seas is the implementation of Multi-Use (MU). MU provides novel opportunities for maritime activities with potential added values for the environment and socio-economic development of the ocean space. Within the MUSES Project (Multi-Use of European Seas, Schupp et al. (2019) defined MU as "*the joint use of resources in close geographic proximity by either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users*". Although several studies were analysing the potentialities to MU across different sea areas (e.g. MUSES and MARIBE), none of the studies attempt to systematically account how a MU can supply and support the demand for multiple ecosystem goods and services. This chapter analyses the environmental and socio-economic benefits provided by Multi-Use Platforms (MUPs) as an example for MU. The study proposes a MUP and marine ecosystem goods and services (MES) assessment matrix (MES-MUP matrix) to address the socio-ecological relationships a MUP can disclose. The matrix is tested for two different MUP cases, namely the MWA Porto Corsini (Northern Adriatic Sea; Italy) and the FINO 3 (*Forschungsplattform Nordsee;* North Sea; Germany). An expert-based approach will be used to analyse socio-technical system components that can contribute to human-needs and welfare, the potential synergies and trade-offs emerging among MES and the potential implications of the use of socio-ecological analysis for the assessment and development of MUPs.

2 Data & Methods

2.1 Analytical Framework

The analytical framework that defines the five methodological steps for the analysis of MUP from a socio-ecological perspective is presented in Fig. 26.1. The framework is composed by five steps: (1) review of MES typologies applicable in Blue Growth contexts; (2) definition and review of MUP case studies to be analysed; (3) the definition of the socio-technical systems (STS) composing the MUP, (4) the design of a MES-MUP assessment matrix through literature and (5) the expert based evaluation of results in terms of MES provision by MUPs and potential MES synergies-trade-offs emerging from MUPs. In the following paragraphs a detailed rational for each step will be provided.

2.2 Step 1: MES Typologies for MUP Analysis

We analysed existing marine ecosystem services classification schemes relevant for the marine realm and Blue Growth (EU, 2020; Hattam et al., 2015; Lillebø et al., 2017) through a structured literature review. In order to be operational, MES identification was firstly performed considering the maritime sectors that MUP can potentially aggregate. A typical example of a MUP can refer to offshore wind turbines combined with aquaculture cages that can function as an energy-food

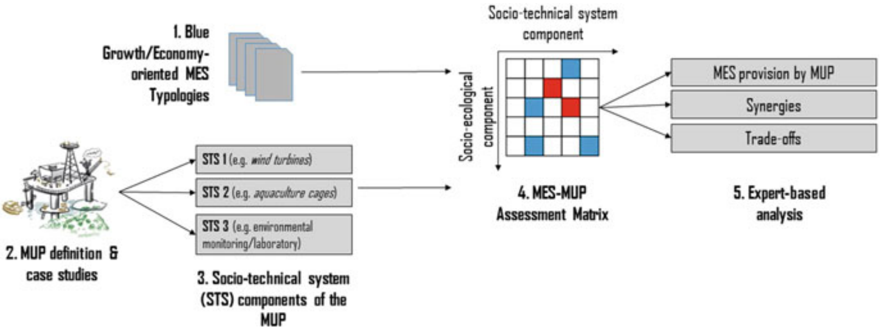

Fig. 26.1 Framework applied for the analysis of socio-ecological dimension of MUPs.

production installation (e.g. van den Burg et al., 2020) or marine renewable energy devices combined with a desalination device for a water-energy production infrastructure (e.g. Schupp et al., 2019).

2.3 Step 2: Characterization of MUP Case Studies

We analyzed the results from two EU funded projects on MU, to identify MUP case studies to be tested: The MARIBE Project (Marine Investment for the Blue Economy; www.maribe.eu) explored cooperation opportunities for companies that combine different Blue Growth/Economy sectors. The MUSES project (Multi-Use in European Seas; www.muses-project.com) explored the opportunities and barriers for MU in European Seas across five EU sea basins (Baltic Sea, North Sea, Mediterranean Sea, Black Sea and Eastern Atlantic). Both projects provided material to characterize MUPs and supported experts in the analysis of MES. According to van den Burg et al. (2020), MUPs are physical structures hosting multiple activities. MUPs are central to achieving EU's Blue Growth targets and can contribute to the implementation of several Sea basin Strategies as a central component to boost ocean sustainability. To test our hypothesis we selected two well studied MUP cases (Table 26.1 and Fig. 26.2), the MWA Porto Corsini MWA (Adriatic Sea, Italy; Depellegrin et al., 2019) and the FINO 3 Platform (*Forschungsplattform Nordsee,* North Sea, Germany; Viertl, 2006; UNITED Project, 2020).

Table 26.1 Overview of MUP types analysed

MUPs type	Geographic Area	Socio-technical system of the MUP	Development stage	Reference
MWA Porto Corsini Platform	Emilia-Romagna region Northern Adriatic Sea, Italy (Mediterranean Sea)	1. Extractive aquaculture 2. Nautical tourism 3. Diving 4. Recreational fishing 5. Research & monitoring laboratory	The platform needs to be decommissioned by 2021 and conceptual design for re-purposing the platform was developed by several stakeholders	Depellegrin et al. (2019)
FINO[1,2,3]	Southern North Sea, German bight, EEZ	1. Research & monitoring laboratory 2. Offshore test site 3. Extractive aquaculture	The platform is currently in use as a multi-use research station with future aspirations to include more economic activities such as extractive aquaculture	Viertel (2006), FINO 3 (2020) and UNITED Project (2020)

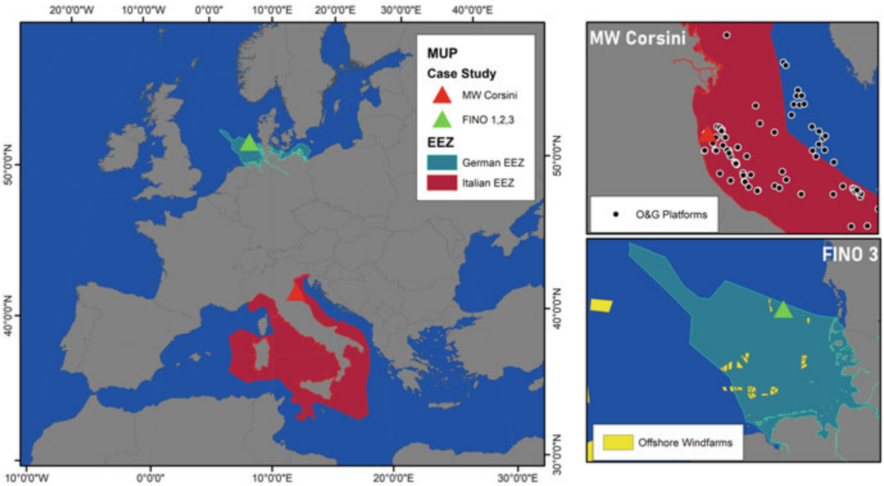

Fig. 26.2 MUP case studies. (For further graphical visualizations on the MUP design we refer to Castellani et al., 2017 (MWA Porto Corsini) and FINO 3, 2020)

Case 1 – MWA Porto Corsini Platform The twelve-legged Gas platform was constructed in 1968 operated by the energy company ENI and located in the Emilia-Romagna coasts (Italy) in the Northern Adriatic Sea (UN-MIG, 2017). The main driver for the potential conversion of the Platform to a MUP is the need for decommissioning in 2021. According to Italian Ministry of Economic Development (DGSUNMIG; Grandi, 2017) at least 20 offshore platforms (mainly extracting natural gas in shallow waters) will come to end of their production lifetime between 2017 and 2021. The need for decommissioning of O & G marine platforms has induced several pilot studies in diverse conceptual designs for the re-purposing of the platform as an alternative to a full or partial removal. The proximity to the coast line (7 km from coastline) and the intensive coastal tourism activity and infrastructure of the *riviera* suggest a re-purposing of the platform as a tourism and recreational attraction centre. Conceptual designs identified include the use of the platform as an anchoring support for aquaculture cages, the use of the site for nautical tourism purposes. Recreational activities such as diving and recreational fishing were planned as additional activity to be performed along with a marine research and monitoring laboratory (Depellegrin et al., 2019).

Case 2 – FINO 3 Platform The FINO 3 platform is part of a series of three offshore research platforms in Germany's North Sea and Baltic EEZ. They were constructed in the 2000s as part of the German federal government's newly developed offshore wind energy strategy and were erected in areas of immediate suitability for future offshore wind energy projects (Viertl, 2006). The FINO 3 platform is located roughly 80 km west of the island of Sylt and is made up of a 13 × 13 m work deck and a helipad roughly 22 m over sea level on a 4.7 m monopile foundation, topped with a 105 m tall lattice mast. It is situated in immediate vicinity if multiple active offshore wind farms (FINO 3, 2020). The platform is meant to provide a continuous monitoring station for meteorological, oceanological and ecological data as well as to serve as a test bed for new offshore technologies, training and construction methods (IEA Wind, 2011). While the FINO platforms have always acted as MU research platforms, FINO 3's sister platform in the North Sea, FINO 1, has previously also been investigated for its potential to host marine aquaculture installations (Buck et al., 2017). More recent investigations into the suitability of FINO 3 MU scenarios, as part of the EU H2020 BG5 Project "UNITED", have focussed on realising a combination of the research platform with extractive mussel and seaweed aquaculture in close vicinity to offshore wind farms (UNITED Project, 2020). The platform could potentially serve as a logistical hub, data centre or central monitoring station for connected mussel or seaweed aquaculture installations.

2.4 Step 3: Definition of Socio-Technical System Components (STS) constituting the MUP

The STS can be defined as systems designed to meet societal needs and generate benefits and value for markets, policy, behaviour, technology, science, industry, business, etc.. . . (EEA, 2020). Maritime activities such as ocean energy devices, aquaculture or port facilities are STS that can compose the MUP and that require access/alter/protect/exploit of marine ecosystem good and service due to a specific human demand. STS require continuous inputs from marine biotic and abiotic ecosystem services. STS could refer to traditional (e.g. shipping, coastal tourism or Oil & Gas extraction) but also combine emerging maritime sectors (e.g. marine aquaculture, ocean energy, marine biotechnology sampling sites). In addition, the operation of STS can cause adverse environmental effects on marine ecosystems responsible for the MES delivery, such, as pollution, marine litter or underwater noise.

2.5 Step 4: Design of the MES-MUP Assessment Matrix

This step includes the design of the MES-MUP assessment matrix. The matrix cross-links the socio-ecological components in form of MES and the STS components of the MUP that are responsible for MES flows. The matrix consists in the *x-axes* of the MUP types identified and the STSs features composing the MUP. The *y-axes* is composed of the MES category, the intermediate MES and the final MES. Intermediate ecosystem goods and services are services that offer humans indirect benefit (e.g. CO_2 storage, waste and pollution removal). Final ecosystem goods and services are the directly enjoyed, consumed or used by humans and so make a direct contribution to welfare (Boyd & Banzhaf, 2007; 619). The matrix (see Table 26.3) is composed by seventeen MES grouped into four categories: provisioning services (e.g. food provisioning and water storage), regulating & maintenance services (e.g. water purification, climate regulation or coastal protection), cultural MES (e.g. effects on tourism or recreational activities) and MES produced by abiotic means (Alexander et al., 2016) that refer to non-living components (e.g. water temperature) of the marine environment and by non-living processes (wind, wave and tidal motion).

2.6 Step 5: Expert-Based Compilation of the MES-MUP Matrix

The MES-MUP assessment matrix is compiled and evaluated by a dedicated expert group with experience in the MUP evaluation and MES assessment. Experts were asked to assess the direct and indirect linkages among the MUP based on the key concepts presented in Table 26.2.

3 Results & Discussion

3.1 MES Provision by MUP

Table 26.3 presents the MES-MUP assessment matrix for the two MUP cases. In the *x-axes* the socio-technical system components of the MUP were defined and the *y-axes* presents the socio-ecological components in form of MES. For example the

Table 26.2 Terms and definitions composing the MES-MUP matrix

Term	Definition	Reference
Social-technical systems	Systems designed to meet societal needs and generate benefits and value for markets, policy, behaviour, technology, science, industry, business, etc...	EEA (2020)
MES use	The access/alteration/management or protection of an ecosystem being due to ES demand	Turkelboom et al. (2018)
Direct MES use	The goods or benefits derived from the services provided by an ecosystem that are used directly by an economic agent. These include consumptive uses (e.g., harvesting goods) and non-consumptive uses (e.g., enjoyment of scenic beauty)	Openness (2020)
Indirect MES use	The benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. The indirect use of the MES from an actor or entity outside the MUP is omitted from this definition	Openness (2020)
MES synergies	The simultaneous enhancement of multiple services through the use of an ES.	Spake et al. (2017)
MES trade-offs	The reduction of the provision of a service as a consequence of increased use of another.	Spake et al. (2017)

Table 26.3 MES-MUP assessment matrix. MES included in the matrix were retrieved from the following documentation: EU (2020), Lillebø et al. (2017), Hattam et al. (2015). Note: P-Provisioning ES; R-Regulating ES, C-Cultural ES; A-Abiotic ES.

ES category	*Ecosystem Service*	**MWA Porto Corsini Platform**						**Fino 3**	
		Decommissioned Oil & Gas infrastructure	*Extractive Aquaculture*	*Nautical Tourism*	*Diving*	*Recreational fishing*	*Research Facility*	*Research & Monitoring*	*Extractive Aquaculture*
P1. Food provisioning	Commercial fisheries								
	Aquaculture production		Direct						Direct
P2. Water storage & provision	Water for human consumption								
P3. Biotic material & biofuels	Biomass production for non-food purpose		Direct						Direct
R1. Water quality regulation	Bio and physicochemical processes for waste and pollution removal	Direct	Indirect		Indirect	Indirect	Direct		Indirect / Direct
R2. Air quality regulation	Air pollution concentration in the lower atmosphere						Direct		
R3. Coastal protection	Erosion prevention, protection against floods, hurricanes								
R4. Climate regulation	Greenhouse gases: uptake, storage and sequestration of CO2		Direct						Direct
R5. Weather regulation abiotic	Influence on local weather conditions as thermo regulator and humidity		Indirect				Direct		Indirect
R6. Life cycle maintenance	Biological and physical support for habitat maintenance and nursery	Direct	Direct		Direct	Indirect	Direct	Direct	Direct
R7. Biological regulation	Biological control of pests may affect commercial activities and human health		Indirect			Indirect	Direct		Indirect
C1. Symbolic & aesthetic values	Recreational services based on hunting, observation of species living in the wild			Direct	Direct				Direct
C2. Recreation & Tourism	Recreational fisheries					Direct			Direct
	Opportunities for nature-based relaxation and amusements			Direct					Direct
C3. Cognitive effects	Marine research, monitoring and education				Direct		Direct	Direct	Direct
A1. Abiotic mean	Provisioning of marine energy (wind, wave, tidal)								
	Creation of space for other uses to exist	Direct						Direct	

Direct (blue): *Direct Use/"MUP impacts"*
Indirect (red): *Indirect Use/"MUP relies on"*

six STS composing the MWA Porto Corsini are, the decommissioned Oil & Gas infrastructure itself, extractive aquaculture, nautical tourism, diving, recreational fishing and a research facility. In the case of the MWA Porto Corsini, provisioning MES are supported through food provisioning by extractive aquaculture activities. In fact, also Emilia-Romagna Region belongs to the important mussel aquaculture producers in Italy (Castellani et al., 2017). The MWA Porto Corsini would be a donor of space for food provisioning through aquaculture in an area that is usually restricted, as the O & G platforms have a safety area of 500 meters (UNCLOS, 1992; *Article 60 - Artificial islands, installations and structures in the EEZ*). In terms of regulating and maintenance MES provide an indirect benefit to the food provisioning as they refer to the bio-physical processes of the marine environment that usually sustain the aquaculture production, this includes waste and pollution removal, suitable weather conditions for harvesting and operations in the aquaculture sites, suitable marine habitats and the pest control. The other four STS components identified would provide direct benefit to society through cultural MES. Adequate anchoring systems would provide opportunity for nautical tourism facilities through the establishment of marinas with multiple recreational opportunities for nature-based relaxation and the enjoyment of seascape and marine habitats. Especially maritime recreation activities such as diving and recreational fishing would directly benefit from a MUP, as hard substrate. The decommissioned oil and gas infrastructure can act as hard substrate that could enhance biodiversity, also known as rig-to-reef (RTR) effect (Ounanian et al., 2020; Macreadie et al., 2011). A concrete example of a reef-to-rig effect is the *Paguro* submerged O & G platform that sank after a fire in 1965 off the coasts of Emilia-Romagna Region (Castellani et al., 2017). Nowadays the *Paguro* is a NATURA 2000 Network (SIC-IT4070026; Regione Emilia Romagna, 2013).

Transitioning the FINO 3 research platform into a MUP includes two STS components: the maritime and marine research and monitoring operations as well as the extractive aquaculture operations. The primary component is the existing research platform which hosts a variety of different efforts for marine and maritime research. This component provides the platform and, thereby creates a space and opportunity for the second component, extractive aquaculture operations, to take place. The extractive mussel aquaculture would potentially supplement natural food provision from the marine ecosystem by providing food for human consumption. If macroalgae aquaculture were to be integrated into a system, it could also provide biomass for other non-food purposes and supplement harvests from wild stock. Non-food biotic materials harvested could potentially serve to capture carbon from the marine environment. Extractive aquaculture heavily relies on the natural water quality regulation services of the host-ecosystem while also positively impacting the water quality by removing dissolved or particulate nutrients from the water column. It also relies on other natural regulating services such as the provision of a stable ecosystem, biological pest control and others.

3.2 MES Synergy and Trade-Offs within a MUP

The MWA Porto Corsini Platform as MUP is a donor of space, infrastructure, logistic support and hard substrate. There is a high synergy of the MUP with all the cultural ecosystem services, as it would provide the necessary structure to support diving (recreational and scientific), recreational fishing and nautical tourism. Potential trade-offs are related to aquaculture activities that could result into marine pollution phenomena to the marine environment (e.g. production of waste, anoxic conditions of sediments or the release of medicines or chemicals) that could affect the overall ecological status of the sea area surrounding the MUP (Farella et al., 2020). Also a MUP could be associated with an increase of maritime traffic activities from nautical tourism, small scale fishery and diving operators that could cause additional stress to the marine environment or spatial conflicts with other activities not directly associated with the MUP, such as commercial fishery or shipping traffic related to port activities in proximity of Ravenna port.

Similarly to the MWA Porto Corsini Platform, the FINO 3 platform is a donor of space. It creates space and opportunities for other STS components, such as extractive aquaculture, to exist within an otherwise crowded coastal sea. The introduction of new system components into a MUP will inevitably increase the possible risks to either component. Traffic from either component can increase the shared and individual infrastructures while also potentially introducing environmental trade-offs as far as contaminants may affect either aquaculture or research and monitoring activities. The platform foundations provide a hard substrate habitat for a variety of benthic species while the floating aquaculture installations provide food, shelter and nursery grounds largely for pelagic species. However, these same habitats may potentially also serve as stepping stones for invasive species and disease vectors.

4 Conclusions

MUP can have several effects on surrounding marine sea areas through the enhancement of the socio-ecological benefits to coastal communities, such as artificial reef effect, fish food yielding or support to scientific knowledge through environmental monitoring devices or laboratories. The presented matrix can be used to screen which MES are used by a MUP and how they can support human wellbeing. The benefit of this matrix-based approach is that it combines socio-ecological knowledge and indicators and allows the STS components to be analysed in a multi-use setting. This is crucial information for understanding the impacts of MUPs. The advantage of the matrix approach is that also other MUP based on other STS components can be analysed (e.g. offshore wind energy in combination with aquaculture or desalination plants), or MU combination based on soft uses, such as for instance *pescatourism*, that refers to small scale fishery with tourism activities. Moreover a socio-ecological analysis can facilitate communication with non-scientific stakeholders on the benefits to welfare provided to coastal communities and society at large. In future the matrix could be extended through a synergy-tradeoff analysis of the MES that could contribute to the design of MUPs and better understand eventual environmental and socio-economic conflicts rising from MUP realization.

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Chapter 27
Localizing the Sustainable Development Goals for Marine and Coastal Management in Norway: A Venture Overdue

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Significance Statement Meeting global challenges requires regional and local alignment of institutional and business practices. The purpose of our work is to understand, using qualitative systems analysis, how the Sustainable Development Goals can be achieved through local, cross-sectoral solutions. In this chapter, we start by reviewing the status quo of marine and coastal management in Norway and contrast with the United Nations' expectations for localization of the Sustainable Development Goals. One key finding is that despite vast knowledge on ocean and coastal use and management, Norway has very few examples of actual localization of the Sustainable Development Goals. We present a case study from Andøy Municipality where we use Social-Ecological Systems mapping to spawn awareness and spur local businesses to harness relevant sustainability targets at the local level.

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1 Introduction

People and landscapes are intimately connected from local to global scales. What we do, collectively as a world population, has impact on the Earth at a planetary scale (Steffen et al., 2015). These global interconnections necessitate policy goals and management that are matched in scale and reach. The adoption of the 2030 Agenda for Sustainable Development (UN Resolution 70/1, 2015) by the United Nations General Assembly, which includes the Sustainable Development Goals (SDGs), is the first international attempt to create a common framework for further dialogue on and implementation of global sustainability. Of the 17 global SDGs, seven are directly linked to natural environments and the values they represent for human wellbeing.[1]

Besides the strong link to society-nature interactions and the value of nature for human societies, the SDGs are explicitly aimed at a global scale. The formulation of global goals that the international community agrees upon is relatively new and the identification and targeting of sustainable development at a global scale resonates with recent scholarship in sustainability science. Using a number of ideas and concepts – like "the Anthropocene" (Pálsson, 2020; Steffen et al., 2007, 2011), "social-ecological systems" (Folke et al., 2002, 2005; Ostrom, 2009), "earth system" (Lui et al., 2007); and "planetary" or "earth stewardship" (Steffen et al., 2011) – this literature emphasizes that human societies and nature are interconnected and interdependent at a global scale.

But, the realization of the SDGs, or any other global agenda, depends on institutions that are targeting people and places at lower scales, i.e. national, regional or local levels. "Localization" is a term explicitly used by the UN for tools to operationalize the SDGs at such scales, many initiated or supported by the World Organization of United Cities and Local Governments (UCLG)[2] and the Local2030 platform.[3] Localizing the SDGs is a critical element of success for sustainable development at global scales (Delgado-Serrao & Ramos, 2015).

In this chapter, we consider how efforts to achieve the SDGs materialise for Norwegian marine and coastal zones. Knowledge of these efforts are of great value, because marine coastlines and seas have high ecological value and are under growing pressure from increased human activity and exemplify the relevance of

[1] These seven include: clean water and sanitation (SDG6); affordable and clean energy (SDG7); sustainable cities and communities (SDG11); responsible consumption and production (SDG12); climate action (SDG13); life below water (SDG14); and life on land (SDG15). Moreover, it can be argued that the ten remaining SDGs are indirectly linked to natural environments. This chapter focus on the "blue" context across the SDGs.

[2] https://www.uclg.org/en/agenda/global-agenda-of-local-regional-governments

[3] https://www.local2030.org/

all the 17 SDGs. Moreover, the literature on SDGs includes very few examples from the Nordic context. This means that examples and lessons learned are not easily accessible to planners in Norway (Lundberg et al., 2020).

In what follows we review a selection of marine and coastal landscapes of Norway, in four management cases (Fig. 27.1) related to national, regional and municipal localization of the SDGs. To identify important social and ecological interrelations that shape the process of localization of the SDGs in these cases we will use Oström's Social-Ecological System, and to this framework we now turn.

