Chapter **5.**

PATHWAYS TOWARDS A SUSTAINABLE FUTURE

IPBES GLOBAL ASSESSMENT REPORT ON BIODIVERSITY AND ECOSYSTEM SERVICES
CHAPTER 5. PATHWAYS TOWARDS A SUSTAINABLE FUTURE

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EXECUTIVE SUMMARY

Current evaluations (chapters 2, 3) and most future scenarios (chapter 4) show that goals for conserving and sustainably using nature and achieving sustainability cannot be met by current trajectories, and goals for 2030 and beyond, the 2020 Aichi Biodiversity Targets, and Paris Agreement on Climate Change may only be achieved through transformative changes across economic, social, political and technological factors. This chapter examines pathways towards successfully achieving these overarching goals. Our purpose is to distil from these and broader literatures the key elements of sustainable pathways—that is, ones that at a minimum would achieve the global goals related to nature by 2050 or earlier.

This analysis was rooted in the existing scenario literature mainly at the global scale incorporating results from IPBES' regional assessments, focusing on target-seeking scenarios, sustainability-oriented exploratory scenarios, and selected policy-screening scenarios. From this scenario review and our syntheses of broader literatures related to multiple drivers and complex human-nature dynamics, we analyse interactions between multiple sectors and objectives through a **nexus approach**—that is considering interactions between diverse goals and sectors. We apply this approach via six complementary foci for achieving clusters of SDGs. This analysis revealed synergies, trade-offs and common key elements in the simultaneous achievement of clusters of SDGs, incorporating thinking across scales, domains, sectors and disciplines. Below are key findings pertaining to these.

1 **The pathways to achieve global goals related to nature vary significantly across geographic contexts, with different changes needed to achieve them at all scales (e.g., local, national, regional and international) (*well established*).** Sustainable pathways are flexible, within a range. These pathways imply major deviations from current trends and indicate the need for sustained efforts over decades to meet internationally-agreed objectives. Despite the diversity, there is much commonality across these pathways and the interventions to achieve them {5.1. 5.2.2 and 5.3}.

2 **The first focus of our nexus approach is the challenge of feeding humanity while enhancing the conservation and sustainable use of nature (SDG 15, also considering 2, 12). Our analysis concludes that future agricultural systems could feed humanity and conserve biodiversity inclusively and equitably. Such pathways imply transformation of production (e.g., broad adoption of region-specific agroecological approaches and cross-sectoral integrated landscape and watershed management), supply chains (e.g., responsible trade, phasing out harmful subsidies), and demand sides of food systems (e.g., waste reduction, diet change) (*well established*) {5.4.2.1}.** Competing uses for land, e.g., for land-based climate mitigation through bioenergy production, only exacerbate these needs {5.4.2.2}. (a) Related to **agricultural production**, the diversity of agricultural systems, from small to industrial-scale, create opportunities and challenges for transformation to sustainability. The uniformity at the heart of many agricultural systems—particularly at industrial scales—and their reliance on chemical fertilizers, pesticides and preventive use of antibiotics, triggers negative outcomes and vulnerabilities. However, across these different systems, pathways to sustainable production are emerging guided for instance by agroecological principles, landscape planning, and sustainable intensification technologies. These practices could be enhanced through well-structured regulations, incentives and subsidies, and the removal of distorting subsidies. (b) Related to **supply chains**, a few food companies are in positions of power to influence positive changes at both production and consumption ends of supply chains (such as standards, certification and moratorium agreements). This creates opportunities but also risks of co-option and inaction, which can be addressed through regulations and global governance mechanisms to check or override commercial interests in maintaining monopolies and the status quo. The same applies to agricultural input companies regarding restrictions on pesticides and chemical fertilizers considered harmful to human health and the environment. (c) Finally, **end consumers** have the potential to influence the supply chain and agricultural production through their purchases and activism, via certification and pressure on brands for transparency and particular practices {5.3.2.1}.

3 **The second focus is meeting climate goals while maintaining and restoring nature and its contributions to people (SDGs 7 and 13, also considering 2 and 15). In order to meet substantial climate mitigation objectives (such as the Paris Agreement's 'well below' 2°C target), a major escalation of dedicated bioenergy plantations has been proposed, but due to its large land area, this is unlikely to be compatible with biodiversity targets (*well established*). Nevertheless, a combination of other land-based mitigation activities, such as nature restoration and improved land management, have large potential for climate mitigation with positive effects on nature and its contributions to a good quality of life, including, food and water security (*established but incomplete*).** Bioenergy systems can also positively affect biodiversity, carbon storage and other ecosystem services. Economic incentives might be carefully designed to promote those bioenergy systems that minimize biodiversity losses and deliver multiple benefits. However, demand-side climate mitigation measures (e.g., reduced food waste or demand for energy and livestock products) can often be more successful in achieving multiple goals, such as greenhouse gas emission reduction, food security and biodiversity protection than bioenergy plantations. These actions imply a gradient of change in consumption and lifestyles, some of which pose challenges. {5.4.1.1, 5.3.2.2}.