2 Social-Ecological Systems and Localization

The SDGs, in their breadth and diversity, underscore the interrelations among nature and ecosystems, humans and institutions. To conceptualise these interrelations, we use a systems approach to highlight feedback between natural systems and human systems. Within the various complex systems approaches and frameworks, Ostrom's Social-Ecological Systems (SES) (Ostrom, 2007, 2009) is particularly suited for studies of localization of SDGs, since it pays explicit attention to the role and function of institutions (Fig. 27.2). The development of the SES framework was motivated by the need for a systems approach, highlighting that it is not enough to look at institutions in a vacuum because they need to be related (or considered) in their wider social and ecological context. Our perspective is that Ostrom's SES framework offers a comprehensive tool through which to capture the ecological and social complexities of coastal and marine areas, and the ways in which institutions try to intervene in these complexities. The SES framework is for these reasons the theoretical fundament for our study. For each of the cases outlined in this chapter, we apply an adapted version of the Ostrom SES framework.

To begin, any SES is characterized by perpetual feedback among the components. For instance, within the *Governance system* the law shapes institutions, and these institutions enable and limit the actions of *Users* of the Resource system and its Units (Fig. 27.2; Ostrom, 2007, 2009). In turn, actions of the *Users* shape the *Governance system*. Thus, the cycle continues as the *Governance system* gradually moulds the *Resource system* according to our uses and needs and vice versa.

Localization of the SDGs in a marine or coastal area gives scale and scope to an SES. Localizing SDGs in an SES framework means to fully describe the local system in order to understand the systems aspects of Ostrom's social-ecological topography. The SDGs apply across sectors and SES connects the SDGs to the relevant interactions and outcomes. In Fig. 27.3, we expand the traditional SES diagrams (Ostrom, 2007, 2009) by replicating the SES framework for three institutional scales: local, regional and national.

To exemplify localization of the SDGs at the Norwegian national, regional and local level scales of marine and coastal planning, we have selected four sites and described the relevant management purpose. An aim of our study is to test the use of SES in localizing SDGs by mapping the sites main attributes according to Ostoms's

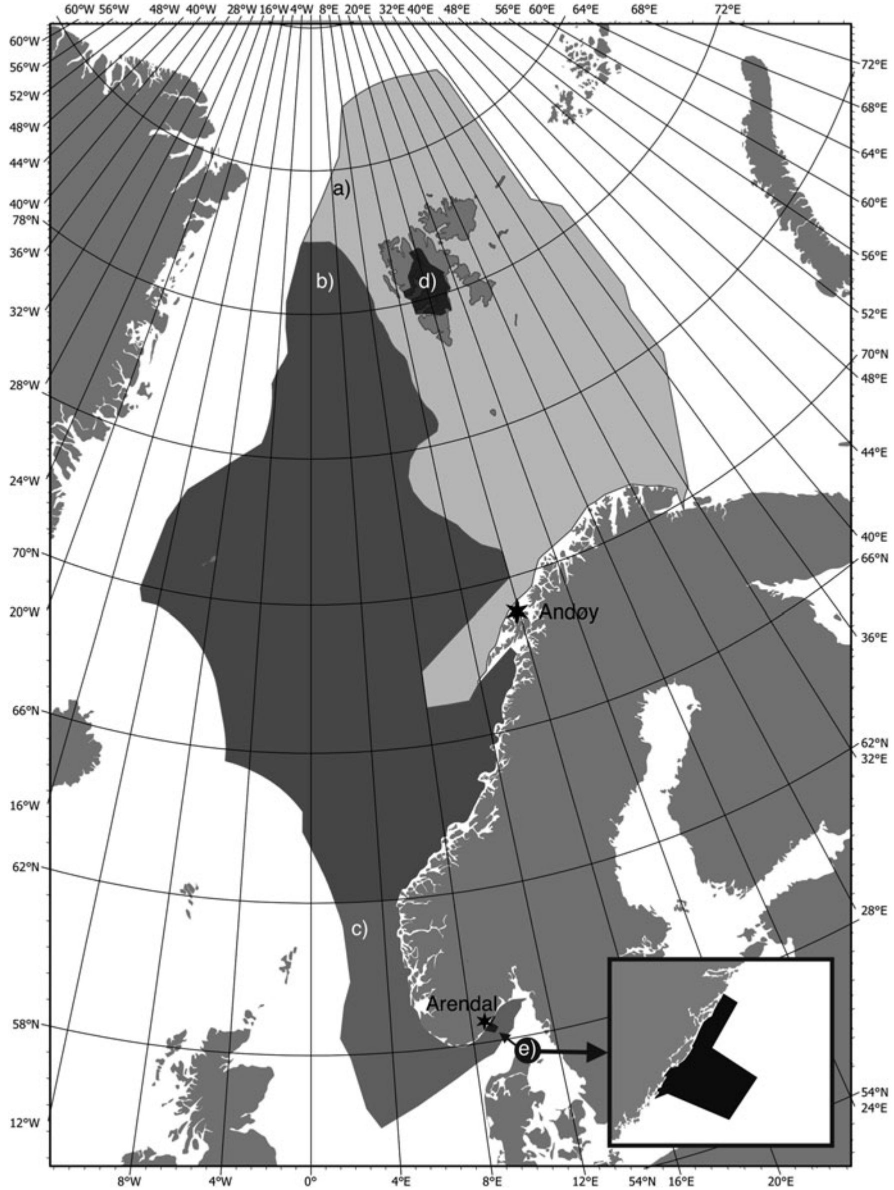

Fig. 27.1 A map of the Norwegian marine and costal management cases we compare in this chapter: (**a**) Management plan of the Barents Sea, (**b**) Management plan for the Norwegian Sea, (**c**) Management plan for the North Sea, (**d**) Central Spitsbergen management plan, (**e**) Raet National Park, partly managed by Arendal Municipality. The municipalities are indicated with stars.

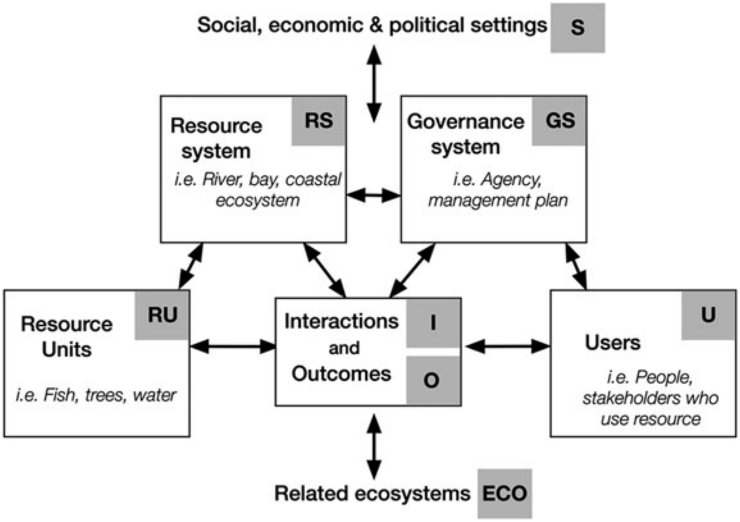

Fig. 27.2 A simplified Social-Ecological System diagram. Abbreviations of the system components are in grey boxes. The four main tiers (Resource Units, Resource Systems, Governance Systems, and Users) are indicated with boxes, and examples of each tier component are italicized. Arrows indicate interaction direction. (Adapted from Ostrom (2007, 2009))

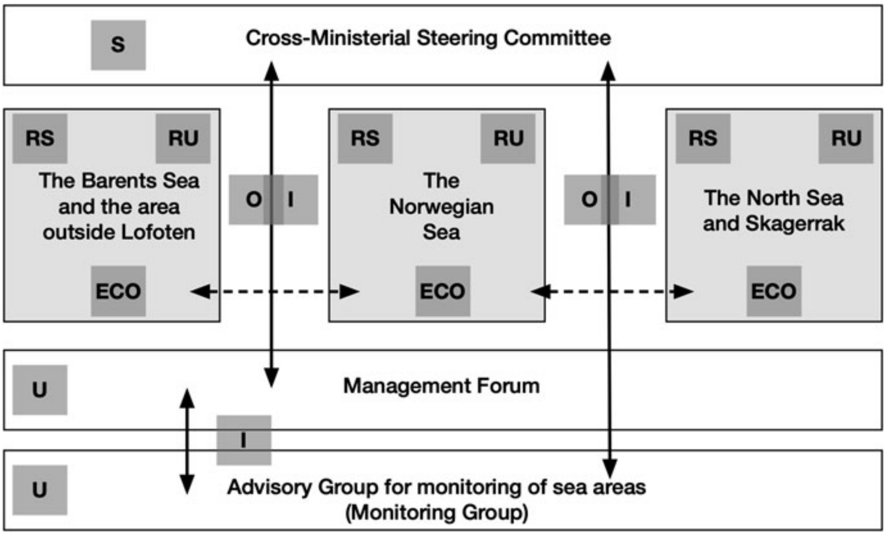

Fig. 27.3 Organizational map over the three Norwegian EBM Ocean Plans in the Barents Sea, Norwegian Sea and North Sea regions. Light grey boxes represent the three EBM Ocean Plans. Overlayed darker grey boxes show the abbreviation of the applied Social-Ecological System, with reference to Fig. 27.2. Solid arrows indicate the communication among committees and groups. Hashed arrows indicate connections of the three adjacent ecosystems (see Fig. 27.1)

Table 27.1 Summary of the four case studies using Ostrom's Social-Ecological System (SES) framework

Case Study	Scale	Related ecosystems (ECO)	Governance system (GS)	Users (U)	Resource unit (RU)	Resource system (RS)	Social, economic, political settings (s)
Integrated ocean ecosystem-based management plans	National	North Atlantic and Arctic oceans	National government of Norway	Trans-sectoral committees, scientists and managers from a wide range of agencies	Plankton, benthos, fish, seabirds, sea mammals, space for energy projects	Open oceanic areas within Norway's economic exclusive zone	Convention on Biological Diversity (Agenda 21), the OSPAR treaty (Convention 1992), and "soft law" arrangements like the WSSD 2002 Johannesburg Plan of Implementation (UN, 2002)
Management plan for Central Spitsbergen, Svalbard	Regional	Svalbard archipelago, Arctic Ocean	Norwegian territory, governor of Svalbard, holistic, multi-sector planning and development rooted in the precautionary principle	Multiple sectors, local business communities, innovation Norway and the Research Council of Norway to attract more activities and actors, tourists, scientists, students	Arctic landscapes, geopolitical setting, with existing facilities for permanent communities, research facilities	Arctic ecosystem, including coastal ecosystems	Svalbard Treaty (1920), co-localization of permanent Norwegian (Longyearbyen) and Russian (Barentsburg) communities
Arendal & Asker inter-municipal plan for Raet National Marine Park	Regional	Skagerrak Strait and Kattegat Sea, urban outflows of freshwater from Oslo, Drammen and Kristiansand	Managed by National park regime (Nature Diversity Act), inter-municipal marine spatial plans	Local business owners, farmers, citizens, tourists, researchers, children	Recreational areas for boating and fishing, fish, lobster, crabs, Flødevigen Research Station, Blue Competence	Coastal ecosystem with islands and skerries and related wildlife	UN Agenda 2030, economic strategy of sustainable tourism, Innovation Norway

					Center in Southern Norway		
Andøy municipality: Developing projects to attract tourists and high-tech jobs	Local	Northeast Atlantic Ocean, Lofoten islands	Local, municipal spatial plans	Local business owners, fishers, researchers	Geographical location of building projects, natural spaces, marine and coastal flora and fauna	Coastal landscape with close proximity to continental shelf ecosystem	UN Agenda 2030, need for influx of new citizens and economic growth

Social-Ecological System framework (Table 27.1). The mapping illustrates the contextuality and complexity in localizing SDGs in a SES framework, requiring thorough understanding of the relevant system and its sustainability challenges. Further, in facilitating localization of the SDG, we ask if academic interaction is a way forward, illustrated by interaction in the Andøy Municipality.

3 Localizing at the National and Regional Marine and Coastal Management Level

3.1 Background: Coastal and Marine Planning in Norway

Coastal zones, as hot spots of high human pressure and activity, exemplify the relevance of all the 17 SDGs. Coastal landscapes intersect Life on land (SDG 15) and Life below water (SDG14). In Norway, land-use planning, integrated coastal zone planning, and not least, marine or maritime spatial planning are all instruments that aim for trans-border management of different economic sectors.

Planning is a public process of analysing and allocating the spatial and temporal distribution of human activities in areas to achieve ecological, economic, and social objectives that have usually been specified through a political process.[4] Norway has adopted several planning acts, such as the Norwegian Land-Use Planning Act[5] that is, with few excemptions, cross-sectoral, as municipal land-use plans are political guidelines for planning across sectors. Coastal planning is delegated to the municipal level and is legally binding for future land use. The legislation aims for sustainable development but there is no mention of the SDGs. Norway, which is not a member of the European Union but is a member of the European Economic Area (EEA) agreement, has implemented the EU Water Framework Directive (EU, 2000)[6] but abstained from the Marine Strategy Framework Directive[7] and the Maritime Spatial Planning Directive.[8]

Norway has signed the Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic, OSPAR) and the Convention for Biological Diversity and other international instruments of relevance for nature protection.

[4] See The United Nations Educational, Scientific, and Cultural Organization (UNESCO) definition in relation to Marine Spatial Planning http://msp.ioc-unesco.org/about/marine-spatial-planning/

[5] «Lov om planlegging og byggesaksbehandling (*Plan og bygningsloven)*» 27 June 2008 nr 71.

[6] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

[7] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056

[8] Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014; https://eur-lex.europa.eu/eli/dir/2014/89. For the background for not implementing these directives, see further details in Schütz, S. E. (2018). Marine Spatial Planning – Prospects for the Arctic, section 4. *Arctic Review*, *9*, 44–66. https://doi.org/10.23865/arctic.v9.899

These agreements become most relevant in planning for special natural site that include the Arctic territory of Svalbard and the oceanic Ecosystem-Based Management Plans outlined in the next section.

3.2 Localizing at the National Level-Integrated Ecosystem-Based Management Ocean Plans in Norway

Norway has jurisdiction and management responsibility for one of the world's most productive coastal and oceanic ecosystems. The Ecosystem-Based Management (EBM) Ocean Plans were officially established to safeguard marine ecosystems and long-term value creation, to ensure that activities in the area do not threaten natural resources or opportunities for future value creation (Ministry of the Environment, 2014–2015). Goals were set for biological diversity, economic value creation, pollution, seafood safety, and acute oil pollution risk (Olsen et al., 2007). An underlying aim was to reconcile petroleum development with environmental concerns and fisheries (Olsen et al., 2016).

The strength of the Norwegian EBM Ocean Plans are the cross-sectoral committees, offering communication and direct discussions between scientists and managers from a wide range of agencies (Hoel & Olsen, 2010). Each meeting includes scientific presentations improving holistic understanding of social-ecological complexity. But the EBM Ocean Plans have no legislative standing (Hoel & Olsen, 2010). The laws regulating human activities are split between sectors (petroleum, fisheries, environment, shipping). Keeping the regulations within each sector allows for efficiently implementing regulations but counteract inter-related considerations (Hoel & Olsen, 2010). Each agency makes decisions that are not always in line with the ecosystem-based approach. The SDGs were briefly introduced, but not integrated, in the EBM Ocean Plan 2020 update.

3.3 Localizing at the Regional Level, Svalbard and Raet National Park

The Management Plan of Central Spitsbergen builds on the main goal of conservation of Svalbard's distinctive Arctic wilderness nature through the Norwegian Svalbard policy, cf. No. 32 (2015–2016). The Governor emphasizes that the precautionary principle outlined in the Nature Diversity Act of Norway (2009) is used as a basis for administration of the management plan. At the same time, the government of Svalbard wants to open up for Innovation Norway and the Research Council of Norway to be able to support new establishments and development of projects in Longyearbyen to a greater extent. However, neither the SDGs, nor Coastal zone management planning is addressed in these overall documents, although holistic planning is the main goal.[9] The EEA agreement does not apply for Svalbard, and the Water Framework Directive is thus not implemented.

An example of localization of the SDGs through regional processes is the development of Raet National Park along the southeast coast of Norway, in Agder County. Raet coastal area was first established as a landscape protected area regulated in the overall spatial plan in Arendal Municipality. In 2013, the Governor of Agder County (the state's representative in local counties, responsible for monitoring the decisions set out by the Storting and government) and the mayors in the adjacent municipalities agreed to start the process of regulating it as an intermunicipal national park. More than 60 organizations, business actors, landowners, and farmers participated in the process. In November 2016, Raet National Park was regulated according to the Norwegian Biodiversity Act. Raet is also anchored in coordinated municipal spatial plans, and further managed according to the establishment of the "Blue Growth Agder"[10] collaboration. Innovation and business opportunities are addressed through a holistic and knowledge-based approach, building on co-creation with the Institute of Marine Research, the Norwegian Institute for Water Research (NIVA), Grid Arendal and the University of Agder, guiding and motivating entrepreneurs to development and innovation for greater utilization of marine resources in a way that reduces the risk of negative environmental consequences. Arendal is now being certified as a sustainable tourist destination according to Innovation Norway and UN indicator regulations.

These sites and analyses demonstrate that the Norwegian municipalities in Raet National Park have underscored the importance of co-production of resource management plans across multiple sectors and multiple knowledge holders (classified as *Users,* in Fig. 27.3) when it comes to localizing the SDGs. Even though the planning work that took place in Central Spitsbergen could have addressed ways to act on the SDGs the actual work started later. The Local Council in Longyearbyen started the implementation of the UN's sustainability goals through adopting "From global goals to local action in Longyearbyen" into the "Planning Strategy 2020–2023". Participation from the local community and the Longyearbyen local council enabled the preparation of strategies for achieving the SDGs and implementation of concrete measures that support the goals.[11]

It is striking that the EBM Ocean Plans do not include integration of the SDGs. But at the national level in Norway, the different ministries have divided the SDGs among themselves and according to their specific mandates. Thus, there is a lack of cross-sectoral understanding of the goals at the national level (Lundberg et al., 2020) which is evident in the EBM plans. The EBM Ocean Plans are developed in uneven cyclic phases. Systematic delay may not explain the lack of inclusion of SDGs, as they are still not part of the preparations for the next EBM Ocean Plan revision.

[9] https://www.regjeringen.no/no/dokumenter/innovasjon-og-naringsutvikling-pa-svalbard/id2671061/

[10] http://en.south-norway.no/south-norway/bluegrowt/

[11] Longyearbyen Lokalstyre Nov 16 2020, ref. 2020/1066-8-000.

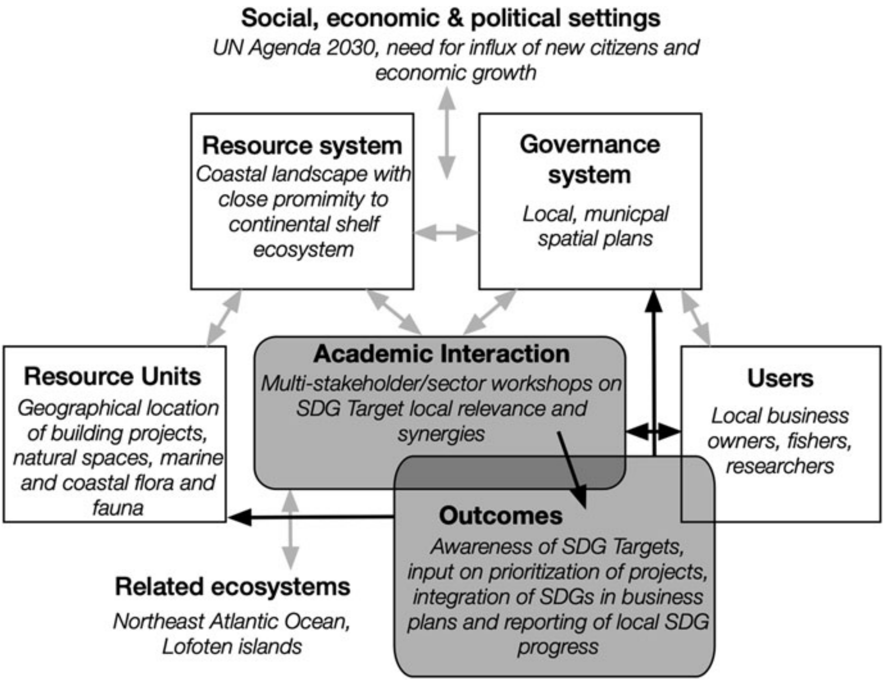

Fig. 27.4 The local SES framework (shown in white boxes with light grey arrows, see Fig. 27.1) contextualized with the local Andøy Muncipality case of sustainable coastal development. The academic interaction of Dankel et al. (Sect. 27.4, this chapter) and its outcomes indicated in the grey boxes and the solid black arrows indicate interactions that resulted from these

Otherwise, we recognize that the temporalities of the Governance System affect localization: municipalities in Norway plan in cycles of four years[12] which could cause delays in implementing new values and policy goals. The last local election was in 2019, making 2020 the year for developing new planning strategies in the municipalities. Already in 2019, we saw some of the SDGs reflected in national planning guidelines (required under the Land-Use Planning Act Section 6-1), guidelines for the years 2019–2023 (Ministry of Local Government and Modernization, 2019). But due to the time lags of local election and planning strategy processes, we see an urgent role for academic interactions. (Fig. 27.4). This observation is also shared by the Norwegian status report of SDG localization (Lundberg et al., 2020) and Leal Filho et al. (2020). This leads us to our last site, Andøy Municipality where members of the author team are testing academic interaction as means for fueling localizing SDGs.

4 Localizing the SDGs at the Local Level with an Academic Interaction Within Andøy Municipality

4.1 Background

The cases of marine and coastal planning management in Sect. 27.3 show that the SDGs are of national concern in Norway but that little is happening at lower scales of governance. In this section, we focus on field data from Andøy Municipality to begin to explore how broader localization can occur.

In a project funded by the Research Council of Norway,[12] an interdisciplinary interest in localizing the SDGs in the ecological-cultural heritage sites of Lofoten, Vesterålen and Senja led to the unique case of Andøy Municipality (Andøy Kommune). The municipality of Andøy is located in the archipelago in Nordland county in the north of Norway (population 4588 persons[13]). The region is known for its role in the traditional Northeast Arctic cod fishery, an annual million-dollar industry, and for its whale and sea bird safaris that attract international tourism. The Andøya military Air Station also has had an important presence in the community since 1957, as well as the Andøya Space rocket range since 1962.

4.2 New Developments for Andøya

In 2018, the Andøya Space started planning for an expansion to their facility, which is designed to be Europe's first launch base for commercial satellites. Another significant development in the island municipality is the innovation-based salmon producer Andfjord Salmon AS, which is building a large-scale recirculation aquation system for a land-based production of approximately 10,000 tons of Norwegian salmon per year. Traditionally, the production in Norway has been sea-based, but environmental challenges, particularly in relation to seal lice contamination to wild salmon, hinders further growth in sea-based salmon production. And lastly, to promote education-based tourism on the island, the municipality is building a world-class museum and cultural centre called "The Whale", which is scheduled for completion in 2023.

These three ambitious development plans for the small area of Andøya coincide with a closure of the military Air Station. In 2016, it was decided to relocate the Andøya military Air Station, a civilian and military airport that is the workplace for more than 300 people on the island. The loss of the military workplace, and the national trend of population emigration from the rural districts of Norway to larger cities (Leknes & Løkken, 2020), has created a challenging situation for Andøy

[12] https://sdg.w.uib.no/

[13] https://www.ssb.no/kommunefakta/andoy

Municipality. The socio-economic predictions for the municipality are population loss of 87 persons by 2030 and 253 persons by 2050 (Statistics Norway, Leknes & Løkken, 2020). As a result, these three projects have the potential to add to the reverse of this trend with their projected growth being around 500 new employees.