4 **The third focus is achieving nature conservation and restoration on land while contributing positively to human well-being (SDG 15, also considering 3). Expansion of current protected area networks—and making them ecologically effective, representative and well-connected—is central to successful pathways (*well established*). However, to accommodate conservation and restoration where land is an increasingly limited resource, extensive and proactive participatory landscape-scale spatial planning is key (*well established*).** The scenarios literatures, especially at local to national scales, point out ways to further safeguard protected areas into the future, including enhancing monitoring and enforcement systems, managing biodiversity-rich land and sea beyond protected areas, addressing property rights conflicts and protecting environmental legal frameworks against the pressure of powerful interest groups (agribusiness, mining, and infrastructure). Facilitating and scaling up financing mechanisms to promote restoration and conservation within and outside protected areas are critically important, particularly in developing regions. In many areas, conservation will require building capacity and new forms of stakeholder collaboration, and removing existing barriers (e.g., unresolved land tenure, land/sea access, harmful economic incentives and policies, etc.). Also important are economic alternatives, technical assistance, well-designed payment for ecosystem services (PES) programs {5.4.2.1}, new value chains for local agricultural and biodiversity products, and better access to basic services (education, health, etc.). Indigenous Peoples and Local Communities (IPLCs) are central players, as at least one quarter of the global land area is traditionally managed, owned, used or occupied by Indigenous Peoples[1]. These areas include approximately 35 per cent of the area that is formally protected, and approximately 35 per cent of all remaining terrestrial areas with very low human intervention. Finally, well-designed innovations for the conservation-oriented economic use of biodiversity (e.g., biomimicry in pharmaceuticals, cosmetics, food) could foster conservation while benefiting local populations and regional economies {5.3.2.3}.

5 **The fourth focus is maintaining freshwater for nature and humanity (SDG 6, also considering 2 and 12). Pathways exist that improve water use efficiency, increase storage and improve water quality while minimising disruption of natural flow regimes. Promising interventions include practising integrated water resource management and landscape planning across scales; protecting wetland biodiversity areas; guiding and limiting the expansion of unsustainable agriculture and mining; slowing and reversing de-vegetation of catchments; and mainstreaming practices that reduce erosion, sedimentation and pollution run-off and that minimize the negative impact of dams (*well established*).** Major interventions enable achievement of these SDGs, differing across contexts. Key among these are three general changes: (a) improving freshwater management, protection and connectivity; (b) participation of a diversity of stakeholders, including Indigenous Peoples and Local Communities, in planning and management of water and land use (including protected areas and fisheries); and (c) strengthening and improving implementation and enforcement of environmental laws, regulations, and standards. Slowing and reversing deforestation of catchments is key to buffering surface and underground storage, and maintaining sediment transport regimes and water quality. Sector-specific interventions include improved water-use efficiency techniques (including in **agriculture, mining and energy)**. Freshwater biodiversity goals can be facilitated by **energy** production interventions, including scaling-up non-hydro renewable energy generation (wind, solar), transitioning to air and sea-water cooling, and judicious evaluation of hydropower developments. Increased **water storage** can be achieved through policies that implement a mix of groundwater recharge, integrated management (e.g., 'conjunctive use') of surface and groundwater, wetland conservation, low-impact

1. These data sources define land management here as the process of determining the use, development and care of land resources in a manner that fulfils material and non-material cultural needs, including livelihood activities such as hunting, fishing, gathering, resource harvesting, pastoralism, and small-scale agriculture and horticulture.

dams, decentralized (for example, household-based) rainwater collection, and locally developed water conservation techniques (such as those developed by Indigenous Peoples and Local Communities) and water pricing and incentive programmes (such as water accounts and payment for ecosystem services programmes). Balancing competing human and environmental demands for water entails improved recognition of the different values of the resource (e.g., via water accounts, payment for ecosystem services programs, etc.), and improved governance systems inclusive of diverse stakeholders. Pricing policies that respect the human right to safe drinking water are important to manage **water consumption and reduce waste and pollution**. Further investments in infrastructure are important, especially in developing countries, undertaken in a way that considers ecological function and the careful blending of built with natural infrastructure {5.3.2.4}.

6 **The fifth focus is harmonizing food provision and biodiversity protection in the oceans (SDG 14, also considering 2, 12). Successful pathways include the effective implementation and expansion of marine protected areas and ecosystem-based fisheries management, with spatial planning and targeted restrictions on catches or fishing effort (*well established*).** Achieving biodiversity and food security goals in marine ecosystems will involve close attention to their synergies and trade-offs. In particular, safeguarding and improving the status of biodiversity will often entail reducing the negative effects of fish harvest and aquaculture, potentially resulting in near-term losses in access to living marine resources. There is also complementarity between biodiversity and food provision, however meeting food security goals will often involve promoting the conservation and/or restoration of marine ecosystems including through rebuilding overfished stocks; preventing, deterring and eliminating illegal, unreported and unregulated fishing; encouraging ecosystem-based fisheries management; and controlling pollution through removal of derelict gear and addressing plastics. Some of the trade-offs between food provision and biodiversity projection can be managed or avoided through appropriate social participation and community engagement in decision-making and implementation. Sustainable pathways also entail addressing growing problems with many marine pollutants—particularly those prone to bioaccumulation—which both affect marine ecosystems and undermine seafood safety and human health. Similarly, attaining sustainable pathways will be more feasible given stronger greenhouse gas reductions, which should lessen trade-offs between biodiversity and food provision. Thus, pathways to sustainable ocean development involve addressing multiple human stressors {5.3.2.5}.

7 **The sixth focus is sustaining cities while maintaining the underpinning ecosystems (both local and regional) and their biodiversity (SDG 11, also 15). Successful pathways generally entail integrated city-specific and landscape-level planning for retaining species and ecosystem in cities and surrounding regions, as well as limits on urban transformation. These can be achieved by strengthening local- and landscape-level governance and enabling transdisciplinary planning to bridge sectors and departments, and to engage businesses and other organizations in protecting public goods (*well established*).** Because many aspects of life within cities are underpinned by nature, achieving these goals is important not only for global biodiversity but also for local human quality of life. Opportunities to integrate ecological and built infrastructure are increasingly important, particularly for cities in developing countries with high deficits of infrastructure. Maintaining and designing for ecological connectivity within urban space is critical for nature and people, especially in large cities. Particularly important at the regional scale are policies and programmes that promote sustainability-minded collective action protect watersheds beyond city jurisdiction and ensure the connectivity of ecosystems and habitat (e.g., through green-belts), and that city expansion towards key regional biodiversity sites does not undermine their conservation mandates. Sustaining nature's contributions to people—for current and future needs—implies integrating these considerations into planning and development of infrastructure investments. Specifically, this includes encouraging—at all scales—compact communities, underlying road network designs, and sustainable transportation systems (including active, public and shared transport), which enable low-carbon and low-resource lifestyles throughout the decades or centuries over which this infrastructure will persist {5.3.2.6}.

8 **The cross-scale nexus analysis reinforced the importance of including regional and local perspectives in global pathways to sustainability.** Global scenarios alone do not capture some difficulties and unintended consequences of implementing certain measures at regional and local levels. Key constituents of regionally sensitive global pathways include (a) substantially bolstering monitoring and enforcement systems, which are especially weak in developing nations; and (b) enabling locally tailored choices about consumption and production, accounting for poverty, inequality and cultural variability.

9 **The analysis based on the nexus approach suggests several common constituents of sustainable pathways that contribute to the achievement of seven nature-based Sustainable Development Goals (SDGs 2, 3, 6, 11, 13, 14 and 15).** These key constituents include (a) safeguarding remaining natural habitats on land and sea by strengthening, consolidating, expanding and effectively

managing protected areas and their integration with surrounding land uses *(well established),* (b) undertaking large-scale restoration of degraded habitats (*well established*), and (c) integrating these activities with development through sustainable planning and management of landscapes and seascapes so that they contribute to meet human needs including food, fibre, water and energy security, while continually reducing pressure on natural habitats *(well established*) {5.3.3}.

10 These SDG outcomes can be achieved through complementary top-down and bottom-up action on eight priority points of intervention (leverage points) and employment of five governance mechanisms (levers) {5.3.3, 5.4} (Figure 5.1). Supplementing with additional analysis from social sciences and other literature on transformative change and human-nature relationships suggests that these leverage points and levers may be non-substitutably important. Leverage points can be engaged via a range of different mechanisms, including the five levers and more.