4.3 How Can Sustainable Development Be Localized for Andøy Muncipality?

The first part of a so-called academic interaction consisted of a series of qualitative interviews with representatives of local businesses starting in January 2020. Through these interviews, it became clear that these businesses struggled to understand the full implications of the SDGs, beyond using them in a superficial way:

> *You can say sustainable as much as you like and you can have the SDG pictures, it's a nice downloadable file so you can put it basically anywhere and just say. . .of course we're going to be sustainable. But if you don't really mean it then it's just advertising. (Interviewee 5, Stakeholder Interview, 3:39, 2020-11-23, Zoom)*

This problem is compounded by the fact Norwegian businesses do not have any clear strategic plan from the government on how the SDGs could, and should, be incorporated into businesses. Much like how the struggle of implementation rests with individual countries for the SDGs themselves, businesses are expected to find their own way of incorporating the SDGs. Given the complex and, at times, contradictory nature of the SDGs, this can stop efforts before they even begin:

> *I think because for many businesses, they struggle to understand how to work with sustainability and how to incorporate it in their business. (Interviewee 1, Stakeholder Interview, 2020-11-16, Zoom)*

These results point to the need for clear and comprehensive guidelines for local businesses to begin exploring what the SDGs might look like in their business plans. Andøy municipality recently established a restructuring programme (*SAMSKAP)* that grants funding to innovation-based projects and businesses in the municipality. The general aim of the programme is to encourage social and economic growth on the island, but it has also adopted an unofficial role of integrating the SDGs into local businesses. For instance, the application for funding from SAMSKAP requires applicants to describe which specific SDGs their businesses relate to or will help achieve. While this is not a major factor for bringing the SDGs to Andøya, it does illustrate a certain awareness of the municipality on the SDGs and an attempt on their part to influence local development to be more in line with the SDGs.

4.4 Next Steps Towards Localization of the SDGs: Example from Andøya

Cross-sectoral localization of the SDGs is the focus of the next stages of the academic interaction in Andøya. Detailed mapping of the social-ecological system of Andøya, further refined with a social network analysis of key actors on the island, feeds into the development of a method called “SDG Target Relevance-Tracing” which we have prototyped with the three actors involved in major development projects on the island of Andøya. To achieve this, first a meeting was held with each representative *User* to determine which of the 169 SDG targets were relevant for each business. A map where the common targets across these three *Users* was shared. Finally, a multi-stakeholder workshop was moderated to discuss local synergies among the identified common goals that could be put into play at the municipal level. It was clear that this academic interaction on localizing the SDGs was a necessary step; the multi-stakeholder workshop was the first meeting of these local representatives. The result of the workshop was an understanding of the clear commonalities of SDG Targets each of these unique businesses have. The stakeholders agreed that speaking with one voice, instead of three separate voices, in regards to preferences in prioritization of municipal decisions based on the SDG Targets is a wise strategy. And finally, the stakeholders acknowledged their new awareness of not just their own relevant sustainability targets, but also how much overlap these relevant, localized, SDG Targets among the other stakeholders there is. This gives a solid foundation for further interactions at the local level.

5 Conclusion: Steps Forward for Systems Thinking and Localizing the SDGs

In this chapter, we have reviewed how a selection of marine and coastal landscapes of Norway, illustrated by four cases, grapple with the realisation of global sustainability as put forward in the SDGs. Marine coastlines are under growing pressure from increased human activity and exemplify the relevance of all the 17 SDGs. Sector-based and divisive management approaches in Norway have implications for SDG localization. Divisive management approaches will only keep affecting small pieces of the SES system. Further, the lack of national drivers for localizing SDGs, in combination with inherent time lags in the management system, makes localizing progressing slowly.

From a local-to-global approach we need mechanisms that help bridge sectors in order to become truly holistic. Without a common strategy for all sectors at all governance scales (national, regional, and local), sustainability efforts for each of the 17 goals will remain fragmented with minimal impact. Putting this in terms of

Ostrom's framework, sectorisation among the *Users* and *Resource units* and lack of holistic perspectives highlights a general problem for management within the *Governance system.*[14]We find that using Ostrom's Social-Ecological Systems framework allowed us to identify important social and ecological interrelations that shape the process of localization of the SDGs in these four examples. The case of Raet National Park illustrates that the Norwegian management system is flexible enough to facilitate localization of the SDGs through co-production of resource management plans across multiple sectors and multiple knowledge holders. Localizing with academic interactions in Andøya is work in progress, but has already proven as a complementary way forward.

These experiences of localizing SDGs are also relevant in other parts of the world, although the impacts of national, regional and local governance systems always need to be contextualised. As pointed out by several international reports, the need for strengthened localization process frameworks in order to reach the SDGs are increasing rapidly.[15] But considering the ever-shortening timeline of Agenda 2030 and the earliest systematic local planning not expected until after the Norwegian local elections in 2023, localization of the SDGs might turn out as a venture both urgent and overdue.

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[14] https://www.riksrevisjonen.no/rapporter-mappe/no-2020-2021/undersokelse-av-styring-av-og-rapportering-pa-den-nasjonale-oppfolgingen-av-fns-barekraftsmal/

[15] https://unhabitat.org/voluntary-local-reviews-are-changing-the-way-we-think-of-sdg-localization-and-the-approach-to-the

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Chapter 28
Coastal-Marine Ecosystem Accounting to Support Integrated Coastal Zone Management

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Significance Statement Coastal and marine ecosystems face historical deterioration worldwide. This negatively affects the provisioning of ecosystem services to society. The UN has recently approved a statistical standard for ecosystem accounting to measure the contribution of ecosystem services to the national economy and track changes in the value of naturel capital. It has been suggested that ecosystem accounting can also be used to support policy and management at regional and local level. This study presents an exploratory assessment of ecosystem accounting's role in supporting integrated coastal zone planning using the Oslofjord in Norway as a case. We discuss how ecosystem accounting, and ecosystem service use and monetary accounts in particular, could be useful to support various aspects of integrated coastal zone planning, nature conservation and financing.

Keywords Ecosystem accounting · Coastal and marine ecosystems · Integrated coastal zone management · Oslofjord

1 Introduction

Ecosystem accounting aims to identify the contribution of ecosystem services to the economy and the impacts on ecosystems from economic activities (UNCEEA, 2021). In March 2021 the UN Statistical Commission adopted the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) providing a statistical standard for physical ecosystem accounts and their integration in reporting for the national accounts.[1] The expectations are high: UN secretary-general

[1] https://www.un.org/en/desa/un-adopts-landmark-framework-integrate-natural-capital-economic-reporting

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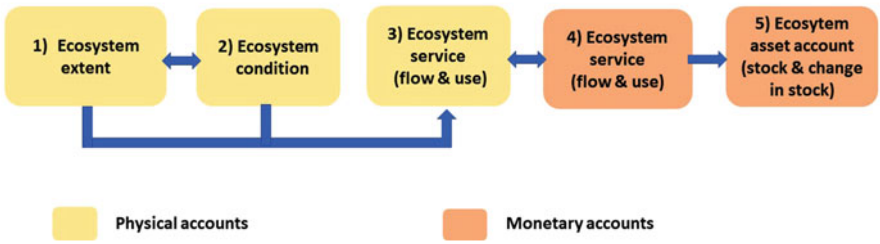

Fig. 28.1 The five core accounts in the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA). (Adapted from UNCEEA, 2021)

António Guterres called it "(. . .) a historic step forward towards transforming how we view and value nature. We will no longer be heedlessly allowing environmental destruction and degradation to be considered economic progress." SEEA EA aims to periodically report on (1) physical ecosystem extent, (2) biophysical indicators of ecosystem condition, (3) biophysical flow of ecosystem services supply & use, (4) monetary valuation of ecosystem services flow, and 5) the monetary value of ecosystem assets.[2] The physical accounts (1–3) are a UN statistical standard, whereas the monetary accounts (4–5) are recommendations that follow recognized national accounting practices, subject to further testing before they are adopted as a standard (Fig. 28.1).

As statistical standards that is compatible with the system of national accounts, SEEA EA provides a tool to identify ecosystems' contributions to the national economic development as measured by e.g. GDP. Application in support of policy development at the national level has been a key motivation for the framework. Guidance on thematic accounts for e.g. climate, biodiversity, oceans and urban areas is also provided. The novelty of Ecosystem Accounts (EA) relative to previous Environmental and Economic Accounts, is that reporting is both tabulated and mapped. As the data collected are spatial, it may also be used at sub-national geographic levels of aggregation. SEEA EA at sub-national level could aim to assess multi-period change in habitat extent and condition in a region or municipality, assess effects on ecosystem services supply, correlate with past implementation of local policies on the ecosystems, in order to support future decision-making on financing of measures (UNCEEA, 2021). Accounts provide a consistent historical reporting, in order to support forward looking methods and decision-support tools such as cost-benefit analysis, risk assessments, scenario analysis and trade-off analysis (UNCEEA, 2021). A global ocean account partnership[3] has been formed to facilitate ocean ecosystem accounting. However, coastal and marine ecosystem accounting is still in its infancy (Chen et al., 2020). The main interest so far has been to consider the ocean as a contributor to national wealth. However, many decisions affecting the oceans are taken at lower levels than the national. Decisions in the

[2] Discounted flow of benefits from ecosystem services

[3] https://www.oceanaccounts.org/

coastal zone affect the marine environment, challenging spatial accounting boundaries. Thus, there is a need to develop accounting methods that can provide inputs to regional level coastal-marine spatial planning, integrated coastal zone management and resource management. In this chapter, we study the preliminary efforts to integrate ecosystem accounting into a plan for the Oslofjord in Norway. The plan includes the fjord and a 100-meters belt of the shoreline, thereby sharing characteristics of integrated coastal zone management (ICZM). The study is based on the existing ecosystem service literature and public hearing documents for coastal zone planning of the Oslofjord. Ecosystem accounts that can be used to support ICZM should have a different spatial scale than that mentioned in the thematic ocean accounts. The chapter is among the first to assess how ecosystem accounting can provide decision-support to Integrated Coastal Zone Management (ICZM).

Several recent systematic reviews have called for further research on processes that may facilitate uptake of physical ecosystem service assessment and monetary valuation in decision-making (Laurans et al., 2013; Lautenbach et al., 2019; Mandle et al., 2021). Ecosystem accounting partly identifies plural values through spatially explicit biophysical as well as monetary indicators of ecosystem services. This resonates with calls for integrated valuation and value pluralism in decision making (Jacobs et al., 2016; Pascual et al., 2017). The Convention on Biological Diversity (CBD) refers to the valuation methods in The Economics of Ecosystems and Biodiversity (TEEB; Kumar & Martinez-Alier, 2011) and SEEA EA as tools for achieving post-2020 targets of integrating biodiversity valuation in planning and reporting (CDB, 2020). The Dasgupta Review (HM Treasury, 2021) identifies the need for using multiple valuation methods reflecting inclusive wealth in planning and policy.

2 Integrated Coastal Zone Management in the Oslofjord

Figure 28.2 shows the Oslofjord and the municipalities located along the fjord. It is Norway's most populated fjord with about 1.6 million people (1/3 of the national population) and has experienced significant population growth in the recent decades. The Oslofjord faces historical deterioration of ecosystem condition. The more densely populated inner fjord has the least amount of publicly accessible coastline in Norway due to private property development (NEA, 2019). Coastal water chemical condition is "poor" and ecological condition "moderate" in most of the inner fjord according to Water Framework Directive (WFD) standards (NEA, 2019). Stocks of two coastal cod species historically important for commercial and more recently for recreational fishers have plummeted during the 1990s without recovering, resulting in fishing bans (NEA, 2019). Seagrass has declined in inner fjord and kelp has been lost in outer Oslofjord (Christie et al., 2019; Moy & Christie, 2012). There are increasing conflicts of interests among economic developments along the coastline, nature conservation and the recreational use of the fjord. In a public hearing in 2018, the priority environmental problems identified by the stakeholders

Fig. 28.2 The Oslofjord and activities around the fjord. (**a**) map of Norway (naturbase.no), (**b**) Skyline view from the inner Oslofjord, (**c**) A family in their sailing boat in the fjord, (**d**) Camping site on an island in the outer Oslofjord, (**e**) Map of the Oslofjord (naturbase.no), (**f**) A sign marking the coastal trails, (**g**) People fishing along the fjord, (**h**) Crowded coastal real estates in the inner Oslofjord, (**i**) People bathing in the fjord. (Source: Chen et al., 2019)

included eutrophication of coastal water, coastal real estate development, ship traffic and related accident risks, noise from motorized boats, contaminated marine sediments near harbors, and invasive species such as the Pacific Oysters (Chen et al., 2019).

Due to the importance of the Oslofjord and its deterioration, the Norwegian parliament took the unusual step to request the government to make an Integrated Plan for the Oslofjord (IPO). The first version was published by the Norwegian Environmental Agency in the end of 2019. The proposal covers the inner and outer basins including a 100-meter zone on land, which has a peculiar legal status in Norwegian planning. The goal of the plan is to facilitate cross-sectoral collaboration and to achieve ecosystem-based management of the fjord.

As an input to the planning, the Agency commissioned a knowledge synthesis on the values of the Oslofjord (Chen et al., 2019). The first version IPO plan recognizes the importance and the challenges of ecosystem accounting to support coastal management. Current Norwegian coastal-marine monitoring programs focus largely on ecosystems' extent and conditions, but hardly at all on identifying the supply and use of ecosystem services. Operationalization of ecosystem service approaches remains low 15 years after the Millennium Ecosystem Assessment, both in (i) planning according to the Norwegian Planning and Building Act (Ellefsen et al., 2020), (ii) spatial planning in coastal waters (Kvalvik et al., 2020) and (iii) environmental impact assessments in coastal areas (Hersoug et al., 2019). A lack of guidance and tools on how to use ecosystem service valuation in local planning is known to be a barrier to adopting ES in the coastal planning (Marre et al., 2016), partly due to lacking information platforms to facilitate coordination (Kvalvik et al., 2020). This is a knowledge gap recognized by the IPO (NEA, 2019).

3 Ecosystem Accounting of the Oslofjord (Selected Examples)

The knowledge synthesis on values of the Oslofjord estimates economic values of various ecosystem services including provisioning, regulating and cultural services. The monetary values for various ecosystem services in the Oslofjord were compiled using existing literature. Table 28.1 shows a bridging table between accounting compatible exchange values and welfare values of ecosystem services, reporting valuation results for provisioning, regulating and the cultural services that could be valued with available data.

A bridging table is recommended by the SEEA EA as a way for statistics compilers to reference welfare values *complementary* to the national accounts (p.252, ch12). Welfare values for a regulating and cultural services are often larger than exchange values because they are *unrealized* (p.252, ch12) by existing economic institutions which are the basis for historic accounts. Welfare values are complementary decision-support because they can be internalized in prospective policy analysis. The light green and brown shadow in Table 28.1 (the first row) indicate methods that are compatible with SEEA EA standard, while those with light

Table 28.1 Bridging table between accounting and welfare value of ecosystem services: valuation methods and accounting compatibility

Ecosystem service	Sector interest	Inner Oslofjord (assessed)	Outer Oslofjord (assessed)	Market price (mill. kr./yr.	Time value (mill. kr./yr)	Maintenance cost (mill. kr./yr)	Capital cost (mill. kr./yr)	WTP (mill. kr./yr	Cost of measure (mill. kr./yr)	WTP (mill. kr.)	Cost of measure (mill. kr.)
Provisioning	Commercial fishing	yes		25							
Regulating	Carbon storage kelp, seagrass	insig.	yes	10							
Cultural services	Tourism	yes		209							
	Bathing and walking, market substitute	yes	yes	10657							
	Bathing, walking & boating	yes	yes		25718						
	Boating, maintenance	yes	yes			2595					
	Boat and fjord access	yes	yes				2104				
	Residential view and access amenities	yes	yes				1500				
	Recreational fishing	yes						312			
	Water quality for recreation	yes	yes					4350			
Costs of measures	Sewage treatment	yes	yes						2730		
	Sediment remediation	yes	yes							1279	
	Oil spill remediation	yes	yes							1546	
	Sediment remediation	yes	yes								406

Note: Market price – Values estimated with market prices include: Time value – opportunity cost of time, Maintenance costs – expenses related to keep up and maintain the boats, Capital costs – investment costs, WTP – Willingness to pay, Cost of measure – direct economic costs related to measures to improve sewage treatment and soil remediation; Kr. = Norwegian krone. (Source: Adapted from Chen et al., 2019)

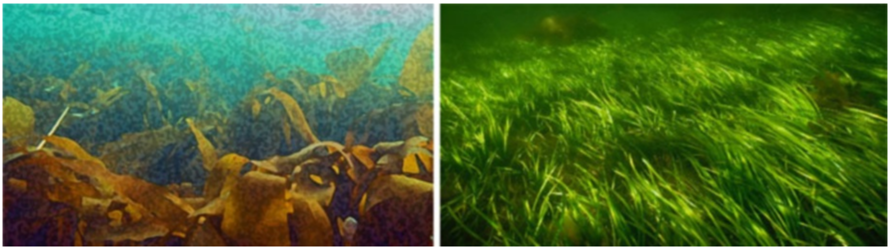

Fig. 28.3 Kelp forest (*Laminaria Hyperborea*) and seagrass (*Zostera marina*). (Foto: NIVA)

red are not. For example, cost of sewage treatment and sediment remediation are estimated using market price and are accounting compatible. On the other hand, beach habitat value is estimated using the willingness-to-pay to avoid oil spill remediation which as a welfare measure is incompatible. Nevertheless, both approaches offer complementary perspectives on values of the Oslofjord which are relevant for policy and planning.

The value of provisioning services is estimated using the market price of commercial fishery. Recalling the historic decline in fish stocks, there is only limited commercial fishery in the outer Oslofjord and the market value in 2019 was relatively small. For regulation services in Table 28.1, the focus is on the blue carbon regulating services (Chen et al., 2019). The seagrass and kelp forest have suffered degradation in the inner Oslofjord due to for example eutrophication and siltation. Figure 28.3 shows the kelp forest (*Laminaria Hyperborea*) and seagrass (*Zostera marina*) that can be found in the Oslofjord.

Coastal monitoring programs have followed trends in the extent of the two habitats. Recent research has focused on the carbon regulation function of the two habitats (e.g. Frigstad et al., 2021). The values of carbon regulating services were calculated directly from the extent data using the social cost of carbon and carbon price from the EU Emission Trading System (ETS) market. While both approaches are consistent with SEEA EA exchange value concepts, the value from EU ETS market is much lower than the value estimated by social cost of carbon.

Cultural services have the highest monetary values of all ecosystem services reviewed by Chen et al. (2019). Examples of recreational activities along the fjord are shown in Fig. 28.1. The value for tourism is estimated by cruise payments and the cabin fees. The recreational values for coastal trails, boating and beach bathing were calculated using the market substitutes and the opportunity cost of time. The value estimated from market substitutes for bathing is much higher than the opportunity costs of time in travel and on site. Both methods are SEEA EA compatible, although the opportunity cost of time is subject to strong assumptions about labour-leisure opportunities, so we have reported it separately. For values of recreational boating, investment cost and operational costs are used for motorized boating and the opportunity costs of time are used for non-motorized boats. Value of residential view and access to amenities is calculated using the hedonic property pricing method. The hedonic property pricing method relies on market price for real estate properties with different environmental amenities to determine the implied value or implicit price of the environmental amenities (Champ et al., 2017). Value for recreational fishing is estimated using welfare-based value transfer from the freshwater recreational fishing estimates. Values for improved water quality for recreation were calculated using both sewage treatment costs and welfare-based choice experiment. Choice experiment method is a non-market valuation method. In this case the respondents were asked to choose between various pair of attributes for water quality, water related recreational activities and the payments. The marginal willingness to pay can be estimated for each attribute and for the various bundles of attributes (Adamowicz et al., 1998; Champ et al., 2017). The estimated willingness to pay is a welfare measure.

In the SEEA EA global consultation draft (UNCEEA, 2021), a similar bridge table between accounting and welfare value of ecosystem services is provided (Table 12.1 in UNCEEA, 2021). It assumes that for each service there is only one exchange value compatible method and only one welfare compatible value. It also assumes that ecosystem services can be uniquely identified. A broad lesson from Table 28.1 is that available valuation studies and statistics cover different geographical areas, and portions of cultural and regulating services which are partly overlapping. Different accounting compatible and incompatible valuation methods mean that all estimates cannot be aggregated. Table 28.1 highlights the challenge of standardizing monetary valuation for ecosystem accounting using only available data generalized to the accounting area using value transfer methods. It demonstrates the need for primary valuation methods implemented for the specific purpose of compiling accounting compatible monetary values. Crucially, this includes monitoring of physical supply and use, and in particular recreation, given indications of its high value in the Oslofjord.

4 Uptake of Ecosystem Accounting in ICZM of the Oslofjord

4.1 Ecosystem Accounting Purpose, Scale and Resolution

EA has high requirements for spatially explicit periodic data. While marine ecosystem extent data is available spatially, much of the ecosystem data still needs to be downscaled at finer geographical levels. In general, marine ecosystem may have larger uncertainties related to regime shifts and more spatial diffusion through currents, resulting in non-linear supply of ecosystem services across larger areas than for terrestrial ecosystem. Ecosystem based management has aimed to tackle the fragmented management across administrative borders. This results in institutions and cross regional collaboration that can integrate coastal-marine systems (i.e. ICZM including land-sea interactions) in a larger unit to manage the dynamic and spatially diffused ecosystem.

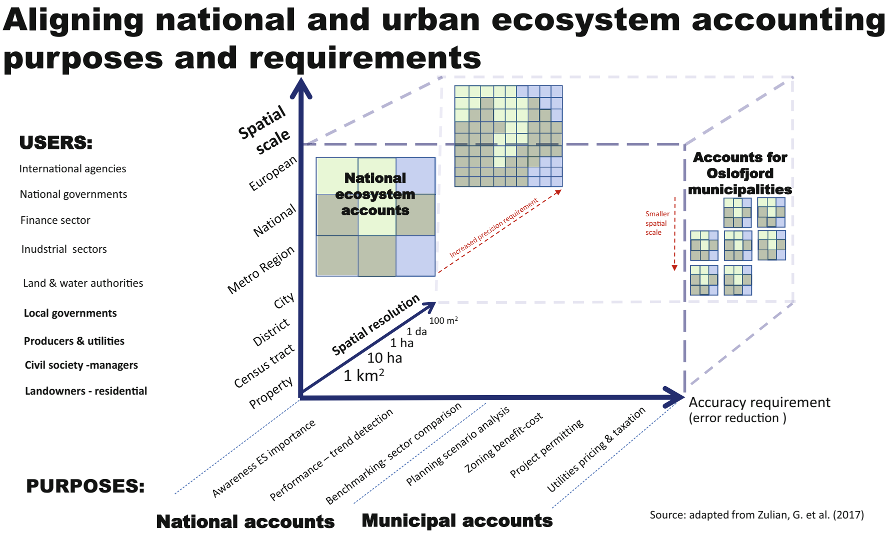

Fig. 28.4 Precision differential between biophysical and monetary accounts. (Source: adapted from Zulian et al., 2018)

The need for spatial data and its resolution varies across regions, users and purposes of ecosystem accounting. Figure 28.4 outlines how different purposes of ecosystem accounts and their users may have different requirements for reliability of ecosystem accounts. It illustrates that costs of accounting information increase with scale, resolution and reliability requirements of purposes and users. Reliability requirement is understood here as the requirement to reduce measurement and modeling error to a level where e.g. trends in ecosystem service flow can be identified with statistical confidence. Reducing measurement and modeling error requires more data and effort, which implied higher information costs.