11 Five main interventions ("levers") can generate transformative change to address the indirect drivers that are the root causes of nature deterioration: (1) incentives and capacity-building; (2) cross-sectoral cooperation; (3) pre-emptive action; (4) decision-making in the context of resilience and uncertainty; and (5) environmental law and implementation. Employing these levers involves the following, in turn: (1) developing incentives and widespread capacity for environmental responsibility and eliminating perverse incentives; (2) reforming sectoral and segmented decision-making to promote integration across sectors and jurisdictions; (3) taking pre-emptive and precautionary actions in regulatory and management institutions and businesses to avoid, mitigate and remedy the deterioration of nature, and monitoring their outcomes; (4) managing for resilient social and ecological systems in the face of uncertainty and complexity to deliver decisions that are robust in a wide range of scenarios; and (5) strengthening environmental laws and policies and their implementation, and the rule of law more generally. All five levers may require

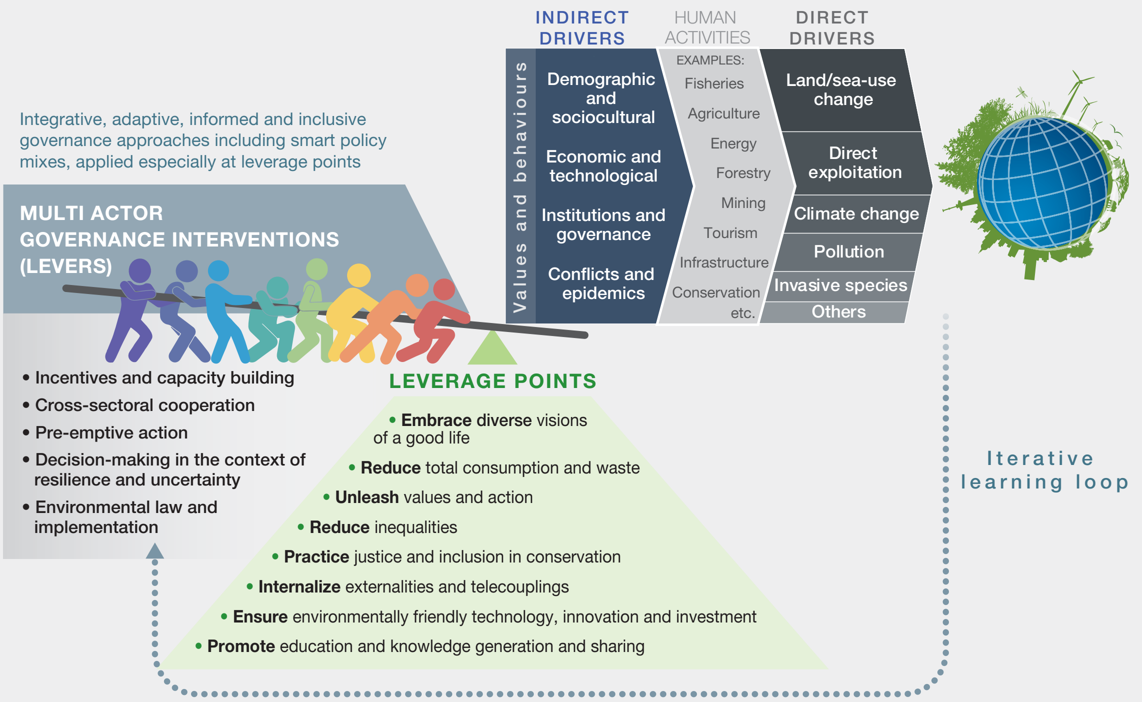

Figure 5 1 **Transformative change in global sustainability pathways.**

Collaborative implementation of priority governance interventions (levers) targeting key points of intervention (leverage points) could enable transformative change from current trends towards more sustainable ones. Most levers can be applied at multiple leverage points by a range of actors, such as intergovernmental organizations, governments, non-governmental organizations, citizen and community groups, Indigenous Peoples and Local Communities, donor agencies, science and educational organizations, and the private sector, depending on the context. Implementing existing and new instruments through place-based governance interventions that are integrative, informed, inclusive and adaptive, using strategic policy mixes and learning from feedback, could enable global transformation.

new resources, particularly in low-capacity contexts such as in many developing countries.

12 **The first two points of leverage are enabling visions of a good quality of life that do not entail ever-increasing material consumption (including due to population growth and waste), and lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts.** Whereas the ability to increase consumption is key to improve human quality of life in some regions and countries, in more-developed contexts human quality of life can be enhanced with decreasing overconsumption and waste (*well established)* {5.4.1.1}. Such changes in consumption may be achieved by fostering existing alternative visions of a good quality of life (*well established)* {5.4.1.2}.

13 **The third leverage point is unleashing existing widely held values of responsibility to effect new social norms for sustainability, especially by extending notions of responsibility to include impacts associated with consumption.** Such norm changes require concerted effort but are feasible when infrastructure and institutions (including social arrangements, regulations and incentives) activate values held by individuals (*well established*) {5.4.1.3}. Diverse values are consistent with sustainable trajectories, but not all have received equal attention in global sustainability discourses.

14 **Leverage is also found in addressing inequalities, especially regarding income and gender, which undermine capacity for sustainability and ensuring inclusive decision-making, fair and equitable sharing of benefits arising from the use of and adherence to human rights in conservation decisions. Inequalities tend to reflect and can cause excessive use of resources (*established but incomplete*), and appropriate inclusion of Indigenous Peoples and Local Communities is central to justice and sustainable protection of nature (*well established)* {5.4.1.4, 5.4.1.5}.** Full and effective participation of Indigenous Peoples and Local Communities is important and would contribute to conservation, restoration and management of the extensive areas of land and water over which they retain rights or control (*well established*) {5.4.1.5}.

15 **Crucial but often-overlooked points of leverage are accounting for nature deterioration from local economic activities and socioeconomic-environmental interactions, including externalities, over distances (telecouplings) into public and private decision-making, such that technological and social innovation and investment regimes all work for—rather than against—nature and sustainability, taking into account potential rebound effects. These leverage points are central to a global sustainable economy.** Whereas existing environmental policies and international trade have often reduced negative impacts in a specific place, many have had unintended spillover effects elsewhere (*well established)* {5.4.1.6}. More important in this context than valuation is to actually reflect these costs in economic decision-making (via required payments for mitigating damages), which can be initiated by private or public actors. Similarly, technological innovations are ambivalent in their impact on biodiversity (*well established)* (5.4.1.7). Regulations and non-governmental governance mechanisms including standards and certification can ensure that innovation and investment have positive effects at the global scale, which is key to global sustainable economies and sustainable pathways (*well established)* {5.4.1.6 and 5.4.1.7}.

16 **Transformations towards sustainability are more likely when efforts are directed at the following key leverage points, where efforts yield exceptionally large effects (Figure SPM.9): (1) visions of a good life; (2) total consumption and waste; (3) values and action; (4) inequalities; (5) justice and inclusion in conservation; (6) externalities and telecouplings; (7) technology, innovation and investment; and (8) education and knowledge generation and sharing.** Specifically, the following changes are mutually reinforcing: (1) enabling visions of a good quality of life that do not entail ever-increasing material consumption; (2) lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts; (3) unleashing existing widely held values of responsibility to effect new social norms for sustainability, especially by extending notions of responsibility to include impacts associated with consumption; (4) addressing inequalities, especially regarding income and gender, which undermine capacity for sustainability; (5) ensuring inclusive decision-making, fair and equitable sharing of benefits arising from the use of and adherence to human rights in conservation decisions; (6) accounting for nature deterioration from local economic activities and socioeconomic-environmental interactions over distances (telecouplings), including, for example, international trade; (7) ensuring environmentally friendly technological and social innovation, taking into account potential rebound effects and investment regimes; and (8) promoting education, knowledge generation and maintenance of different knowledge systems, including the sciences and indigenous and local knowledge regarding nature, conservation and its sustainable use.

17 **The eighth point of intervention is promoting education, knowledge generation and maintenance of different knowledge systems, including the sciences and indigenous and local knowledge regarding nature, conservation and its sustainable use. These elements**

are especially important in the face of demographic processes increasing the 'distance' between urbanizing populations and nature. Education generally only fosters changes in consumption, attitudes and relational values conducive to sustainability when it builds on existing understandings, enhances social learning, and embraces a "whole person" approach (*well established)* {5.4.1.8}. Whereas Indigenous Peoples and Local Communities have or had various traditional practices and/or norms that enabled sustainable use of local resources, communities worldwide are facing loss of knowledge transmission along with changes in values and lifestyles. Achieving sustainability from local to global levels will benefit from multiple strategies for education and learning, from recognizing and promoting local environmental knowledge and sustainable practices to integration throughout school curricula (*well established)* {5.4.1.5 and 5.4.1.8}.