Figure 28.4 illustrates our overall experience in the Oslofjord – likely to apply to many coastal sites – that there is a precision differential between existing data on physical ecosystem extent and condition and available valuation estimates. Figure 28.4 also illustrates that landowners will require higher resolution of biophysical or monetary values when making plans for their properties, compared to municipal master plans or higher levels of planning and policy making. For example, the real estate agency will need values for the area of the new estate development, while the municipality will focus on the coastal zones that are located within their administrative area. Real estate developers and costal municipalities will need relatively high-resolution data for public purchase of private estate in the coastal zones. The requirements for the resolution and scale vary with other policy analysis purposes (I-III) to which ecosystem accounting may be applied. While a primary purpose of ecosystem accounting is to identify annual trends in the flow of ecosystem services, temporal resolution of remote sensing-based and environmental monitoring data is often greater. On the other hand, slow ecosystem change may not be detectable at high temporal and spatial resolution. The resolution of physical use and economic data is usually lower than that of environmental monitoring. Therefore, the choice of accounting resolution therefore needs to strike a balance between the benefits and costs of increased resolution for physical and monetary accounts, relative to the reliability requirements of the specific accounting purpose.

4.2 Transaction Values Versus Welfare Values

Grimsrud et al. (2020) argue that the ecosystem extent and condition, ecosystem service use, transaction values and economic welfare indicators of ecosystem service can be regarded as parallel channels that contribute to the regional planning, or in the context of this paper marine spatial planning and ICZM in the marine context. Table 28.1 shows that transaction values, estimated using market price, can be much lower than the welfare values derived from non-market valuations such as choice experiments and contingent valuation. Only transaction values are compatible with core accounts in the SEEA EA standards. As not all ecosystem services are traded in the markets, the bridging Table 28.1 shows that transaction values measured as ecosystem contributions to the economy (in the sense of SNA) represent only a partial valuation of ecosystem service contributions to people. From the perspective of ICZM it is important to allow for value pluralism for decision making, awareness raising and fund raising. The plural values include transaction values-SEEA EEA approach, welfare values, and biophysical and qualitative indicators.

4.3 Uptake of Monetary Ecosystem Accounting in Norwegian Coastal Planning

The IPO, sharing characteristics with ICZM, is an independent and unique strategic plan. The major mechanism for the successful implementation of the IPO is for the national government to engage in close collaboration with the municipalities and counties in the Oslofjord region. Key areas for collaboration have been identified such as outdoor recreation, spatial planning (including planning for habitat conservation and marine protected areas), wastewater treatment, local agricultural management. Collaboration between the three political-administrative levels in Norway (i.e. national, county and municipality, each with various sectorial responsibilities) is institutionalized in two relevant planning systems: the spatial planning and the ecosystem-based management. Spatial planning, involving municipal master plans covering land and sea, zoning plans and building permissions, is primarily the responsibility of the municipalities. Ecosystem-based management of freshwater and coastal waters according to the Water Framework Directive is primarily the responsibility of the counties which work through water basin authorities. In these plans, political decision-makers balance diverse interests, give guidance for future developments and adopt action plans. Thus, ecosystem service valuation must be integrated into these types of plans.

There exist several shared databases in Norway for planners providing information about species, habitats and the conditions of ecosystems such as naturbase[4] and vann-nett[5] Ecosystem accounting requires improved data about ecosystems and their condition and a new and coordinated effort in Norway also to integrate ecosystem services. EA offers a standardized framework and links ecosystem services to the change of ecosystems over longer time periods. If shared across administrations involved in spatial planning and water management, EA would increase data and information transparency and could enhance the coordination of local and regional policies (Chen et al., 2020). The common and consistent reporting framework of SEEA EA should make it easier to agree on a shared understanding of the ecosystem, which is a topic that often creates conflict.

Better availability of spatially explicit data on biophysical assets will be an important contribution from EA to improved resource management. Environmental Impact assessments and Strategic Environmental Assessment are important tools that would take advantage of this. In Norway, such assessments are mandatory for spatial plans. While environmental and socioeconomic issues are incorporated in such reports, there has been limited consideration of ecosystem services. Norwegian national regulations on environmental impact assessment specified for the first time in 2020 that ecosystem services must be considered. This will be a main policy driver for getting more data about ecosystem services.

Monetary valuation of ecosystem services has not been widely used in coastal and marine decision making in Norway. However, there are many purposes for which monetary valuation (i.e. EA monetary accounts of ecosystem services) would be important. Conflicts between coastal zone real estate development and public access to the coast is one example. SEEA EA has a potential to provide a common data platform to provide information both on biophysical indicators of impacts on the ecosystem and recreational use values, showing negative and positive effects of the new estate development. The municipalities, which are responsible for planning and issuing building permits, could use the information to weight the financial gain from the new estate development and the potential loss of recreational value and use of the public. Where conflicts between public access to the coastal zone and private estates are high, ecosystem use and value accounts will provide decision support on whether to purchase the private estate to safeguard “the coast for all”, which is a primary Norwegian policy objective. These accounts could also provide a basis for ecological fiscal transfer from national budget to municipality to support nature conservation at the local level.

[4] https://www.miljodirektoratet.no/tjenester/naturbase/

[5] https://www.vann-nett.no/portal/

Another application of EA monetary supply-use accounts of ecosystem services in coastal planning is to support prospective cost benefit analysis (CBA) of policy measures. This will be useful for instance as a basis for the water management plans which contains an action program with measures to ensure the achievement of good ecological status according to the Water Framework Directive. A key challenge in the Oslofjord is to reduce eutrophication caused by sewage and agricultural run-off. Cleaning of sewage will cost billions of kroner for the municipalities (Table 28.1). Similarly, farmers will incur high costs for building e.g. retention basins or set aside cultivatable land as buffer zones. The monetary supply-use accounts for ecosystem services can provide data on historic costs incurred in sewage cleaning and agriculture run off reduction measures, to achieve past eutrophication levels. Exchange values of measures that were recorded in accounts can be complemented in CBA with the welfare measures of willingness-to-pay to achieve water quality objectives, in order to analyze various prospective policy scenarios.

5 Conclusion

Using the Oslofjord as an example, the study presents an exploratory assessment of the role monetary valuation in ecosystem accounting to support integrated coastal zone planning. The study highlights that ecosystem service use and monetary accounts in SEEA EA has a large potential to support the integrated coastal zone planning of the Oslofjord such as Environmental Impact Assessments, Strategic Environmental Assessments and Cost Benefit Analysis. The requirements on the resolution and scale of EA depends on who is the user of the EA and what are the policy targets. Our study also shows that both transaction values measured as ecosystem contributions to the economy and welfare values need to be considered in the coastal zone planning. We found that available statistics on supply-use of ecosystem services and existing monetary estimates were not designed for ecosystem accounting purposes and could not easily be aggregated. However, comparison in bridging tables of different types of monetary values was still considered useful for decision-support.

With the value transfer approach used by Chen et al. (2019) based on generalizing existing data, exchange values were not spatially explicit - monetary values acted as scaling constants for the biophysical use data. In such cases all the information on spatial variation in ecosystem services is contained in the physical supply-use accounts. As long as monetary valuation is based on simply unit value transfer methods, the information value-added of ecosystem accounting for Norwegian environmental governance is mainly in terms of physical ecosystem extent and condition accounting, rather than monetary valuation of ecosystem services. In the Oslofjord there is a lack of spatially resolved physical monitoring of supply-use of ecosystem services. Finally, monetary accounts compatible with the SEEA EA will require monetary valuation studies that are designed explicitly to be part of regular statistics compilation in support of the Integrated Plan for the Oslofjord.

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Chapter 29
Exposure of Coastal Ecosystem Services to Natural Hazards in the Bangladesh Coast

Sanjoy Roy and Daniel Depellegrin

Significance Statement Knowledge about the impacts of natural hazards on ecosystem services is crucial to guide the effective management of ecosystem components in a particular landscape. The coastal landscape of Bangladesh is a source of numerous ecosystem services on one hand and also exposed to natural hazards, especially to tropical cyclones on the other hand. Almost every year the tropical cyclones and associated storm surges cause severe devastation to the ecosystem services in the eastern coastal region of the country. We for the very first time in Bangladesh applied the remote sensing method with the Millennium Assessment technique to map coastal ecosystem service capacity and assess their degree of exposure to the tropical cyclone in the eastern coastal region of the country. Our study identifies the aquatic environments, mangrove and hilly forests having the highest potentials of ecosystem service capacity, which needs to be protected from the natural hazards through implementing appropriate land use and nature-focused disaster management policies for sustainable, equitable, and effective use of the ecological resources.

Keywords Ecosystem services · Tropical cyclone · Remote sensing · Coastal Bangladesh · Ecosystem threats

1 Introduction

Extreme meteorological events, such as tropical storms, hurricanes, and cyclones can cause severe environmental degradation and damage to socio-economic assets (Meixler, 2017). Within these increasing threats also ecosystem services (ES) can be

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exposed to extreme events leading to ecosystem services loss, or temporary impairment of flow and use of the ES (Menegon et al., 2018). In the last decade, an increased amount of literature dealing with ES risk or damage assessment in the context of extreme events was produced. Moreover, the growing use of satellite-based remote sensing and geospatial techniques has brought significant advancement in the field of ES assessment throughout the globe. For instance, for the Indian Ocean Tsunami of 2004 Kaiser et al. (2013) applied remote sensing and GIS techniques to analyze coastal risk to ecological resources on the coast of Thailand. A study conducted by Meixler (2017) analyzed the ES loss caused by Hurricane Sandy in habitats within Jamaica Bay and New York using orthoimagery and land use maps. Another study successfully estimated specific ES loss and recovery in mangrove ecosystems through the assessment of the impacts of Hurricane Charley 2004 on the aboveground carbon stock in Southwest Florida (Peneva-Reed et al., 2020). Despite several pieces of literature on the ES assessment, there is little knowledge for the coast of Bangladesh.

Bangladesh is a coastal state exposed to the Bay of Bengal and is subjected to a number of natural and anthropogenic hazards, which cause substantial damage to the ES every year. Among different hazards, tropical cyclone causes severe damage to the ESs in coastal Bangladesh due to its intensity and recurrence nature.

The aim of this study is to analyze the ES capacity from remote-sensing based land use (LU) detection for the eastern coastal districts such as Chattogram and Cox's Bazar located in the south-east of Bangladesh. The threat to ES provided by LU units will be analyzed for a cyclone database from 1952 to 2017 and administrative units called *upazila* of highest ES loss/impairment will be defined and discussed.

2 Materials and Methods

2.1 Study Area Description

The study area includes the entire eastern coastal region of Bangladesh, which traverses Chattogram and Cox's Bazar districts (Fig. 29.1). Geographically it extends from 20°35′17″ – 22°59′28″ N latitude to 91°16′20″ – 92°21′37″ E longitude and covers 7113 km^2 area, approximately. This region is bounded by the Feni river to the north to Saint Martin's Island to the south and the Bay of Bengal to the west to Chattogram hill tract to the east, which is characterized by heterogeneous landscapes including coastal plain, sandy beaches, marshes, and hills of tertiary origin. Tropical monsoon climate characterized by high summer temperature (≈32.3 °C), high humidity, and sufficient rainfall during the monsoon (≈3000 mm) prevails in the study area (BMD, 2013; Roy et al., 2020). The hilly areas are covered by the semi-evergreen deciduous to tropical evergreen rain forests, whereas the extensive plain land is mostly dominated by different species of homestead vegetation. This region holds 10.16 million populations (BBS, 2011), where a significant

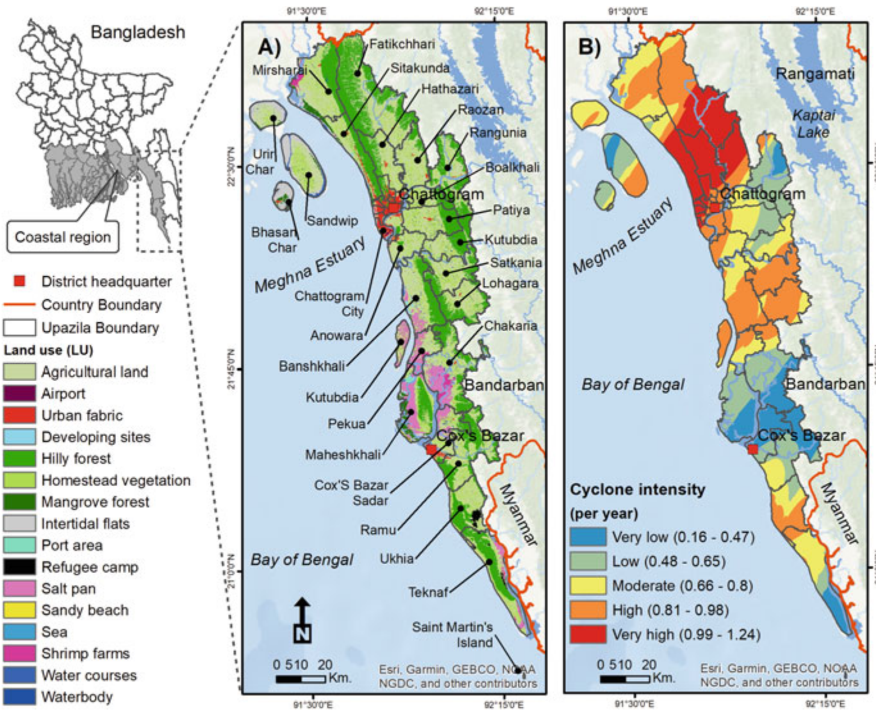

Fig. 29.1 Geographical setting and administrative units of the study area. (**a**) Land uses derived from Landsat 8 Operational Land Imager (OLI) satellite image-based remote sensing technique and (**b**) Cyclone intensity per year per 20 km radius calculated based on cyclone occurrences from 1952 to 2017

portion lives in Chattogram city, the largest port city and the major economic hub of the country. With a number of tourist spots and a 145 km long sandy beach, the longest sea beach in the world, this region is the major touristic part of the country. Diverse LU existed in the region are the sources of different ecosystem services and provide ample benefits to the inhabitants and the natural environment. Among several natural and anthropogenic hazards, this region is highly exposed to tropical cyclones and cyclone-induced storm surges (Hoque et al., 2019). Since 1952 approximately 34 catastrophic cyclones have made landfall in the region, which caused significant damage to ecosystem services with loss of lives and economic properties.

2.2 Extraction of LU Using Remote Sensing

Four cloud-free and near dated Landsat 8 Operational Land Imager (OLI) images were retrieved from the USGS global data hub (https://earthexplorer.usgs.gov/) for

Table 29.1 Properties of the satellite imagery and cyclone data used in the study

Dataset	Years of analysis	Sensor/ sources	Image acquisition dates	Path/row	Spatial resolution
Satellite imagery	2020	Landsat 8 OLI	28-Jan-20	135/45	30 m (visual and infra-red spectral bands)
			28-Jan-20	135/46	
			19-Jan-20	136/44	
			19-Jan-20	136/45	
Tropical cyclone tracks	1952–2017	IBTrACS (International Best Track Archive for Climate Stewardship; http://ibtracs.unca.edu/)			
Cyclone wind speed (km/h)	1952–2017	National newspaper archive (Daily Ittefaq, Daily Prothom Alo, The Daily Star, Jugantor, and The Sangbad); Alam and Dominey-Howes (2014)			

extracting LU of the study area (Table 29.1). The images were subjected to atmospheric correction for obtaining surface reflectance with minimal atmospheric and aerosol effects. Given the higher accuracy, the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube (FLAASH) was applied to the images for correcting them atmospherically (Emran et al., 2018). FLAASH atmospheric correction module is the first-principles atmospheric correction modelling tool that starts with the conversion of image data to at sensor spectral radiance for obtaining surface reflectance through a set of equations (Emran et al., 2018; FLAASH User's Guide, 2006). In the first stage of the atmospheric correction process, the Digital Numbers (DN) of the images were converted to the Top of Atmospheric Radiance (TOA) using the following standard equation (USGS, 2020).

$$L_\lambda = M_L Q_{cal} + A_L \tag{29.1}$$

Whereas, L_λ is the TOA spectral radiance, M_L is the band-specific multiplicative rescaling factor obtained from the image metadata, Q_{cal} is the quantized and calibrated pixel's DN values, and A_L is the band-specific additive rescaling factor.

In the second stage, the FLAASH was applied over the TOA radiance images using the appropriate definition of aerosol model, image properties, Modtran Multiscatter model (FLAASH User's Guide, 2006), and ground elevation. Finally, the output atmospherically corrected surface reflectance images were mosaiced together and used as an input in the LU extraction procedure.

In the study area, 11 dominant LU were identified which were extracted from the surface reflectance image through the hybrid image classification approach (Roy & Mahmood, 2016). In the image classification procedure, the image was first classified into 300 arbitrary classes based on the spectral responses of the pixels using the Iso Cluster Unsupervised algorithm. From these arbitrary classes, 20 spectral signatures for each LU category were selected and thus a set of training samples was developed. In the second stage, this training sample set was used in the Random Forest Supervised classification algorithm to extract the LU for the entire study area. A 3 * 3 median filter was further applied to reduce noise in the classified image. After that, the waterbody was reclassified into three classes (i.e., waterbody, sea, and watercourse) and port areas (i.e., airport and seaport) and shrimp farms were manually defined in the classified LU image as these are difficult to distinguish from the spectral characters of the urban fabric and salt pan, respectively. Thus, 16 final LU categories were obtained from the satellite imagery (Fig. 29.1a), where the overall accuracy of the classification was obtained higher than 90%.

2.3 Calculation of Cyclone Intensity

Spatial tracks of the tropical cyclones that made landfall in the study area between 1952 and 2017 were obtained from the International Best Track Archive for Climate Stewardship (IBTrACS) database. Wind speeds of the corresponding cyclone tracks were collected from the national newspaper archive and Alam and Dominey-Howes (2014). We considered a 20 km radius circle from each track as the maximum impact area of the respective cyclone and thus developed a number of circles throughout the study area. Finally, the intensity of the cyclones in the study area was calculated (Fig. 29.1b) using the circle radius, track length that falls within the circle, and corresponding wind speed according to the following equation.

$$Cyclone\ intensity\ (CI) = \frac{\sum_{k=1}^{k=n} L_k \times W_k}{R_c} \tag{29.2}$$

Where, L_k is the length of cyclone track k that falls in the circle with 20 km radius, W_k is the wind speed of the cyclone track k, and R_c is the radius of the circle (20 km).

2.4 Assessing Ecosystem Services and Threat Exposure

Based on the LUs extracted through remote sensing technique an ES capacity analysis was performed using literature review and expert scoring. According to Villamagna et al. (2013) the ES capacity (ES_{Cap}) is defined as the potential of ecosystems to provide goods and services. A popular approach to analyze and map ES on large spatial scales is to link ES classifications, such as the Millennium Assessment (MA 2005) with LU components into an ES-LU matrix/look-up table (Campagne et al., 2020). The advantage of the ES-LU matrix approach is its applicability in different biomes, e.g., terrestrial (Müller et al., 2020) or coastal marine (Depellegrin et al., 2017), its ability to cover different spatial scales and its ease for communication to decision-makers and non-scientific stakeholders. In contrast to the archetypical ES-LU matrix (e.g., Burkhard et al., 2009) we represent the ES_{Cap} using an alluvial diagram (Fig. 29.2a). The alluvial diagram is organized into ES-ES Categories-LU paradigm that links the ES_{Cap} to the LU of the study area.

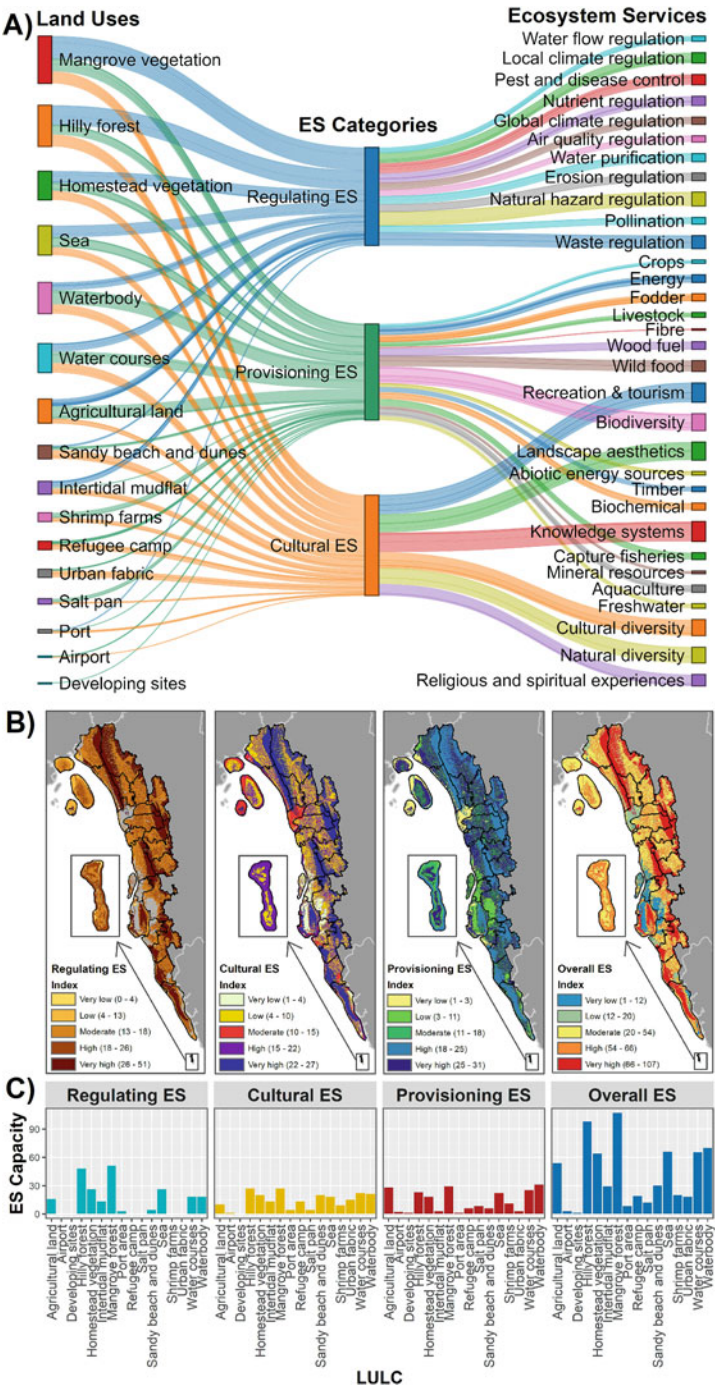

Fig. 29.2 (**a**) Alluvial diagram representing the ecosystem services identified, the ES categories, and the ES_{Cap} of different LU types to support ES provision. (**b**) Geographic distribution of Coastal Ecosystem Services Capacity; (**c**) Average contribution in % by LU to ES_{Cap}

The thickness of the flow bars corresponds to the ES_{Cap} scored from 1 (very low) to 5 (very high). In this case study a total of 16 LUs were identified, which were used to estimate a total 35 ES across three ES categories (e.g., regulating, cultural and provisioning). The following Eq. 29.3 shows the algorithm for ES capacity (ES_{Cap}) calculation as the sum of regulating (R), provisioning (P) and cultural (C) ES.

$$ES_{Cap} = R + P + C \tag{29.3}$$

Some of the past studies demonstrate the assessment of vulnerability of ecosystem services to different natural and anthropogenic hazards using variable methods. For example, Malekmohammadi and Jahanishakib (2017) assessed wetland ecosystem service vulnerability using a driver-pressure-state-impact-response model in south-western Iran; Lee et al. (2017) used storm and sea-level data to assess the vulnerability of mangrove ecosystem to climate change in Mozambique; Depellegrin et al. (2020) calculated marine ecosystem service exposure to anthropogenic threats in Lithuanian sea space using pressure propagation model and threat exposure index; and Willaert et al. (2019) assessed vulnerability of marine and coastal ecosystem services in the western Atlantic coast of Portugal using InVEST habitat risk assessment tool. A similar approach to the present research was used by Stratford et al. (2011) to assess the vulnerability of lake ecosystem services in the Himalayan area of Nepal. Stratford et al. (2011) assessed different values (i.e., ecological, economic, hydrological, social, etc.) provided by the wetland ecosystem services in the study area and considered associated threats (i.e., ecological, economic, hydrological, social, etc.) to calculate the vulnerability of ecosystem services. In this study, we used a 66 years inventory of tropical cyclone data as a threat proxy to assess the exposure of coastal ecosystem services to natural hazards in the Bangladesh coast.