18 Applicable across many intervention points, the first lever is developing incentives and widespread capacity for environmental responsibility. Important actions would often include eliminating perverse subsidies and improving fairness in regulations and incentive programs at every scale (*well established*) {5.4.2.1}. Whereas many incentive programs are designed in ways that may undermine stewardship and responsibility-taking (*well established)*, there appears to be great scope for subtle changes to policies and programs to instead reinforce commitment with such relational values (*established but incomplete)* {5.4.1.3 and 5.4.2.1}.

19 Three levers pertain to management and governance institutions. These are reforming business and economic, political and community structures to enable decision-making that (2) promotes integration across sectors and jurisdictions, (3) takes pre-emptive and precautionary actions in regulatory and management institutions and businesses to avoid, mitigate and remedy the deterioration of nature, also monitoring these outcomes, and (4) manage for resilient social and ecological systems in the face of uncertainty and complexity to deliver decisions that are robust in a wide range of scenarios. Whereas many resources are managed separately with only limited capacity to account for interactions between resources in social-ecological systems, management that integrates more fully across sectors and jurisdictions appears to be central to achieving global sustainability goals (*well established*) {5.4.2.2}. Most resource management and environmental assessment approaches are reactionary, generally enforcing regulations after damage occurs, rather than anticipating it, despite the latter being more suitable for sustainable trajectories (*well established*) {5.4.2.3}. Finally, achieving global goals entails avoiding undesirable collapses of resource systems and restoring underperforming degraded systems, both of which follow from governance for resilience and adaptation (*well established*) {5.4.1.4, 5.4.2.3 and 5.4.2.4}.

20 The final underlying key intervention that emerges is strengthening environmental laws and policies and their implementation, and the rule of law more generally as a vital prerequisite to reducing biodiversity loss and human and ecosystem health (*well established*). This includes not only strengthening domestic laws but also international environmental laws and policies, including mechanisms to both harness and rein in the power of business**.** Stronger international laws, constitutions, and domestic environmental law and policy frameworks, as well as improved implementation and enforcement of these rules, are critical in protecting biodiversity and nature's contributions to people (*well established)* {5.4.2.5}.

21 Although these various changes may seem insurmountable when approached separately, each enabling intervention removes barriers associated with implementing others (*well established*) {5.4.3}. Accordingly and perhaps counter-intuitively, multiple interventions can be achieved more feasibly than individual ones (*well established*) {5.4.3.1}. Governments, businesses, and civil society organizations have many opportunities to boost ongoing processes and to initiate new ones that collectively constitute transformative change (*well established*) {5.4.3.2}. The most important of these may involve laying the groundwork for changes to leverage points {5.4.1} and levers {5.4.2} at the root of environmental degradation or its reversal, by reducing opposition and obstacles, including those with interests vested in the status quo, but such opposition can be overcome for the broader public good {5.4.3.2}. Chapter 6 further details these challenges and also the opportunities and options for overcoming them, achieving long-term transformational change by initiating short-term measures today.

5.1 INTRODUCTION

While nature and its contributions to people are on a deeply unsustainable trajectory (c.f. chapters 2, 3, and 4), there is a multitude of voices demanding fundamental changes in the global socioeconomic structure and action. To change course toward a sustainable future, numerous organizations and individuals have called for actions at least since the 1980s (e.g., Our Common Future report, Agenda 21, The Future We Want). In response to the calls, many sustainability goals and targets have been set across local to global levels, including Aichi Biodiversity Targets and the 2030 United Nations Sustainable Development Goals (SDGs). Efforts around the world are under way for transformation to sustainability (CBD's Vision for Biodiversity 2050, Bennett *et al.*, 2016). Unlike the Intergovernmental Panel on Climate Change (IPCC), which has clear and single targets and timelines, single targets have limited capacity to address biodiversity declines. While proposals for using a combination of existing metrics exist (e.g., Red List index, Living Planet Index, Biodiversity Intactness Index) (Mace *et al.*, 2018), IPBES' work is guided by these and other existing targets including the Aichi Biodiversity Targets and the SDGs, which represent the closest option for an overall policy target for both ecosystems and human well-being.

In-depth understanding of the past trajectories and the current status of the global coupled human and natural system provides some useful knowledge needed to develop and employ models for a sustainable future (chapter 2; MA, 2005; Pimm *et al.*, 2014). Recent rapid and unprecedented changes, however, mean that historical trajectories may serve us very poorly. Therefore, forward-looking, scenario approaches are required that take those changes into account. Chapter 4 established that most trajectories rooted in current and past trends will fail to meet the full suite of Aichi Targets and biodiversity-relevant SDGs. However, chapter 4 also explored sustainability-oriented scenarios showing that positive futures are possible and failure is not inevitable. This indicates that it may not be too late to meet those goals and targets if bold systemic and incremental changes are made.