In Eq. 29.4 the method of assessing ES exposure to threats cyclones is defined. We defined the threat exposure as the action of a pressure (the cyclone) on a receptor (the single or multiple ES provided; ES_{Cap}), with regards to the extent (the 20 km area of influence), magnitude (the cyclone intensity score) and the duration of the pressure (Robinson et al., 2008):

$$ES_{threat} = ES_{Cap} \times CI \tag{29.4}$$

3 Results

3.1 Ecosystem Services Capacity in the Coastal Area

Figure 29.2a presents an alluvial diagram linking the ES capacity scores from 1 (low capacity) to 5 (very high), with the LU identified in the study area (Fig. 29.1a). Results indicate that the study area has the highest ES_{Cap} for cultural ES (recreation, landscape aesthetics and knowledge systems) and for biodiversity provision. The LU with highest ES_{Cap} are mangrove forests, hilly forests and aquatic environments (waterbodies, water courses and coastal seas). In Fig. 29.2b the geospatial results of the ES_{Cap} mapping were illustrated and in Fig. 29.2c the average contribution in % by LU to the ES_{Cap} is quantified. The overall ES_{Cap} shows that those with the highest ES capacity are located in the southern tip of the study area, in the north and inland. The LU with highest contribution to ES_{Cap} are mangrove forest (16.1%), hilly forests (14.8%), coastal sea (9.9%) with water bodies (10.5%; Fig. 29.2c). LUs with lowest ES capacity are mainly urbanized areas, such airports, port areas and developing or construction sites.

The highest contribution to ES_{Cap} for cultural ES is provided by hilly forests (12.1%), mangrove forests (12.1%), beaches (8.9%) and water courses (9.8%). Areas of highest ES_{Cap} score are located in the southern tip of the study area and in the north. In terms of provisioning ES, LUs with the highest capacity are agricultural land (12.9%) mainly for crop yield, mangrove forests (13.4%) and water bodies (14.3%). the LU of highest contribution to regulating ES are mangrove forests (22.9%), hilly forest (21.5%) and homestead vegetation (11.7%). In particular mangrove forest is the land use providing multiple ES, such as biodiversity and habitat maintenance (Brander et al., 2012), climate regulation (Peneva-Reed et al., 2020), source of wild food harvesting (Saenger et al., 2013) and sites with recreational attraction (Spalding & Parrett, 2019).

3.2 Ecosystem Services Exposure to Natural Hazard

From 1952 to 2017 the study area was hit by 34 tropical cyclones with varying intensities. Among them, some of the most devastating cyclones which caused substantial loss and damage to the lives and ES were the Bhola cyclone (1970), Urir Char cyclone (1985), Chittagong cyclone (1991), and Cyclone Mora (2017). Due to the extreme wind gust with associated storm surge, the Bhola cyclone (1970) and the Chattogram cyclone (1991) together caused 0.6 million deaths, the most devastating ever recorded (Bern et al., 1993; Frank & Husain, 1971). In the last decade deadliest tropical cyclone Mora (2017) hit the study area that caused widespread devastation and flooding in South-eastern Asia including Bangladesh, Myanmar, and East and North-east India (NOAA, 2017).

Figure 29.3 represents a workflow to assess the exposure of LU providing ES to tropical cyclones at *upazila* level. According to the cyclone intensity, as presented in Fig. 29.3a, the coastal areas most frequently hit by cyclones are located to the north of the Chattogram city covering Fatikchhari, Sitakunda, and Hathazari *upazilas*. Among 34 cyclones, 17 cyclones made landfall in this region in the last 66 years causing significant damage to the ES. Figure 29.3b shows that *upazilas* with the highest overall mean ES_{Cap}, thatare located in the northern (Fatikchhari and Sitakunda) and mid-eastern (Rangunia, Chandanaish, and Lohagara) and southern (Ramu) segments of the study area. The ES threat exposure (Fig. 29.3c) reveals that

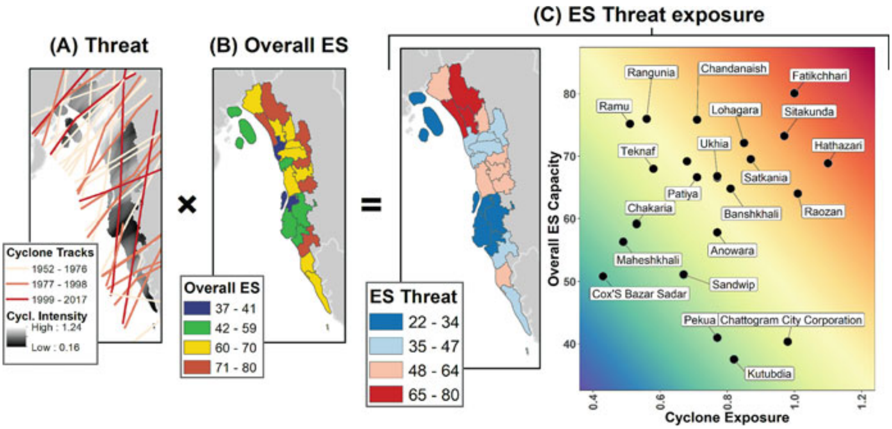

Fig. 29.3 ES threat analysis. (**a**) Cyclone tracks within the period 1952 to 2017 and resulting cyclone intensity; (**b**) mean overall ES_{Cap} at *upazila* level and (**c**) resulting ES threat exposure map and a 2D plot comparing ES_{Cap} with cyclone exposure

ES provision is most threatened by cyclones in the *upazilas* located in the northern part of the study area, while coastal *upazilas* situated in the central and the south show comparatively lower impacts. The 2D plot comparing the overall ES_{Cap} with cyclone exposure gradient represents the *upazilas* named Fatikchhari, Sitakunda and Hathazari belong to the most threatened sites with comparably higher overall ES_{Cap} (Fig. 29.3c). In contrast, *upazilas* like Kutubdia, Pekua, Sandwip, Maheshkhali, Cox’s Bazar Sadar, and Chattogram City have a low ES_{Cap} with comparably lower cyclone exposure. This plot concludes that all the higher ES provisioning administrative units fall in the with higher exposure to tropical cyclones in the eastern coast of Bangladesh.

4 Discussion and Conclusion

Bangladesh is a multi-disaster-prone country in South Asia. Being exposed to the Bay of Bengal, the southern coastal region of the country is vulnerable to numerous anthropogenic and natural hazards. Current century climate change has been posing a severe threat to the coastal habitats and livelihood by accelerating other hazards such as sea-level rise, salinity intrusion, tidal flooding, tropical cyclones, and associated storm surges. Apart from these changing land uses, unregulated mass tourism, unplanned emergence of economic activities, coastal water pollution, and acidification has been exerting tremendous pressures on the coastal ecosystems. Over the last decades, several policies and strategies have been adopted at the national level aiming to reduce exposure of the coastal region to different natural hazards. The major policies/strategies considering the reduction of coastal region’s vulnerability to coastal hazards and increasing resilience include National Development Strategy (2010–2021), Environmental Policy (1992), Coastal Zone Policy (2005), Coastal Development Strategy (2006), National Fisheries Policy (1998), National Adaptation Program of Action (NAPA), Bangladesh Climate Change Strategy and Action Plan (2009), National Plan for Disaster Management (2010–2015), and Bangladesh Delta Plan-2100. Most of these policies and strategies focused on building the resilience of the coastal communities to natural hazards, while few strategies considered infrastructural development and establishing coastal green belt through planting mangroves for the protection of coastal ecosystems and livelihoods during disaster events. Since 1966 several afforestation and reforestation projects have been implemented in the coastal and offshore regions of the country for protecting coastal communities from cyclone and storm surges. Subsequent to the 1991 Chittagong Cyclone, a number of multi-purpose cyclone shelters were established throughout the coastal area under government and private sector investments, which significantly reduced loss of lives and economic properties during the cyclones of the following years. Despite Bangladesh has an improved disaster management framework, the existing initiatives are still inadequate to provide protection to the coastal ecosystem services from particular hazards such as cyclones. Furthermore, the lack of appropriate regulation and monitoring for coastal land uses and their transition to other uses, respectively, have been deteriorating coastal habitat quality and ecosystem functioning. Though some of the uses proving people more economic benefit, these are degrading environment for the long term on the other hand. For example, sea salt production and shrimp farming at the Maheshkhali area are economically profitable but these land uses are environmentally unsustainable due to their uncontrolled practices.

The presented research shows how the integration of ecosystem services knowledge can be flexibly incorporated into disaster risk assessment from tropical cyclones. It shows the areas having the potentials of providing different ES and their gradient of exposure to the most dominant hazard, tropical cyclone, in the eastern coastal region of the country.

The geospatial distribution of the ES and threat scores together can inform the policymakers which areas are high potentials for getting benefit and how to protect them from cyclone hazard. Considering that according to our study about 3723 km^2 (52%) of the study area belongs to green infrastructure such as mangroves, hilly forests and tidal flats that provide high to very high protection from natural hazards. The findings can be used for developing sustainable land use plans for the coastal region, which together can provide sufficient ES provision to support human well-being, livelihoods and increase environmental security.

This presented approach is not free of limitations. In this research to estimate ES, we considered dominant land uses practiced in the area. There are certainly other uses with ES potentials that should be considered in the assessment stage. Moreover, the modelled cyclone intensity considered a 20 km buffered cyclone track as the high impact area. But the impact area of different cyclones can be variable. Moreover, the storm surge accompanied by cyclonic events, which causes secondary damage to the coastal ES, is overlooked in our approach.

The ES indicators used in this research should be further extended by incorporating the quantitative indicators (e.g., economic values) for ES services flow and demand. In particular, this is important for the quantification of damages on ES supporting livelihoods, agricultural yield, clean water, irrigation, and cultural well-being. ES can act as a green infrastructure and provide protection services from cyclones. LUs that are particularly important for natural hazard protection are mangrove forests and hilly forests. Attention should be given to coastal planning and land use management practices that ensure natural protection from natural hazards.

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Chapter 30
Adaptations to Climate Variability in Fisheries and Aquaculture Social-Ecological Systems in the Northern Humboldt Current Ecosystem: Challenges and Solutions

Giovanni Romagnoni, Lotta Clara Kluger, Jorge Tam, and Matthias Wolff

Significance Statement The Peruvian Upwelling ecosystem is highly productive. El Niño variability affects species abundance and distribution, and thus marine activities. Climate change is modifying El Niño patterns, compromising the strategies of marine organisms and human activities to cope with its variability. We focus on three marine social-ecological systems to identify weaknesses and leverage points for adaptation and resilience. We find that (1) the Peruvian artisanal fishery and aquaculture sectors urgently need an institutional framework for adaptation to future environmental changes; (2) bottom-up adaptation strategies require institutional support, tailored to socio-ecological specificities; and (3) additional research on socio-ecological tipping points and their effects for human-nature interactions and societal repercussions is necessary. These finding may be useful in other systems undergoing similar challenges.

Keywords Resource use · Human-nature interaction · El Niño · Climate change adaptation

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1 The Northern Humboldt Current Social-Ecological System and Its Sensitivity to Climate

The Humboldt Current flows northward along the coast of Chile until Northern Peru, producing an upwelling of cold, nutrient-rich waters which allow sustained growth of phytoplankton. The upwelling supports one of the most productive systems globally, the Northern Humboldt Current Ecosystem (NHCE) (Chavez et al., 2008; FAO, 2020a). This system is home of the Peruvian anchovy or *anchoveta* (*Engraulis ringens*), a small, fast-growing pelagic fish, target of the largest single-species fishery worldwide. The Peruvian fishing sector provides jobs, revenues, and food, overall accounting for up to 3% in the national GDP (Central Reserve Bank of Peru, 2020). The *anchoveta* industrial fishery is the most important sector in terms of landings and revenues, while artisanal fisheries constitute an increasingly important employment option for coastal communities and aquaculture is a comparatively novel and rapidly growing activity in coastal areas. Industrial fishery for *anchoveta*, artisanal fishery and marine aquaculture are all embedded in distinct complex social-ecological systems, comprised of different stakeholders, target resources, value chains and drivers of change.

The NHCE is strongly subjected to El Niño Southern Oscillation (ENSO), a recurring climate-oceanic phenomenon in the Tropical Eastern Pacific that causes climatic fluctuations with a pseudo-cyclical appearance every 3–7 years. ENSO presents two alternating phases: an anomalous warm phase ("El Niño", EN) and an anomalous cool phase ("La Niña"). Different types of events exist, including Central Pacific warming (CP-EN or Niño Modoki), and Eastern Pacific El Niño (PE-EN), the most famous and visible, differentiated in moderate and extreme EN events. EN generally causes a warming of coastal waters that disrupts the upwelling in front of the Peruvian coast (Chavez et al., 2008; FAO, 2020a; Wolff et al., 2003). This interaction affects the local climate (e.g. increasing temperature and heavy rainfall with floods), the pelagic and coastal marine ecosystems and the human activities depending on them, thus impacting the whole social-ecological system. Although the full extent of EN impacts on ecosystems remains unclear, the most visible effects include changes in species distribution and abundance (e.g. FAO, 2020a; Ñiquen & Bouchon, 2004). The impact of ENSO on fisheries depends critically on the event type: landings can drop by 3 million tonnes during extreme EN events, and increase by 1.1 million tonnes during La Niña (FAO, 2020a). However, impacts differ greatly by spatial scale, location, species and activities, as shown by the contrasting response of scallops to EN events in different areas (Wolff, 1987; Wolff et al., 2007; See also Sects. 2 and 6).

Typically, EN events start with sea surface temperature (SST) anomalies in the Western Pacific Austral winter (JAS), hit the Peruvian coast in summer (JFM), and recede in autumn (AMJ) (Chavez et al., 2008). These first warning signals allow early detection and adaptive management measures (Oliveros-Ramos et al., 2021). However the intensity, duration, and typology of EN events cannot yet be well predicted (FAO, 2020a), and some events, such as the marine heatwave of 2017 develop too rapidly for marine activities and society to prepare in time.

The aim of this study is to compare differences and similarities between three Peruvian case studies of human use of marine resources: (i) the industrial, large scale fishery targeting *anchoveta*, operating offshore (ca. beyond 10 nm), and two inshore activities (ca. within 10 nm), namely (ii) the small-scale and artisanal fisheries (hereafter, artisanal fishery) and (iii) the scallop aquaculture (further described in Sect. 2). By looking at different social-ecological systems at large and small spatial scale, this cross-scale comparison highlights the challenges encountered in the past when being confronted with climate variability, the solutions applied to face these challenges, and the future outlook, using a social-ecological perspective.

2 Case Studies: *Anchoveta* Fishery, Artisanal Fishery and Scallop Aquaculture

The *anchoveta* fishery accounted for 86% of landings in Peru and 10% of global landing in 2018 (FAO, 2020b, c), resulting in 1% of the total national GDP (Christensen et al., 2014). Anchovies fuel the export-oriented fishmeal/fishoil industry for the global animal feed market, which produces about 50% of global fishmeal (FAO, 2020a, c). This activity is therefore of strategic economic and social importance for the country. The fishery started in the 1950s and rapidly developed thereafter, despite the stock fluctuations attributed to environmental variability (Arias Schreiber et al., 2011; Chavez et al., 2008), and EN-related stock collapses, notably in 1972–1973 and 1983–1984. However, favourable environmental and management circumstances during the EN of 1997–1998 allowed the stock to rapidly recover, permitting the fishery to resume (Arias Schreiber et al., 2011; Bertrand et al., 2004; Ñiquen & Bouchon, 2004). The advanced adaptive management strategy in place (see Sect. 4) likely facilitated the recovery, avoiding stock collapse (Bertrand et al., 2018). As such, the *anchoveta* fishery is considered to be a well-managed, sustainable fishery (FAO, 2020a; Oliveros-Ramos et al., 2021).

Artisanal fisheries vest a key role for food security and employment in Peruvian coastal communities (Alfaro-Shigueto et al., 2010; Jara et al., 2020), with increasing landings and employment trend in recent years (De la Puente et al., 2020; Guevara-carrasco & Bertrand, 2017). These fisheries are mostly informal and not extensively managed (Guevara-carrasco & Bertrand, 2017). Artisanal fishers have exclusive rights up to 5 nautical miles from the coast, where they target coastal fish and invertebrates with a variety of gears and metiers. Large and small pelagic fish seasonally migrating inshore complement local catches, while some fleets venture offshore to target pelagic species. 335 species are reportedly landed (7 species represent >80% of landings), for a total of over 430,000 tons in 2018 (IMARPE, 2018). While artisanal fisheries are important along the entire Peruvian coastline, the Piura region (*cf.* Fig. 30.1) represents a hotspot: this region hosts about one third of

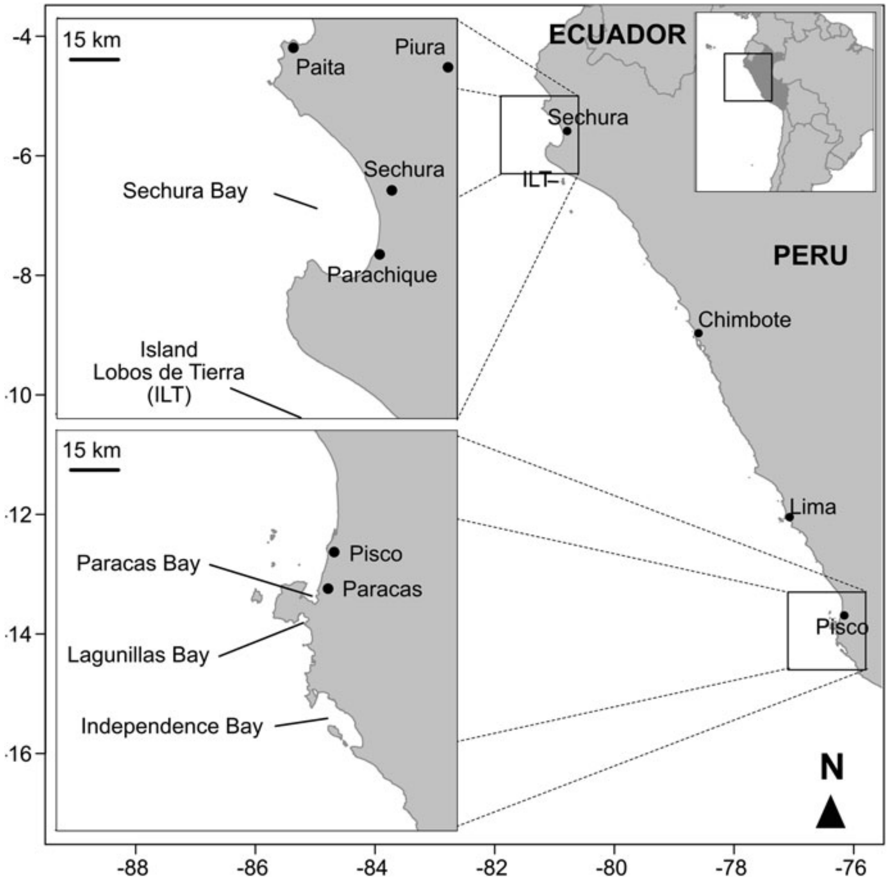

Fig. 30.1 Map of the Peruvian coastline. The region of Piura and province of Pisco, key areas for artisanal fisheries and for scallop aquaculture, are showed in the insets (Figure constructed in the R environment (R Core Team, 2019) using the maps (Brownrigg, 2018) and TeachingDemos (Snow, 2016) packages and Peruvian administrative area (region-level) geographical information that was retrieved from the Database of Global Administrative Areas (GADM, www.gadm.org, subdivision level 1))

artisanal fishing vessels (over 5500 vessels in 2012; Guevara-carrasco & Bertrand, 2017) and a large part of the population depends on fisheries-related activities (Figs. 30.2 and 30.3).

The aquaculture sector targeting the Peruvian bay scallop (*Argopecten purpuratus*) has emerged in the past 20 years: the traditional scallop diving fishery within the region of Pisco (central Peru; Fig. 30.1) experienced a boom during the scallop stock outburst resulting from the strong El Niño events in 1983/84 and 1997/98 (Wolff, 1987; Wolff et al., 2007), which prompted cultivation attempts. Since the early 2000s, Sechura Bay (North Peru, Fig. 30.1) has developed into a hotspot for scallop culture, where it constitutes a locally important socio-economic

Fig. 30.2 Artisanal purse seine fishing vessel operating in the waters of Northern Peru. (Photo: L.C. Kluger)

export-oriented activity, providing direct and indirect jobs to 25,000 people (Kluger et al., 2019a; Fig. 30.4). Sechura Bay is located in a transition zone, where the upwelling waters from the south meet warmer, equatorial waters from the north, creating favourable scallop culture conditions when compared to colder settings in the south. However, EN events impact drastically this region through torrential rains and substantial water temperature increase, causing die-offs of scallops and other benthic organisms. In Pisco, in contrast, scallops typically thrive during EN events. As a response, scallop fishers and farmers migrate between these locations according to changes in resource abundances (Kluger et al., 2020).

3 Challenges Posed by El Niño and Climate Change: Ecological Aspects

EN and climate change impact the NHCE through increase in temperature, frequency of tropical storms and of marine heatwaves and flooding events (Gutiérrez et al., 2019). Critically, these processes do not occur in isolation, and might interact and reinforce each other. For example, the localised but severe impact of the 2017

Fig. 30.3 Small-scale fishing vessels awaiting their next trip; Laguna Grande/Independence Bay, Pisco. (Photo: L.C. Kluger)

Fig. 30.4 Worker (Span. *tripulante*) on a scallop harvesting boat in Sechura Bay storing freshly harvested scallops in meshbags for transport ashore. (Photo: L.C. Kluger)

marine heatwave event might have been amplified by a climate change-related long-term warming of the ocean (Christidis et al., 2019).

Climate models do not allow accurate predictions about EN occurrence (amplitude, frequency and pattern) nor about EN interaction with climate change, however some studies propose an increase in frequency of extreme EN or suggest that climate change will drive a slight reduction of upwelling in the NHCE (Echevin et al., 2020; FAO, 2020a). These predicted patterns could negatively impact especially short-lived species such as anchovy, causing warming-induced reduction in abundance and southward spatial displacement (Gutiérrez et al., 2019; Oliveros-Ramos et al., 2021). Such effects are effectively observed during EN events; however, recent evidence suggests that *anchoveta* may be well adapted to the ENSO, having developed ecological mechanisms to cope with environmental variability at evolutionary time scale, such as the capability to find spatial-temporal windows of favourable conditions (e.g. seeking refuge in shallow, coastal areas) during EN years (Bertrand et al., 2004; Salvatteci et al., 2019). However, there is a risk that climate change may compromise the capability of anchovies to exploit refuge windows, eroding the resilience of the system to oscillations and increasing the risk of permanent stock collapse and regime shifts (Bertrand et al., 2018; Chavez et al., 2008). In addition, other pelagic species (e.g. mackerel, tuna, bonitos, dolphinfish, Humboldt jumbo squid) show apparent increasing or decreasing trends associated with EN events, potentially affecting predation pressure on *anchoveta* and causing unpredictable changes to the ecosystem dynamics.

During EN, enhanced equatorial subsurface countercurrents (SSCCs) carry eastward oxygen-rich waters contributing to ventilation in the otherwise poorly oxygenated NHCE (Espinoza-Morriberón et al., 2019). In the last decades, a change in ENSO nature was observed, with no extreme EN events occurring after 1997 and increasing predominance of the CEP-EN (Modoki). This novel pattern may be attributable to global climate change and, if currently observed trends continue, will lead to further deoxygenation of the ecosystem and the shrinkage of important habitats for fishery target species. Associated to this situation is the expected increase in the occurrence of extreme events such as anoxic and sulfidic events, which may cause mass mortality episodes (Wolff, 2018).

Coastal areas are influenced both by regional oceanic-atmosphere patterns and by local pressures. EN events can cause die-offs of benthic organisms, reduction or southward displacement of cold water species, and increase of tropical, warm-adapted species. These patterns are reflected in the variability of coastal species catches (Jara et al., 2020). Warming event types may affect coastal areas differently: marine heatwaves typically have a marginal influence on the offshore system (Bouchon et al., 2019), but affect substantially inshore areas in the North. During the 2017 marine heatwave, in Sechura Bay, the combination of increase in temperature, reduction in salinity caused by strong rains and river runoff and hypoxic conditions on the sea bottom caused a die-off affecting both farmed scallops and other bottom invertebrates, including locally important target species (Kluger et al., 2019a). The negative effect of EN on scallop farming in the North is contrasting to how the Southern part of the county is affected: here, increased temperature during EN leads to tremendous proliferations of scallops (Wolff, 1987; Wolff et al., 2007) attracting scallop fishers in the region. Such divergent response reflects the fine-scale spatial granularity of consequences of environmental disturbances along the long, diverse Peruvian coastline. The effects on local social-ecological– systems can thus hardly be predicted by regional patterns alone. Irrespectively, the predicted increase in frequency and intensity of EN events may drive larger variability and permanent changes to the coastal and bays ecosystems. However, the limited knowledge of ecosystem-environment dynamics hampers a better understanding of the plausible effects on individual systems.

4 Case Study 1: *Anchoveta* Fishery

4.1 Socio-economic Challenges

The highly specialised *anchoveta* fishery is strongly dependent on the dynamics of its target species. Stock oscillations can be highly problematic for the industry: as an example, the 1972/73 anchovy collapse forced 1500 fishing vessels and 200 processing plants out of activity, leaving over 100,000 people unemployed (FAO, 2020a). The current management system focuses on long-term maintenance of the stock, with catch limitations during EN events to allow the stock to rebuild. These limitations can be a challenge for the industry that must adapt to fluctuations in allowed catch and in profit. The stock's spatial displacement during EN events, with fish moving southwards, represent another challenge, increasing fishing and labour costs, as well as logistics complexity.

4.2 Existing Adaptation Approaches and Outlook

The anchovy fishery sector gradually constructed a robust set of institutional and industry-led measures to cope with climate variability and its impacts (Arias Schreiber et al., 2011; Oliveros-Ramos et al., 2021). These include an adaptive management approach with two stock assessments and seasonal catch limits per year, coupled with spatial-temporal fishing closures, based on near real-time monitoring of biological and environmental conditions. Early warning forecast of the ENSO conditions allows to implement further catch restrictions to protect the stock. Moreover, reduction of excess fleet and fish processing plant capacity, and an individual quota system were introduced to reduce the risk of overfishing (Bertrand et al., 2018; FAO, 2020a; Oliveros-Ramos et al., 2021).

Other adaptation strategies include exploration of alternative/complementary species for fishmeal production, such as mesopelagic fish, and the diversification of the production activity from fishmeal to food fish targeting species that increase during EN events (e.g. chub mackerel). However, entrepreneurs are as yet reluctant to adopt this strategy due to the lower profitability of food fish compared to anchovy for fishmeal (FAO, 2020a).

Industry-led adaptation strategies are manifold: for example, the availability of fishmeal processing facilities along the entire coast and the integration of all value chain steps into the same company allowed relocating the fishing activities southward following spatial displacement of anchovies in EN years (Arias Schreiber et al., 2011). A critical adaptation to catch fluctuation was the industry-led mechanism linking fishmeal price to anchovy catches volumes, which allowed compensating lower catches with higher prices.

Ad-hoc adaptation strategies are implemented at enterprise level (e.g. boats moving to tuna fisheries in the context of fleet capacity reduction) or even at individual level (e.g. fishers switching to small-scale fishing when losing their job due to temporary restrictions; Kluger et al., 2019a).

While no specific climate change-focused adaptation measures are in place, the currently operating management system and adaptation strategies was argued to potentially be well suited for coping with the challenges faced by the *anchoveta* fishery (Oliveros-Ramos et al., 2021). However, there is a risk that the effects of climate change may turn this management approach insufficient. Ongoing efforts for diversification of species for the fishmeal industry, and development of a market for warm-water species need to be strengthened and framed in a multispecies management system, in order to avoid the collapse of the productive system upon ecosystem changes. It can be expected that the industry will proactively develop and apply similar adaptation strategies, but institutional role is paramount in supporting such initiatives, and in particular in promoting research and monitoring of ecosystem dynamics in a changing climate.

5 Case Study 2: Artisanal Fisheries

5.1 Socio-economic Challenges

Climate variability impacts coastal fisheries through alterations in catch composition and abundance, impacts on infrastructure and equipment, and increased risk at sea (FAO, 2020a). These changes may result in substantial economic and social impacts for fishers. For example, the 2017 marine heatwave hit hard the coastal fishery in Sechura (Kluger, et al., 2019a). Heavy rain halted fishing, damaging infrastructures and equipment. The road system disruption due to floods compromised access to fish markets, interrupting fisheries value chains. In areas where entire families rely on income generated by fishing, even a short interruption of the fishing season can have economically strong impacts, affecting provision of food and healthcare and worsening living conditions (Kluger et al., 2019a).

In addition, in EN years when other activities (e.g. *anchoveta* fishery) are impaired, artisanal fishing – with its low entry requirement – represents a safety option for many. It is likely that climate change will push many into this safety option (“refugee space”), increasing pressure on resources, leading to conflicts for resource use, ecosystem degradation, and ultimately increasing sensitivity of the socio-economic system to environmental variation (Jara et al., 2020; Kluger et al., 2019a).

5.2 Existing Adaptation Approaches and Outlook

In contrast to the industrial fishery, Peruvian artisanal fisheries has yet to implement an institutional framework for adapting to ENSO, let alone to climate change (FAO, 2020a). The sector relies on endogenous initiatives to withstand climate challenges. Adaptation capacity is related to individual or business-level disposition, financial capacity and independence, individual fishers' and community characteristics, and to market dynamics.

Artisanal fisheries are naturally dynamic and flexible, being adapted to inter-annual and seasonal stocks fluctuations. Individual fishers routinely switch gear types, fishing methods or target species to deal with these changes, or migrate towards other fishing areas (Guevara-carrasco & Bertrand, 2017; Jara et al., 2020; Kluger et al., 2019a; Kluger et al., 2020). Such flexibility proved a key factor to cope with ENSO-related oscillations or other occasional disturbances in the past. For example, artisanal fishery in Sechura Bay demonstrated a fast recovery within a few months after the marine heatwave event in 2017 (Kluger et al., 2019a). Seasonal and long term migrations are an important adaptation strategy: fishers move to other areas or other fisheries, while maintaining connection to the location where their family remains (Kluger et al., 2020). Though a successful individual coping mechanism, these migrations can also cause impacts on the receiving fishing community, e.g. increasing conflicts about resource access.

However, individual initiatives focus on ad-hoc, temporary solutions, lacking any strategic long-term horizon. The adaptive capacity of artisanal communities needs to be strengthened through institutional support, which has been limited in some cases, as reported by stakeholders in the aftermath of the 2017 marine heatwave in Sechura (Kluger et al., 2019a). Critically, adaptive capacity and resilience building must be rooted on both ecological and on social aspects, and tailored to the individual characteristics of each community. In fact, the characteristics of the community determine the vulnerability of the socio-ecological system to environmental change, and thus its adaptation potential. Jara et al. (2020) related the vulnerability and adaptation capacity of artisanal fishing communities to a combination of ecological factors, social factors, presence of infrastructures and conservation management. Vulnerability is predicted to increase with projected climate change. Action on the socio-economic characteristics may be the key to positively modify the path to adaptation, through increased biodiversity protection, economic diversification and poverty reduction measures. These measures need to be case-specific and tailored to the individual context, integrating the diverse local actors and players.

A number of adaptation measures for coastal fisheries susceptible to environmental variability are proposed for example by Daw et al. (2009), and Jara et al. (2020), also reported by FAO (2020a). These focus on strengthening the resilience of the local communities and of the fishery sector; establishing financial mechanisms to buffer the socio-economics effects of resource fluctuations; implementing the monitoring of oceanographic changes, and others. These mechanisms require, in parallel, the development of a management system with establishment of fishing limits under a co-management framework, with direct involvement of fishers in the co-design of sustainable fishing practices, to foster stewardship and increase compliance.

6 Case Study 3: Scallop Aquaculture

6.1 Socio-economic Challenges

The scallop aquaculture sector is highly vulnerable towards any environmental change that threatens the survival of the target species: the Peruvian bay scallop. This dependency of an entire sector on a single species can be – similar to the *anchoveta* industry – a real challenge, especially if the dependency of the human community is as high as in Sechura Bay. EN events and climate change thus have strong socio-economic impact in this area (Kluger et al., 2019b). The marine heatwave of 2017 had drastic negative consequences for scallop farming in Sechura Bay, cascading to the entire industry and affecting the livelihood of over 25,000 people. Most scallop farmer associations stopped production, losing their investment, equipment, and, in some cases, their personal goods (e.g. houses), ultimately compromising their financial freedom (Kluger et al., 2019a).

6.2 Existing Adaptation Approaches and Outlook

The high vulnerability of the scallop aquaculture activity prompted users to proactively develop autonomous adaptation strategies to limit financial losses during times of reduced scallop production. For example, after previous experience with moderate die-offs, several associations decided to delay the scallop grow-out period at the onset of the heatwave in 2017, effectively reducing their loss. Another adaptation strategy is the north-south migration under conditions of strong El Niño or La Niña, to exploit differential effects of EN on scallop productivity along the coastline. Species diversification is another adaptation strategy to contrast the single-species constraint: managers of scallop processing plants reported (in interviews with the second author) to have requested official permission to process a wide range of marine species in their facilities, in the perspective of future changes in farmed and fished species driven by environmental variability, reportedly to exploit a competitive advantage compared to other producers.

Kluger et al. (2019b) recommended a set of measures for a long-term adaptation strategy, which relate to environmental management, development of emergency plans and financial support and investment plans, and mitigation measures such as diversifying and spatially spreading the activity to reduce the risk. For larger scallop culture associations a "spreading the risk" strategy through activities along the whole Peruvian coastline may successfully compensate local mass mortalities with high yields in other areas (Kluger et al., 2019b). Such measures need to be embedded in a long-term adaptation strategy that should be co-designed by farmers associations and governance authorities in order to be economically, socially and ecologically resilient and successful.

7 Conclusion: What Can We Learn from the Cross-Scale Comparison? Challenges and Opportunities

This paper explores the challenges and the potential for adaptation to environmental variability and climate change across marine activities at different spatial scale in the Northern Humboldt Current Ecosystem. Adaptation strategies for coping with climate instability are already in place in all contexts, but are often based on bottom-up initiative. Strong action from institutions is needed to guide and help such bottom-up efforts, shaping a long-term management strategy to deal with environmental change in socio-ecological systems across spatial scales. For artisanal fisheries and aquaculture in particular, there is a strong need of locally developed, ad-hoc measures that can add robustness to the societies, also in light of vulnerable socio-economic situations in coastal communities.

Under this framework, three main take-home messages can be drawn about the three case studies presented:

1. The Peruvian *anchoveta* fishery is well managed under present environmental conditions, and it can be seen as an interesting model of adaptive fisheries management for fisheries targeting small pelagic fish subject to short-term fluctuations and environmental disturbances. However, with progressing climate change, the industrial fishery may need to diversify its target species, possibly requiring a shift to a multi-species management system.
2. Artisanal fisheries are more adaptable to climate change due to their multi-species/multi-gear nature. However, the intrinsic socio-economic vulnerability of coastal communities requires science-based management of important resources under present-day conditions, and the co-design of long-term adaptation planning strategies of resource users and governmental institutions in order to prepare these social-ecological systems for future change.
3. Entrepreneurs of scallop aquaculture must engage with long-term planning, accounting for increasing disturbance with local mortality events. Under future climate change scenario it is likely that the window of opportunity for scallop cultivation will shift from Sechura to the south. Conservation of natural banks, diversification of farmed species and spatial "risk spreading" strategies are therefore advisable.

In order to promote an ecosystem-informed, climate-change prepared fisheries and aquaculture management that can support institutional actions, more transdisciplinary research is needed. In particular, it is paramount to gain understanding of the socio-ecological systems dynamics and their cross-scale differences, and of the potential social and ecological tipping points under future climate change scenarios. Future multispecies fisheries management cannot be isolated from the complex human-nature interactions. This is of key importance in the Peruvian industrial fisheries as much as for the coastal small-scale fisheries, which provide food and income and an important safety option in coastal communities. Critically, these should be coupled with measures to reduce and manage conflicts for resource use, and institution-led initiatives for poverty reduction and enhancement of social resilience.

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Chapter 31
Socio-ecological Transformations in Coastal Wetlands: An Approach from the South-Central Zone of Chile

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Significance Statement The increase in the world population has generated high pressures on the different ecosystems, mainly due to the expansion of urban areas and productive activities such as agriculture. Coastal wetlands are among the most affected ecosystems, which due to their geographical location are highly fragile and susceptible to changes and pressures. The aims of this research are focus on (1) Making a comparison regarding to the changes experienced in two similar coastal wetlands with actual protection measures (one Ramsar site and national reserve since 1996 and another declared a nature sanctuary in 2017). (2) evaluating the main transformations in both wetlands, as socio-ecological systems, from human activity and the extent of public policies that can be generated that go around the protection of these ecosystems.

Keywords Coastal wetlands · Land cover change · South-Central Chile · Human pressure

1 Introduction

The planet is currently facing a new era called Anthropocene, where most of the environmental changes are caused by human activity, these changes are coupled to new scientific evidence suggesting that worldwide landscapes are facing an unstable trajectory (Wu, 2013). It is estimated that one of the most affected ecosystems by these changes are coastal wetlands (Zhang et al., 2019).

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Historically, wetland ecosystems are controversial components in the socioecological system since they have been considered for many years, as objects of low value that require treatments to be useful for development (e.g. urbanization). They have been modified to urban uses, garbage dumps, landfills, they receive runoff of liquid waste and are also fragmented by the construction of roads (Mishra, 2014). Only in the twentieth century the loss of wetlands ranged between 64 and 71% highlighting those located in Asia, where the loss was even larger. Furthermore, the current global rate of loss of coastal wetlands is 4.2 times faster than in recent decades (Davidson, 2014).

The role of wetlands in the socio-ecological system has changed quickly during the last years and they are gaining appreciation due to the significant amount of ecosystem services they can provide to people. Coastal ecosystems also provide ecosystem services that have socio-economic benefits to humans, including provision of oil, forage, building materials, wood, fish, among others tangible products, but also other benefits can be included like tourism or savings caused by disaster prevention (Zhang et al., 2019). In this regard, coastal wetlands protect the coastline against the loss of infrastructure and human lives caused by disasters (Wolanski et al., 2009). However, these ecosystems continue to be threatened by anthropic activities that generate high levels of degradation such as: (a) urbanization; (b) water pollution; (c) diversion of riverbed and (d) deforestation (Rivillas-Ospina et al., 2017). In addition, we must also consider the effects of the increase of natural disturbances due to environmental and climate changes as the differences in rainfall, rise or fall of temperature, sea level, increases of flood during rain seasons and larger periods of drought.

The Chilean coast presents a large variety of wetlands, ranging from the most arid regions in the north of the country 18°S to the Patagonian fjords in the extreme south at 54°S This geographical range offers a high diversity of ecological and socio-environmental characteristics according to its latitude, geomorphology, tidal regimes, recent geological history, the degree of fresh water supply, but especially according to the degree of anthropic intervention (Valdovinos, 2004). The aim of this research is comparing two similar coastal wetlands as socio-ecological systems which present protection measures and are nevertheless highly degraded, and then determining their current dynamics of change. The first case is El Yali wetland located at the south of Valparaiso region at 33°S, and the second case selected was the Putú wetland which is in Maule region, at the south of El Yali at 35°S. Both areas are located in the central zone of Chile where there is a high concentration of coastal wetlands in the central area due to the tectonic activity that has been forming the coast more than 3000 years ago (Contreras-López et al., 2014). The central zone of Chile is the region with major anthropic influence, which has been shaping these landscapes through extensive agricultural activity, urban expansion and facing the incessant expansion of the forestry industry in the Coastal range (McFadden & Dirzo, 2018).

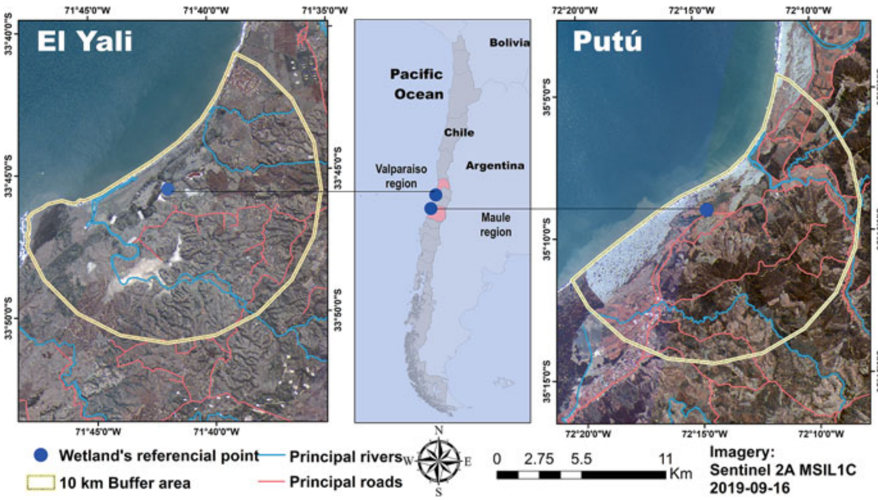

Fig. 31.1 Study area of both cases. In blue: the centroid of the location of both wetlands that were used to make the buffer for the analysis

2 Methods

2.1 Study Area

To select the two cases different and comparable factors were contemplated. Both ecosystems can be considered coastal wetland mainly because they are located near the sea and the beach area (less than 6 km) and are located within the Mediterranean ecoregion of central Chile. In addition, both wetlands are under similar anthropic pressures such as the forestry industry and agriculture. For the delimitation of the areas, a centroid point was generated in the water mirror of each wetland, to which a 10-km buffer was generated, eliminating the area located in the sea (Fig. 31.1).

Since 1996 the El Yali wetland is part of the officially protected area that bears the same name, it is located in the district of Santo Domingo to the southwest of the Valparaíso region, near to the river mouth of the El Yali river. In addition, it is a Ramsar site (N°878) and is recognized as one of the 56 sites with a priority for the conservation of biodiversity, since in this wetland about 28% of the total bird species can be found in Chile (Victoriano et al., 2006). However, this wetland has a strong anthropic pressure derived mainly from the illegal extraction of underground water, diversion of channels for agriculture or industry, livestock and the pressure driven by the expansion of the forest industry in the territory (Fariña & Camaño, 2012; Contreras-López et al., 2017).

The Putu wetland is in the district of Constitución, located in Maule region. This wetland was declared a protected area in 2017 thanks to the participation of citizens and the local government (BCN, 2018). It runs parallel to the coastal road that connects the cities of Constitución with Iloca. This wetland is located between a dune system and, as in the El Yali wetland, it is possible to see many endemic birds, and migratory birds during season.

2.2 Image Classification

For this research we decided to used satellite imagery due to their spatial-temporal scale, and also because Landsat imagery is free for download in comparison to aerial photography and can also provide a lot of useful information at landscape level. In this case the resolution of Landsat is 30 m, which allows to detect land cover changes associated with human intervention. The temporal scale is 16 days which allows to have a set of imagery to choose according to the different requirements, in this case it was necessary to find images with less than 5% of cloud cover in order to avoid noises in the imagery. Another important aspect that was considered in the selection is that Landsat has different bands in the infra-red spectrum, which allows to identify more accurate the vegetation and also the wetland area.

For image classification we used 10 classes of land cover. The selection of land cover classes was based on two major land classifications: first, the classification made by Zhao et al. (2016) who made a classification of the entire country and where the categories were grouped into three levels of specificity. In that study, they used Landsat imagery, so the spatial resolution is 30 m. The second classification scheme check over was the official land cover classification provided by the National Forest Corporation (CONAF). The decision of the final classes used in this work were also verified in the field and in order to be comparable, the same categories were used (Table 31.1).

Table 31.1 Land cover classes selected for the image classification and change analysis

Land cover	Description
Sea	Part of the image that contains the sea. This class was classified to reduce the percentage of error in the classification
Crops	Crop patches caused by agriculture activity including industrial and familiar agriculture.
Plantations	This class represents the forest plantation including Pinus and Eucalyptus
Vegetation	This class includes scrub and sclerophyllous forest mainly located in slopes and near riverbeds.
Continental water bodies	This category includes rivers and lagoons (natural and artificial).
Wetland	The water mirror was classified (permanently flooded area of the wetland) and part of the vegetation on the edge.
Bare soil	Soil with none or little amount of vegetation.
Grasslands	Natural or anthropic grasslands (used mostly for grazing).
Urban infrastructure	Industrial facilities, and urban areas
Sand	Sand located in the beach area and dunes.

We classified two Landsat images for the two different years: 2004 (L5 TM) and 2019 (L8 OLI-TIRS). Both sets of images were atmospheric and topographically corrected to reduce the classification error. The software used were QGIS 3.8 ZANZIBAR and EnMAP toolbox,[1] which is a python plugin designed to process and visualize hyperspectral remote sensing data. In this case the Support Vector Machine (SVM) classifier was selected. SVM is a distribution-free algorithm, based on the optimal separation of classes. Considering that not all classes are linearly separable, this method can get more precisely results because it is optimized to search for a non-linear hyperplane using kernel function (Karatzoglou et al., 2006; Everingham et al., 2007; Huang et al., 2002). 2000 control points were made to classify the imagery of each year and the study area was working at a scale of 1: 25,000.

In order to improve the detection of wetlands and to help the classifier in detecting the natural vegetation from forest plantation and crops we included spectral indices to spectral bands of Landsat L5 and L8. They can be grouped into three categories: (i) for improving the vegetation detection we applied Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI); (ii) to improve water and wetland detection we used the Modified Normalized Difference Water Index (mNDWI), Normalized Difference Moisture Index (NDMI) and Normalized Difference Water Index (NDWI); (iii) finally, for improving the bare soil and constructed area we analysed the Normalized Difference Built-up Index (NDBI).