Change towards sustainability must be profound, systemic, strategic, and reflexive. Many signs of those changes are already starting to emerge, such as encapsulated in the notion of 'seeds of the good Anthropocene' (i.e., hopeful social-ecological practices ("seeds") that could catalyse and expand (grow) to produce more desirable futures, from addressing situations of social precariousness and vulnerability to recovering habitats for water protection and/or to conserve icons like the giant pandas (Bennett *et al.*, 2016; SFA, 2015; Yang *et al.*, 2017). The key implication of current scenario projections (chapter 4) is that successful change will not happen easily or spontaneously. It will likely require a broad and intense effort, informed by the best available understanding of local to global coupled human and natural systems dynamics. Most of the models and scenarios developed so far (chapter 4) have not been built, intended or applied in ways that address profound and systemic changes.

This finding from chapter 4 has bearing on chapter 5's position on sustainability transitions—as reformist, revolutionary, or reconfigurational (Geels *et al.*, 2015). A reformist position sees sustainability as the outcome of incremental changes and constant improvement of a current system. In contrast, revolutionary positions see sustainability as requiring a radical break with current trajectories. Finally, a reconfigurational position is something in between, involving context-related transformation of everyday practices and their structural embeddings. In this chapter we are philosophically ambivalent about these positions, but the chapter 4 finding suggests that a reformist position is likely to fail to achieve some relevant SDGs or Aichi Targets.

There is no single way to transform towards sustainability, and transformations will play out differently in different places (e.g., Arctic, Antarctic, temperate, tropical regions). The analysis in this chapter highlights possible pathways for transformative change to achieve widely agreed upon sustainability goals. It also identifies key leverage points (where a small change in one factor can generate bigger changes in other factors) (Abson *et al.*, 2017; Meadows, 1999) and 'levers' of change (promising management and governance interventions), without which successful transformation would not be possible. While we use the notion of 'levers' and 'leverage points' metaphorically, recognizing that global systems—as complex social-ecological systems—cannot be manipulated as neatly as can a boulder with a stick, it helps us to clarify our intentions.

What are those pathways, points of intervention and key levers or enabling interventions? In this chapter, we seek to answer this question, both for particular important objectives as well as their connections to other objectives within the larger system. We apply the 'nexus' concept to highlight connections representing stark synergies and trade-offs between different sectors and different goals, such as producing food or mitigating climate or producing energy while conserving biodiversity, resource use options, and ecosystem functioning (Liu *et al.*, 2018).

Two kinds of information are central for this chapter: existing scenarios and broader literatures pertinent to sustainability transformations. First, there are two relevant types of scenarios (target-seeking and policy-screening) that are constructed explicitly to achieve sustainability of Aichi

Targets and biodiversity-relevant SDGs. We interpret target-seeking scenarios as alternative pathways to meet one or multiple specific goals. As there are relatively few examples of such studies, we will also examine sustainability-oriented exploratory scenarios as a proxy. Assessing all these scenarios and pathways helps to explicitly analyse assumptions (e.g., economic, political, demographic, ecological, technological, ideological), pinpoint problems of spatial and temporal scales, and identify some complexities such as nonlinearities and regional differences (IPBES, 2016). Although the analysis is global, it builds on the IPBES regional assessments and meta-analyses of local studies in the literature. Particular emphasis is given to local participatory scenarios (e.g., participatory target-seeking scenarios for social transformation and empowerment) to illustrate and deepen the understanding of how global processes play out on a local scale. This is particularly important for biodiversity assessments, and with the emphasis on indigenous and local knowledge (ILK) and practices we anticipate innovative work on exploring alternative pathways at various scales. A second source of insight is necessary, however, because such scenarios represent only a narrow slice of the literature and a subset of the factors more easily rendered in models (e.g., only partly representing ILK), it is necessary to consult a broad range of literatures on societal and biodiversity change, including a burgeoning literature on pathways and transformative change.

In this chapter, we assess these various sources and distil from them alternative pathways for the transformations needed to achieve biodiversity objectives, the SDGs, to limit global temperature increase to 1.5 degrees Celsius above pre-industrial levels (i.e. The Paris Agreement of the UNFCCC) and to mitigate emerging and existing disaster risks (e.g., the Sendai Framework for Disaster Risk Reduction). We also draw upon policy- and management-screening scenarios, and their potential to simultaneously achieve multiple (sometimes conflicting) goals. This chapter culminates in key lessons for achieving multiple biodiversity and ecosystem service goals in the form of the ‘leverage points’ and ‘levers’ that offer unparalleled opportunities for changing unsustainable structures in today’s economies and societies.