For the analysis of land cover changes, categories were made according to the type of change between 2004 and 2019. The groups were made according to the direction of the change: (i) those changes that occurred from a natural cover to a productive uses (e.g. crops, forest plantation, urban infrastructure); (ii) from productive use to natural cover (e.g. native vegetation, grasslands); (iii) changes associated with the area of wetlands and waterbodies (gain and loss); (iv) remains unchanged; (v) ecological succession; (vi) degradation of natural covers.

Finally, the validation of the classification was made using a Cross Validation Accuracy Assessment, method which assesses the performance of a classifier using n-fold cross-validation. This accuracy was performed on the same EnMap ToolBox as the image classification.

3 Results and Discussions

The class that covers most of the land on both wetlands are grassland, other classes with a high occupancy are forest plantations and native vegetation. Before the description of land cover changes it can be noted that the high classification accuracy in all situations. In the case of the Putú area, the classification accuracy was 92% for the image of 2019 and 90% in the case of 2004. For El Yali, the results obtained were

[1] For more detail information visit https://enmap-box.readthedocs.io/en/latest/general/about.html

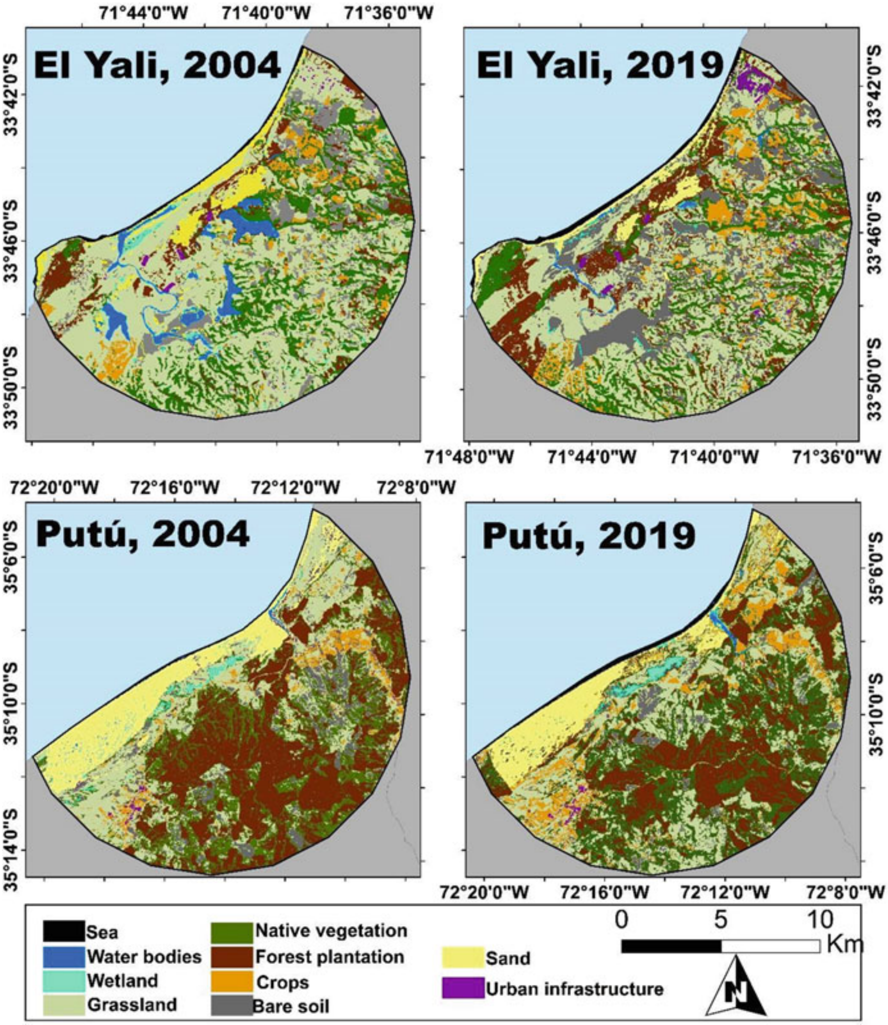

Fig. 31.2 Land cover classification for both study areas. Yali 2004; Kappa index 90%; Yali 2019, Kappa index 91%; Putú 2004, Kappa index 90%; Putú 2019, Kappa index 92%

91% for 2019 and 90% for 2004 (Fig. 31.2). Within the error obtained, it was estimated that a large percentage is related to the confusion between the categories of natural vegetation and crops. In the case of El Yali, this error is given by fruit plantations present in the sector.

Regarding the main results of the classification, it can be observed in the case of Putú that there was an increase in the wetland area, ranging from 142.3 ha in 2004 to 191.4 hectares in 2019 (+35%). This can be contrasted to the case of El Yali, where a considerable decrease in this land cover was seen, passing from 811.36 ha during 2004 to only 323.6 ha in 2019 (−60%) (Fig. 31.3). It is important to notice that the

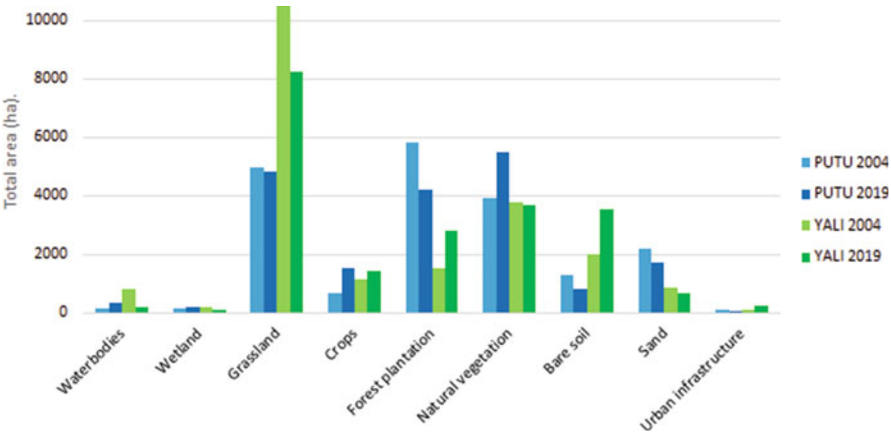

Fig. 31.3 Total area for each category of land cover for Putú and El Yali between 2004–2019

Putú wetland was categorized as protected area (nature sanctuary) only in 2017, while Yali has been since 1996 (national reserve), so the decline in the wetland surface is quite striking.

In the same direction, the change in forest plantations stands out. In Putú wetland, it was observed a decrease from 5803.6 ha in 2004 to 4194.3 ha in 2019 (−28%). The opposite was observed in El Yali, where forest plantations increased considerably from 1517.7 to 2825.1 ha between 2004 and 2019 (+86%) (Fig. 31.4). In addition, the bare soil class increased in this same area, going from 2001.7 to 3506.8 ha respectively (+75%). This can be understood by the recently harvested areas, either corresponding to forest plantations or fruit plantations and in addition to the areas where previously were water bodies that are currently dry. In the case of Putú, the areas with bare soils decreased from 1308.1 to only 798.1 ha (−39%). Among the main changes that explain this decrease is the rise in natural vegetation from 3900.1 ha in 2004 to 5508.3 ha in 2019 (+41%) and water bodies from 141.7 to 326.6 ha respectively (+130%), which is not the case of El Yali where water bodies saw the surface drastically diminished, going from 811.35 ha in 2004 to 192.97 ha in 2019 (−76%).

In the case of urban infrastructure cover, there is an increase of this area in El Yali going from 94.1 ha in 2004 to a total of 239.9 ha in 2019 (+154%). This increase can be explained by the subdivision of land for the construction of second residence (I. Municipalidad de Santo Domingo, 2019).

Regarding the processes of land cover change, both wetlands present similar amounts of change into productive uses as well as the percentage of surface that remained unchanged. However, in the case of Putú, the change into natural vegetation stands out, while in the case of El Yali, the change associated with the degradation of vegetation was higher (Fig. 31.4). This is consistent with the reality of both areas, where in the Putú surroundings there has been intervention from the local government and citizens to protect this ecosystem, it also accounts for a decline

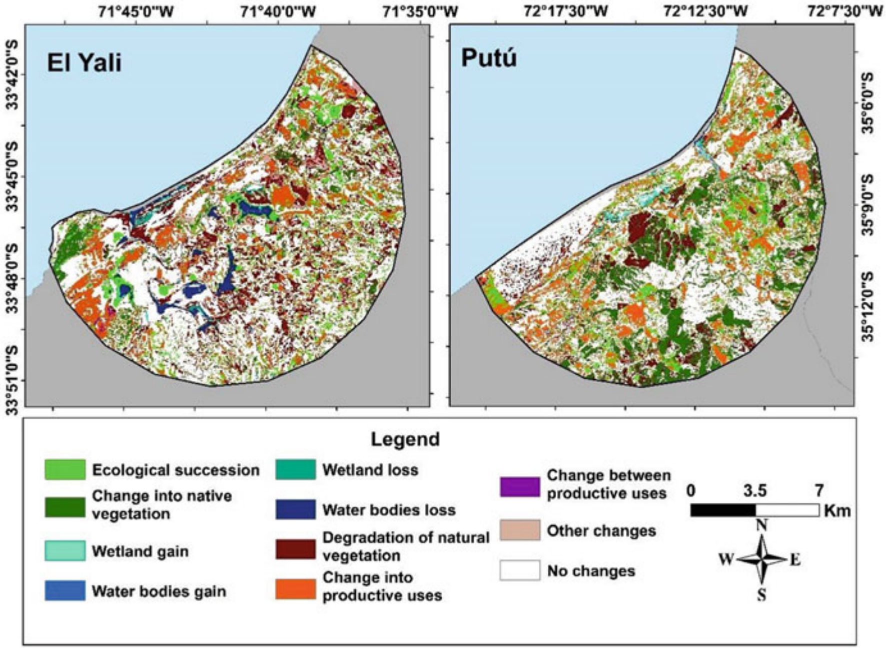

Fig. 31.4 Land cover changes between 2004 and 2019 in both study areas. In the case of El Yali the most important change was the degradation of natural vegetation, Contrary to the Putú case, where the biggest change was towards natural covers

in forest plantations, while in El Yali represents the opposite scenario which despite having protection figures and being in the RAMSAR site category is highly degraded.

It can also be observed that in the case of El Yali, a large part of the water bodies decreased between 2004 and 2019. During 2016 two lagoons located within the national reserve area were completely dried up because of illegal extraction (El Mostrador, 2016) (Fig. 31.5), in addition this socio-ecological system has been strongly affected by the current drought that the country is facing. In the case of Putú, on the other hand, a significant increase in the wetland area is observed, which shows that the protection plans around this ecosystem are giving results.

These results also accounted for the impact of forest plantations on the natural vegetation cover in Chile, which can be seen in the case of El Yali. The change in land covers in this study case is highly related to anthropic activities, where 16% of the changes between 2004 and 2019 were precisely from natural covers to productive uses, where the greatest changes occurred from native vegetation and grasslands to forest plantation. Today in the Anthropocene, it is crucial to understand what effects these impacts will generate at the global and local level to support planning in many sectors (Xie et al., 2019), especially in areas with biodiversity and with pressure of uses by different economic activities like the case of the coastal wetlands in central Chile, as the case of El Yali for example.

Fig. 31.5 Example of the drought that is currently affecting El Yali wetland. (Source: Vannia Ruiz)

Nowadays we are facing the consequences of human activities that have been carried out in the last decades. The interaction and interdependence of social and ecological systems is seen as a driving link to unite understandings and guide actions towards a sustainable future (Berkes & Folke, 1998; Stone-Jovicich et al., 2018). These new concepts incorporate the dynamics of systems over time, focusing the analysis on their ability to persist and respond adaptively to disturbances or changes (Anderies et al., 2013). In this way, the example of the Putú wetland becomes relevant, where, based on the valuation of this ecosystem by society it promoted a change in pursuit of its conservation and protection, where the local government also generated measures to be able to specify social actions, thus allowing the wetland to become a nature sanctuary. These actions could serve as an example in other degraded socio-ecological systems such as El Yali, where greater local actions are urgently needed to promote governance with a clear axis of environmental sustainability.

Despite Chile has been making progress regards legal protection of wetlands through the Urban Wetlands Law (2020), where the citizenship-science and parliament trilogy was validated in the achievement of a common goal, many coastal wetlands are located in the rural area, which have high natural value, they are currently without a protection figure, so they are severely threatened by driving forces such as El Yali, despite being a RAMSAR site. For this reason, evaluations from the socioecological systems approach provide key elements such as the causal relationship between stressors and effects, as well as the interactions between them, allowing to define strategies for Ecosystem Based Management due to the high concentration of ecosystem services and the Integrated Management of Coastal Zones (IMCZ), due to the wide variety of economic interests and the need for regular uses (Barragán Muñoz & de Andrés García, 2020). In Chile, only the IMCZ approach is recognized among public management instruments but with many limitations in terms of its results (Martínez et al., 2019; Hidalgo et al., 2019), for which it is expected that as it is recognize the functioning of these socio-ecological systems, incorporate guidelines for coastal governance capable of effectively promoting a sustainable transformation in these spaces.

4 Conclusions

Through this research we were able to account for how high-intensity productive activities such as the forestry and agricultural industries have generated transformations in the landscape with their consequent environmental consequences. In the case of the El Yali wetland, the high degradation of ecosystems observed despite to their importance for society and to be officially protected area since 1996 and RAMSAR site. On the other hand, the Putú wetland shows that when there is strong local governance, there is a greater awareness of society regarding environmental protection and conservation. That is why it is important to implement public policies with a strong local and environmental component and the citizen participation, capable of promoting the sustainability of the coast, as well as management plans that incorporate ecosystem restoration through nature-based solutions. Finally, for future research it will be interesting to contrast more coastal wetlands with similar conditions, because progressing in the knowledge of the state of the ecosystem and their major pressures could lead to generate better public policies and actions for environmental protection and biodiversity conservation, and at the same time, human well-being.

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Chapter 32
A Nature-Based Solution for Coastal Foredune Restoration: The Case Study of Maghery, County Donegal, Ireland

Paul Lawlor and Derek W. T. Jackson

Significance Statement Climate change has many negative impacts on coastal areas with sea level rise and more frequent and intense storms leading to higher rates of coastal flooding and erosion. Natural coastal features such as beaches and sand dune systems can boost resilience to climate change and provide an effective buffer against negative impacts. This case study from Maghery in Ireland demonstrates how a partnership of stakeholders comprising Local Government, Ulster University and the coastal community implemented a Nature-based Solution to regenerate a coastal foredune system in a Special Area of Conservation. The Nature-based Solution also proved to be a more effective and a more appropriate adaptation response than constructing a hard engineering scheme to protect the coastline.

Keywords Coastal marine environments · Climate adaptation · Ireland · Nature-based solutions · Beach and dune regeneration · Coastal communities

1 Introduction

Coastal areas change naturally over time through various environmental forcing factors (Masselink et al., 2016; Jackson et al., 2019a; Dodet et al., 2019; Jackson & Short, 2020; Short & Jackson, 2021) but indications of recent climate changes may be showing human-influenced acceleration of this (Jackson & Cooper, 2011; Jackson et al., 2019b). Recent rapid climate change is expected to have a wide

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range of impacts on Ireland's landscapes, society and economy through changes to its managed and natural ecosystems, water resources, agriculture and food security, human health and coastal zones. While the observed scale and rate of change are in line with regional and global trends, the changes are expected to continue and increase in the years ahead (DoCCAE, 2017, p. 7). The most immediate risks to Ireland from climate change are those arising from changes in extremes – particularly those from floods, precipitation and storms (DoCCAE, 2018, p. 7) and the need to adapt to these risks is urgent and essential (DoCCAE, 2019, p. 142).

The 5800 km coastline in the Republic of Ireland (Falaleeva et al., 2011, p. 787) is considered to be particularly susceptible to climate change impacts that include inundation, more extreme storm activity and an increase in coastal erosion (EPA, 2013, p. 3). It is estimated that 20–25% of the entire coastline is at risk of coastal erosion with heightened rates of erosion taking place during stormy years (Flannery et al., 2015, p. 162). However, the distribution of these impacts is uneven with environmental modelling indicating that coastal areas to the west and north west are most at risk (Guisado-Pintado & Jackson, 2018, 2019) particularly when sea level rise and a higher number of winter storms are taken into account (Devoy, 2008, p. 330). These risks are recognised in Irelands National Planning Framework which includes an objective to '*. . .address the effects of sea level changes and coastal flooding and erosion and to support the implementation of adaptation responses in vulnerable areas*' (DoHP & LG, 2018, p. 103). However, there is no overarching national level coastal management policy (Falaleeva et al., 2011, p. 787) or guidance for engaging in proactive planning for coastal areas and many Local Authorities lack the required capacity or information for doing so (Flannery et al., 2015, p. 163). The lack of coastal guidance may be about to change. At the time of writing, a national coastal management strategy steering committee has been assigned the task of considering the development of an integrated coastal change strategy.

With no clear national level policy, Irish coastal management has proceeded in an *ad hoc* fashion (O'Hagan & Ballinger, 2010, p. 751). Coastal adaptation projects that respond to climate impacts have often been reactionary (or short-term) in nature, rather than mainstreamed with long-term strategic planning. Despite their reactive approach, the responses of Irish coastal Local Authorities to coastal risks are strikingly similar as they often rely on publically-funded engineered solutions (Flannery et al., 2015, p. 168) such as groynes, sea walls and rock revetments (O'Hagan & Cooper, 2002, p. 545). Also known as 'grey infrastructure', these costly works are highly visible and can have a reassuring effect on receiving communities even though they can provide a false sense of safety and place those behind them at further risk (Cooper & Pile, 2014, pp. 90–98). Recent EU and government policies provide for a more flexible approach to coastal adaptation. While 'grey infrastructure' solutions can continue to be used, it is recommended that more ecosystem-based approaches to adaptation (or green measures) are applied in addition to managerial, legal and policy approaches (soft measures) (EC, 2015, p. 8).

Ecosystem-based adaptations are considered to be part of a suite of Nature-based Solutions (BbS) which is an umbrella term for the nature-based concepts that include ecosystem-based adaptation (EbA), green infrastructure (GI) and ecosystem services (ESS) (Kabisch et al., 2017, p. 41). Nature-based Solutions have numerous commonalities and they all attempt to use nature as a means of complementing, improving or even replacing traditional engineering approaches (Kabisch et al. (2017), p. 39). The recommendation to use Nature-based Solutions is included in a range of key EU policies such as Biodiversity and Climate Change (EEA, 2015, p. 2) as they are considered to be less expensive, more robust and sustainable and they can also be applied to a range of spatial scales from national to local level. The popularity of Nature-based Solutions at EU level has also led to member states including them as adaptation options. In the Republic of Ireland, commitments are included in key national level plans and strategies such as the National Planning Framework, the National Adaptation Framework and the Climate Action Plan to use Nature-based Solutions to enhance the resilience of human and natural systems. The aim of this study is to assess how a Nature-based Solution was designed and implemented in response to significant beach and dune erosion arising from climate change in a coastal area in Ireland. The capacity of the Nature-based Solution to achieve the regeneration of the beach and dune system is considered along with its potential and suitability for more widespread application.

2 Case Study Profile

The small coastal village of Maghery (An Machaire) is located in County Donegal on the north west Atlantic coast of Ireland. The village is located inside Maghery bay which comprises a primary beach and an established dune system in addition to a smaller beach which is located to the south (Fig. 32.1). The main beach is surrounded by local roads, a sports pitch and a community centre. The coastline and adjacent marine areas in Maghery have a range of significant socio-ecological functions. The area forms part of Termon Strand which comprises 85 ha and includes a coastal lagoon as well as the beach and dunes at Maghery Bay. The ecological importance of this coastal area is reflected in its designation as a Special Area of Conservation (SAC) under the Habitats Directive. The beach and dunes at Maghery also provide a valuable amenity as the main beach is particularly popular with visitors during the summer months and residents who use the beach for walking and other recreational purposes all year round.

The high-energy coastline around Maghery means that the beach and dune system are regularly moving in and out of erosional and accretional phases which are driven by storm activity and sediment supply to the system (Jackson et al., 2022). Shoreline analysis reveals that continuous coastal change is taking place with the shoreline advancing seaward by 120 m seaward between 1841 and 1913 (Jackson, 2015, p.10). Post-1913, the shoreline began to retreat and by 2000, it had receded approximately 100 m by which time the location of the shoreline was similar to its position in 1841. A process of shoreline recovery began in 2000 and by 2005, it had advanced between 20 and 30 m. The coastal advance accelerated between 2006 and

Fig. 32.1 Location map and aerial view of Maghery beach in NW Ireland. (Source; Google Earth, 2021)

2011 following the implementation of the Nature-based adaptation Solution (comprising of a sand trapping scheme). The shoreline is believed to have entered an erosional phase between 2011 and 2015 due to a lack of maintenance of the sand trapping scheme combined with the impacts of a series of severe marine storms at the site.

This pattern of movement is consistent with the accounts given by local residents. The beach and dunes were monitored by the coastal community over the period in question and significant variations in the appearance of the beach and sand dunes were apparent in 1994 with pronounced erosion visible. Concerned at these changes, the coastal community made contact with the Office of Public Works (OPW) to make them aware of the erosion of the beach and dunes and these representations led to a proposal to construct coastal protection structures comprising of rock armour at the southern and the northern end of the main beach which were implemented in 1997. It was made clear at this time that coastal protection works were to be limited to the northern and southern parts of the beach and that soft engineering measures would be more suitable for protecting the beach and dunes.

Following the placement of the rock armour (Fig. 32.2), Donegal County Council (DCC hereafter) commissioned a team from Ulster University led by Professor Derek Jackson (a Coastal Geomorphologist) to complete a study of Maghery

Fig. 32.2 Rock Armour on the northern and southern sides of the beach. (Photo: Paul Lawlor, 2019)

beach and coastline. This study, which included consultations with local stakeholders such as residents groups and Non-Governmental Organisations, considered the natural dynamics of the site and how to manage the erosion of the main dune frontage and other associated issues (Jackson, 2015, p. 1). The final report presents a range of management options for the beach and dune system which include ‘grey’ measures (hard engineering approaches such as a sea wall) and ‘green’ measures (such as nature-based approaches). From the outset, grey measures were ruled out as an effective means of addressing the erosion of the beach and dunes. The report stated that; ‘*rock armouring will be counterproductive to the beach dynamics and would set up an instability in the sediment system whereby strong wave action will reflect off hard defences (even porous structures) and strip the beach sand lower than present levels’* (Jackson, 2015, p. 14). The study concluded that the preferred management option was to regenerate the frontal foredune area using a Nature-based Solution comprising of a sand trapping fencing scheme and by revegetation of the restored dunes. This approach was followed in 2005 and it was repeated again in 2015.

3 Methods

The sand trapping system was designed to be consistent with the natural sand transport dynamics of the site and to maintain the stability of the sediment deposition and removal processes that were taking place. Wind-blown (aeolian) sand being transported by onshore winds (especially at low tide) moves up to the back beach area and is forced into deposition by the retardation of airflow through the presence of new dune fences that were placed in front of the dunes at the back of the current beach. The dune fencing (as shown on Fig. 32.3) was made up of circular wooden

Fig. 32.3 The sand trapping scheme in Maghery in 2006 which was comprised of a lattice network of fencing. (Photo: Prof. Derek Jackson)

support poles (150 mm in diameter) placed in rows spaced 2 m apart. Each fence pole was firmly anchored into the sand and protruded a minimum of 0.8 above the surface. The fence poles within each row were spaced 1 m apart with a series of vertical chestnut palings in between. The poles and the chestnut palings were knitted together using stainless steel wiring (to ensure no degrading or rusting) thus creating a lattice network of fencing. Each row of dune fencing extended 11 m from the face of the dune system onto the beach. The sand trapping system, based on those used elsewhere (Scottish Natural Heritage, 2000; Eichmanns & Schüttrumpf, 2020), was relatively extensive, stretching circa 500 m along the beach (between the rock armour to the north of the beach and the vehicular entrance to the south).

Following sand build up, revegetation of the foredunes with local marram grass (only) was also considered necessary to enhance the durability of the regenerated dunes. While natural revegetation was anticipated, it was recommended that this process should be accelerated by planting marram grass stock that was sourced from vigorous clumps in sheltered conditions from as near to the site as possible (e.g. to the rear of the existing foredunes). The use of marram grass stock from inland mature dunes was discouraged as it was less likely to thrive in a vigorous foredune environment. Clear directions were also given on the timing of the marram grass planting (between February and early April), the required root depth and its spacing. In addition, management measures were put in place (such as appropriate fencing and signage) to advise the public that revegetation was taking place along dune sections and that access was restricted. It was also necessary to leave a 'dynamic unvegetated (horizontal) zone' of approximately 5 m at the toe of each profiled dune to allow for a continuation of the natural process of sediment transfer to and from the beach.

The Community of Maghery played a key role in the implementation of the project. While DCC installed the lattice network of dune fencing, the local Community engaged in marram grass planting (in 2015) and the maintenance of the protective fencing and signage. Continuous monitoring and assessment of the dune fencing (especially along the front edge) was considered necessary to ensure that the sand trapping system remained in position and in good condition. According to the 2015 report, the coastal community were assigned the task of monitoring the condition of the fencing (especially following storms and extreme weather) and to report any visible defects. It was emphasised to all parties at the time that a lack of maintenance of the sand trapping system would reduce its effectiveness and potentially lead to a failure to regenerate the dunes.

The above method was followed when constructing the original sand trapping scheme in 2006. In 2015, the process was repeated in order to re-establish the lattice network of fencing based on the overprint of the original scheme and two rows of net fences (parallel to the beach line) were added to address the problem of sand blow from the beach and dunes that was causing significant sediment removal and causing difficulties for surrounding structures such as the community centre and car park. Both net fences were erected by the local community with one line of fencing (1 m in height) positioned on the seaward side and a second line of fencing (2 m high) located on the landward side, 1–2 m down from the crest of the dune. The net fences extended along a 150 m stretch of the beach and dunes immediately adjacent to the community centre and pitch.

4 Results

The results of the original sand trapping scheme in 2006 and the later scheme in 2015 are discussed in sequence. The 2006 scheme was successful as it initiated a significant build-up of sand at the foredunes between 2006 and 2011 with continuous deposits of sand made throughout the 5-year period and a noticeable acceleration in the rate of accumulation between 2010 and 2011. This process led to fully regenerated foredunes in 2011 (Fig. 32.4).

However, noticeable erosion was visible on the lower sections of the dunes and beach (below 2 m in height) by 2015. A survey (taken from representative cross sections) compared sand levels on the beach in 2005 and 2015 and it demonstrated a decline of 0.8 m over the 10-year period and sand levels that were below the levels seen before the original sand trapping scheme was installed (Fig. 32.5). It is understood that the accelerated pace of erosion was caused by the coastal system entering an erosional phase between 2011–2015 combined with a lack of maintenance of the sand trapping scheme and the impacts of a series of severe storms. Despite the erosion, the 2015 back beach and dune levels still retained heights of around 2 m above 2005 levels – confirming that the rebuilt dunes remained intact. However, the experience demonstrates that the Nature-based Solution emplaced here requires continuous monitoring and proactive repair to ensure that it remains fully effective.

In February 2015, the sand trapping scheme was re-established, dune replanting took place and this led once again to the successful regeneration of the lower sections of the dunes and the beach. A survey in November 2015 demonstrated the extent and the speed of the recovery with the lower dune and beach sand levels increasing by 0.8 m in 9 months. This recovery enabled the dunes and beach return to the same sand levels that were recorded in 2005 (Fig. 32.6).

5 Discussion

The case study revealed that the decision to undertake a Nature-based Solution to help manage the beach and dune erosion issues at Maghery was influenced by a number of features of the coastline with the natural dynamics of the site and its socio-ecological importance proving significant. The initial study revealed that using grey infrastructural measures to manage the erosion would be counterproductive as they would risk destabilising the sediment system by causing sand to be stripped from the beach by wave reflection off hard defence structures. The inclusion of the beach and dunes in the Termon Strand Special Area of Conservation also meant that a hard

Fig. 32.4 Stages of dune restoration using a Nature-based Solution from sand accumulation (2006–2010) to revegetation and full regeneration (2011). (Photos: Prof. Derek Jackson)

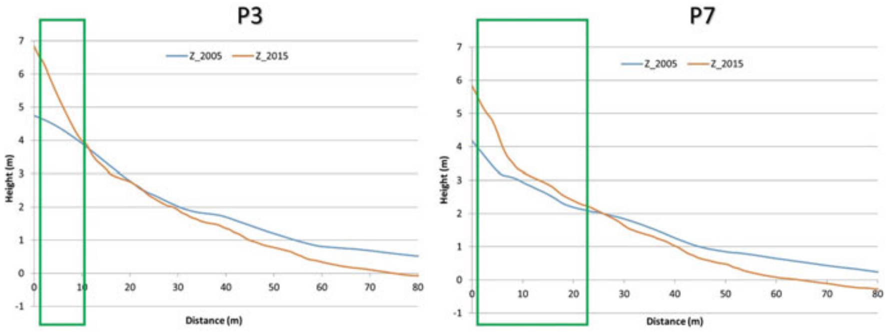

Fig. 32.5 A comparison of beach profile sand levels in 2005 (pre-installation) and 2015 (before second phase of fencing/repair) taken from cross sections. Graphs are based on GPS profile data in Jackson (2015). Note green boxed areas are foredune/back beach areas showing elevated surface levels in new dune heights still intact despite lowered frontal beach levels over the 10 year period

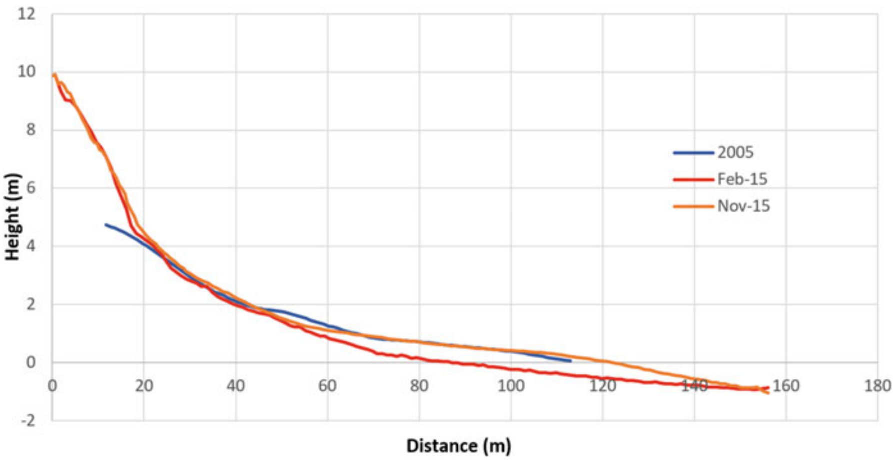

Fig. 32.6 A comparison of beach sand Levels in February 2015 and November 2015 taken from a cross section (Based on data in Jackson, 2015)

engineering solution (such as a sea wall) would not be permissible. Therefore, the options for dealing with ongoing erosion were limited to softer interventions such as a Nature-based Solution to regenerate the foredunes that provide a natural buffer to coastal change.

The preferred Nature-based Solution for regenerating the Maghery dune system involved the construction of a sand trapping system which was designed to harness the natural wind-blown dynamics of the site and accelerate a build-up of sand in the foredunes. The strength of the regenerated dunes was to be supplemented by natural marram grass growth. Following consultation with the principal stakeholders in the area (DCC and the coastal community), it was agreed to proceed with the sand trapping system and associated measures. However, and notwithstanding the constraints pertaining to the site (i.e. its unsuitability to an engineered solution and its SAC designation), some members of the local community retained a preference for a sea wall as it was perceived to be a more permanent and durable solution.

The evidence presented in the case study demonstrates that the Nature-based Solution adopted at Maghery led to the successful regeneration of the dune system and an increase in sand levels on the beach between 2006 and 2011. It is also understood that the costs of building (and maintaining) the sand trapping system were significantly lower than the costs of alternative grey infrastructure coastal protection methods. Furthermore, the study indicates that a series of severe winter storms combined with a failure to maintain the sand trapping system led directly to higher rates of erosion of the beach and dunes after 2011 and this necessitated a reinstatement of the sand trapping system in 2015. While the decline of the sand trapping system in 2011 was not anticipated, it demonstrated the dynamic nature of the adaptation solution in Maghery and the need to continuously monitor and maintain it as a means of ensuring its longer term resilience and effectiveness.

The decline of the sand trapping system after 2011 also highlighted the need for all stakeholders in the process (particularly DCC and the coastal community) to fully understand their roles in the adaptation project. The research revealed that the role of the community was either not made clear or was not fully understood, particularly with respect to the ongoing maintenance and management of the sand trapping scheme and dune revegetation programme. A clear view emerged during the research that the community expected DCC to have a larger role in maintaining the Nature-based Solution following its implementation. The absence of a formal management committee to deal with ongoing issues was seen as a further weakness as it hindered communication between all parties and it reduced opportunities for reflective learning by all stakeholders throughout the process.

6 Conclusion

This example from County Donegal in Ireland reveals that Nature-based Solutions can play a significant role in responding to challenges from climate change in coastal areas and that they can provide workable alternatives to ‘grey’ infrastructure solutions – particularly in areas designated under the Habitats Directive. The case study also demonstrates that Nature-based Solutions are often dynamic and subject to change by the environment in which they are located and while this is often seen as a significant advantage of these approaches, it also means that they require continuous monitoring and maintenance to ensure their effectiveness. These maintenance requirements mean that Nature-based Solutions can lend themselves to partnership arrangements between Local Authorities and local communities or other interests who are interested in a management or stewardship role in coastal areas. However, the case study also reveals that in order for these partnerships to operate effectively, all parties must clearly understand their roles in maintaining the

Nature-based Solution and that continuous communication (through existing governance structures) among stakeholders is crucial.

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Glossary[1]

Bio-cultural diversity The entwined diversity of cultures and biodiversity.
Blue Urbanism It refers specifically to Timothy Beatley's (2014) work by the same title, on integrating coastal city life with its oceanic present and future. The concept has propelled an emerging set of ideas and perspectives in urban planning, design, and engineering (Beatley, 2014).
Climate gentrification Gentrification can be defined as a process of physical, social, and demographic change that is typified by the displacement of a lower socio-economic group by a more affluent one, thus reproducing and strengthening existing class structures, together related ethnic and socio-cultural divides. Such displacement is often associated with urban spaces, although not exclusively. "Climate gentrification", a term popularised by media and in academic scholarship, is often typified by a process whereby a primary concern for a gentrifier is longer-term environmental security. The process is often associated with transitions in real estate value and development (Wiggins, 2018).
Coastal and marine management Organization of the use and development of coastal and open ocean areas and its resources, such as marine living organisms (fish, shellfish) and minerals.
Coastal ecosystem services Benefits people obtain from coastal ecosystems. They can be divided in: (i) provisioning (products from ecosystems, including food, materials, genetic resources and habitat), (ii) regulation and maintenance (functions of ecosystems, which sustain air and water quality, climate regulation and natural hazards), and (iii) cultural (non material benefits people obtain from ecosystems, including recreation, cognitive development and aesthetic experiences).
Coastal land reclamation Reclaiming land from the sea has often been the preferred solution towards meeting the need for more land for urban development

[1] Terms in this Glossary are based on different sources as indicated, otherwise they are taken from the chapters of this Book.

I. Misiune et al. (eds.), *Human-Nature Interactions*,
https://doi.org/10.1007/978-3-031-01980-7

and real estate in coastal spaces, particularly across many of the world's mega-cities. Seaward land reclamation entails the formation of artificial land surfaces which are constructed in such a way as to extend outwards over the sea using geo-engineering techniques. It can be characterised as a historic practice in urban development, as witnessed across globalised cities from Hong Kong and Shanghai to New York and Rio de Janeiro (Sengupta et al., 2018).

Coastal tourism It incorporates the close interaction between beach-based and coastal water-based recreational activities, e.g. swimming and sunbathing, and other activities for which the proximity of the sea is an advantage, such as coastal walks and wildlife watching, and maritime boating, yachting, cruising, and nautical sports often carried out in coastal waters, as well as the associated landside facilities and manufacturing.

Coastal wetland Ecosystems in which continental water has contact with seawater in major or less proportion.

Core areas Important habitat patches or ecosystem features that support environmental quality, biodiversity, and services.

Core city zone Representing historical areas characterized by dense development of tenement houses and urban villas.

Corridors Vegetated areas that connect core areas across the landscape, allowing species movements.

Cosmovision A way of seeing the world, an epistemic approach to conservation based on a belief in the importance of humans being part of the ecosystem.

Disaster Risk Reduction (DRR) Normatively defined by the Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UNISDR) as 'the systematic development and application of policies, strategies and practices to minimise vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development' (see UNISDR, 2004, p. 3). As a multidisciplinary concept and as a broad set of approaches, critical DRR scholarship recognises the interlinks between "natural" hazards, social inequality, and the wider historic and political contexts in which socio-ecological impacts are diversely experienced (Mercer, 2010).

Donegal County Council (DCC) Statutory Authority responsible for Local Government in County Donegal.

Ecosystem disservices Ecosystems' characteristics that give rise to disadvantages for people (Lyytimäki & Sipilä, 2009).

Ecosystem service flow The flow of benefits from ecosystems to people. This flow can be divided into two components: the movement of natural goods and the movement of beneficiaries (people) to access them.

Ecosystem services The contributions of ecosystem structure and function, in combination with other inputs, to human well-being (Burkhard & Maes, 2017).

Enabling factors Measures for environmental threats mitigation that favour sustainable human activities, e.g.: protection and conservation measures, environmental legislation, environmental best practices, governance.

ENSO The El Niño Southern Oscillation (ENSO) is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean, on periods ranging from about 3 to 7 years.

Environmental justice The fair treatment and meaningful involvement of all people in the development and implementation of different actions related to societal development. Environmental justice addresses the unequal distribution of environmental benefits (e.g. access to green spaces and ecosystem services) and harms (e.g. environmental problems such as pollutions).

Equity A multi-dimensional concept of ethical concerns and social justice based on the distribution of costs and benefits, process and participation, and recognition, underpinned by the context under consideration. Sometimes used synonymously with fairness or justice (Friedman et al., 2018).

Exposure The state of human, ecosystem, property or other elements of being exposed to a particular hazard.

Fairness A subjective or perception-oriented notion of what is "fair", shaped by a range of principles and considerations. Also considered the absence of envy. Sometimes used synonymously with equity (Friedman et al., 2018).

Green adaptation measures Measures which utilise ecological properties to enhance resilience.

Green Infrastructure A strategically planned network of natural and semi natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (European Commission, 2013).

Impact It indicates the consequences of environmental state changes in terms of substantial environmental and/or socio-economic effects.

Inner suburbs covering development areas around the city center, including both multi-family and single-family housing estates from the twentieth century.

Integrated coastal zone management (ICZM) A dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning, decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space. Note that in SEEA EA recreation is one of several services – a subset of the economic indicators (social and cultural indicators of recreation would be treated outside core accounts).

Itrofil Mogen A cultural concept in the Mapuche family in Chile, that not only celebrates biodiversity but celebrates local nature and humans within it as a sacred complex, connected to all the elements of the local territory.

Land cover Change Transformation of the original coverage towards a different use.

Landscape connectivity Degree to which ecosystems features are structurally connected and influence the movements of organisms, material, and energy through the landscape.

Landscape fragmentation Disaggregation of contiguous areas of natural ecosystems into smaller elements, driven by human activities.

Links Connection elements between different nodes of a network (or a graph). In a landscape perspective they can be represented by features such as corridors.

Local ecological knowledge It can be used to understand the processes of ecological change when people are faced with rapid transformations of their environment. Such knowledge springs from a local understanding of ecological processes either learned from experienced local inhabitants, like, fishers through social learning and/or gained through daily experience and interaction with the local environment.

Localization The process of adapting a concept (like the global SDGs) or content to a specific location, like a city or municipality.

Mapuche-Huichille The Mapuche people of the south, extending from the river Tolten until the south of Chiloe.

Multi-Use Platform Physical structures hosting multiple activities. MUPs are central to achieving EU's Blue Growth targets and can contribute to the implementation of several Sea Basin Strategies as a central component to boost ocean sustainability (van den Burg et al., 2020).

Multi-Use The joint use of resources in close geographic proximity by either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users (Schupp et al., 2019).

Natural hazard Naturally occurring dangerous phenomenon that causes loss of life and livelihoods, and severe damage of economic property and environmental setup.

Nature-based Solutions Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016).

Network Set of connected elements defined by nodes, that represent a set of key features in the landscape, and links, that represent the relationships between these features.

NHCE The Humboldt Current Large Marine Ecosystem extends along the west coast of Chile and Peru, and the Northern Humboldt Current Ecosystem (NHCE) corresponds to the Peruvian sea.

Nodes Key elements of a network connected to each other by links. In a landscape perspective, nodes can be represented by features such as core areas.

Office of Public Works (OPW) National Level Government Department in Ireland who are responsible for Coastal Protection Works and Flood Alleviation Schemes.

Open Green Space (OGS) It is considered to be every publicly available and accessible natural or seminatural land in the city's urban-footprint or peri-urban area.

Outer suburbs Peripheral areas consisting of single-family housing estates and new multi-family buildings in a mosaic with industrial and agricultural areas.

Participatory mapping An ethnographic technique that uses focus groups of experienced fishers to delineate the adjacent coastal zone's ecological characteristics in a bathymetric map, was employed to document and map critical ecological habitats, targeted species, and perceived changes over the past decade.

Peri-urban farmland The subject, 'peri-urban farmland', is understood here to emphatically include all of the utilizable agricultural land within the functional urban area (urban and peri-urban landscape). Thus, utilizable agricultural land consists of all forms of extensive and intensive farming. Importantly, it also includes agricultural land uses that do not intentionally supply (nor do they appear to do so) any resources, products, or services to the urban area.

Peri-urban landscape 'Peri-urban landscape' is the transition from urban to rural as the area within an urban agglomeration, and can include towns and villages, and any kind of ecosystems affected by the material and energy flows, demanded by the urban and rural systems. Despite shortcomings and challenges for spatial planning, the value of peri-urban landscapes in providing essential ecosystem services of relevance for the sustainability of cities is increasingly being recognized. Together with the urban, it builds the functional urban area.

Pressure Result of a driver-initiated mechanism (human activity/natural process) causing an effect on any part of an ecosystem that may alter the environmental state.

Productive Unit A productive unit in small-scale fisheries integrates a group of people involved in the economic activity of fishing (catching, processing, and distribution) and who can play different roles. These units' composition is linked to recruitment strategies traditionally correlated with close kinship and diverse forms of affinity, depending on the circumstances. Furthermore, production units have the means of production (boats, gears, technology, infrastructures) necessary to develop their activity. For example, a production unit may have more than one boat, and they share the luck and income jointly, usually through some form of share system. Finally, productive units accumulate knowledge, know-how, and skills through generations, allowing them to situate themselves in the marine environment, locate the target species, catch them, optimize the workforce's use, and the means of production (Andersen, 1972; Andersen & Wadel, 1972).

Random forest A supervised machine learning algorithm for classification and regression.

Remote sensing The process of detection and monitoring of physical characteristics of a particular area on earth surface using reflected and emitted radiation at a distance such as from satellite, aircraft or unmanned air vehicle.

Small-scale fisheries In European Union (EU), the concept of small-scale fisheries derives from Council Regulation (EC) No 1198/2006, which states that "small-scale coastal fishing' means fishing carried out by fishing vessels of an overall length of fewer than 12 meters and not using towed gear...". In Spain, the legal category of "small-scale gears" encompasses most of the small-scale fleet, not fully overlapped with the EU category (Pascual-Fernández et al., 2020).

Social demand A person's or group's use, perceptions, preferences, and values of a place or an object.

Socio-Ecological System (SES) Socio-ecological systems are a highly interconnected relationship between society and ecosystems. Resilience of such a system of systems depends on a wide range of factors stemming from the linkages between human societies and ecosystems (Francis & Bekera, 2014)

South central Chile The most populated area of Chile which concentrates nearly 80% of the total population (between Valparaiso and Biobío region). It concentrates most of the productive land for agriculture and forest industry of the country.

Spatial patterns Distribution of a set of elements, such as ecosystem features, across the space.

Storm surge An abnormal rise of water level caused by intense storms such tropical cyclones, hurricanes or typhoons. In the coastal region it is considered as the greatest threat to life, property and ecological resources. The intensity of the storm surge depends on the surge height, wind speed of the storm, central pressure level, land topography, bathymetry, and direction of approach relative to the coastline.

Sustainable Development Goals (SDGs) 17 interlinked global goals from the United Nations Agenda 2030 report from 2015.

The UN System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) A statistical standard aiming to identify the contribution of ecosystem services to the national economy, so as to support economic and environmental policy. The standard encompasses periodically reports on physical ecosystem extent, biophysical indicators of ecosystem condition, biophysical flow of ecosystem services supply & use per year. Guidance using recognized national accounting principles is also provided for monetary valuation of ecosystem services flow per year, and the monetary value of ecosystem assets (not yet a UN standard). Guidance is also provided on thematic accounts (i.e. biodiversity, oceans, urban). SEEA EA standards are important in facilitating consistent assessment over time. This is important for long term monitoring of the effect of policies on the ecosystems, assess ecosystem services supply and support decision making on economics and financing of measures. UNCEEA 2021

Threat It includes the concepts of "pressures" and "impacts" adopted in the DPSIR (Driver-Pressure-State-Impact-Response) framework implemented by the European Environment Agency.

Traditional Ecological Knowledge (TEK) Observations generated by individuals or group of individuals continually with local ecosystems, such as farmers, hunters, and fishers, who can be aware of important environmental details missed by scientists and power over ecological decision making.

Tropical cyclone A rapid rotating storm developed over the tropical oceans, which is characterized by a low-pressure center with spiralling clouds usually anticlockwise and clockwise directions to the north and south of the equators, respectively. It often causes devastation in the coastal landscapes through its intensity, wind speed and associated storm surge.

Unsatisfied Basic Needs (NBI) Is the index developed by INDEC to identify vulnerable groups with structural poverty. This index represents poverty by combining not only the family income, but also basic material needs including essential-housing and children's educational attendance.

Upazila Third order administrative unit in Bangladesh

Urban green space planning tools Strategic plans and process – and counting tools used to facilitate the assessment and implementation of urban green space at different scales in the planning and building process.

Urban green space (UGS) Vegetated land within a city designed to improve public wellbeing.

Urban spaces of arrival Areas that are inhabited by a high proportion of people with an international biography, have a high level of in- and out-migration, thus a high fluctuation of inhabitants and a relatively high proportion of socially disadvantaged people. Furthermore, such areas are characterised by lower rents compared to other urban areas, as well as the existence of diverse support structures, networks for newcomers such as job opportunities, assistance/social associations (based on Haase et al., 2020, p. 2).

Urban wilderness An undeveloped area (save natural surface trails) within city limits that is large enough where human activities are not seen or heard.

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