In the following sections, Section 5.2 provides a conceptual orientation for our approach and explains the methods for our analysis. Section 5.3 summarizes the results of the scenario assessment in the form of a cross-scale analysis of a nexus analysis with six cross-sector foci. Section 5.4 synthesizes insights from the scenario analysis and broader literatures, from which we have identified eight points of intervention (‘leverage points’) and five key enabling interventions (‘levers’) for sustainability. Finally, Section 5.5 provides general concluding remarks.

5.2 METHODS OF ASSESSMENT

5.2.1 Conceptual Framework for Assessing Transformation

5.2.1.1 Change towards sustainability requires addressing root causes, implying fundamental changes in society

The society/nature interface can be described in various ways (see for example Descola, 2013; Haraway, 1989; Jetzkowitz, 2019; Latour, 2004; Mol & Spaargaren, 2006; Takeuchi *et al.*, 2016; for further references to ILK-related concepts of the society-nature nexus see chapter 2 and IPBES, 2018). Here we follow IPBES’ conceptual framework assuming that institutions, governance systems and other indirect drivers are “the root causes of the direct anthropogenic drivers that affect nature” (Díaz *et al.*, 2015; also see chapter 1). These root causes also affect all other elements of the society/nature interface, including interactions between nature and anthropogenic assets in the co-production of nature’s contributions to people (Díaz *et al.*, 2015) In addition to the conceptual framework, we adopt systems thinking because it allows (1) the combination of biophysical and societal understanding of processes, which helps to identify seeds for change, and (2) the combination of results from quantitative and qualitative scenarios and other pertinent literature.

5.2.1.2 Conceptual frameworks addressing transformative change

Various approaches currently discussed in sustainability science address the question of how profound, systemic, and strategic-reflexive changes toward (more) sustainability can be initiated. Our selection of five approaches—complexity theory and the identification of layers of transformation and leverage points, resilience thinking, the multi-level perspective on transformative change, the systems of innovation approach and initiative-based learning—comprises those we identify as widely consistent with the IPBES conceptual framework and mandate. They provide useful concepts for the integration of knowledge on pathways towards a (more) sustainable future and facilitate our imagination throughout the whole chapter.

Complexity theory and leverage points of transformation

Complexity theory attempts to untangle emergent processes in coupled human and natural systems (Liu *et al.*, 2007; Nguyen & Bosch, 2013). It stresses the importance of specific contexts and interdependent influences among various components of systems, which may result in path dependency and multi-causality, where most patterns are products of several processes operating at multiple scales (Levin, 1992). One of the implications of such interdependence is that small actions can lead to big changes (Meadows, 1999), i.e., processes can be nonlinear (Levin, 1998; Levin *et al.*, 2013). These impactful actions are considered *leverage points* because they can produce outcomes that are disproportionate large relative to initial inputs (UNEP, 2012). Although identifying and implementing such leverage points is not easy, the results can be profound and lasting (Meadows, 1999).

Resilience, adaptability and transformability in social-ecological systems

In the context of pathways involving nature and people, changes are bounded not only by technological and social feasibility, but also by spatial and ecological characteristics. *Resilience* thinking enhances our systemic understanding by putting three aspects of social-ecological systems at the center: persistence, adaptability and transformability (Folke, 2016). Resilience refers to the capacity of a system—such as a village, country or ecosystem—to adapt to change, deal with surprise, and retain its basic function and structure (Berkes *et al.*, 1998; Nelson *et al.*, 2007). Adaptability—a component of resilience—represents the capacity to adjust responses to changing external drivers and internal processes, and thereby channel development along a preferred trajectory in what is called a stability domain (Walker *et al.*, 2004). Transformability is the capacity to cross thresholds, enter new development trajectories, abandon unsustainable actions and chart better pathways to established targets (Folke *et al.*, 2010).

A multi-level perspective for transformative change

Complementary to the perspectives above, the *multi-level perspective* sees pathways as an outcome of coupled processes on three levels—niches, regimes and landscapes (Geels, 2002). At the micro level, *niches* are the safe spaces where radical innovations are possible but localized. For innovations to spread to the meso level (*regimes*—interlinked actors and established practices, including skills and corporate cultures), they must overcome incumbent actors who benefit from the status quo. Regimes can either steer for incremental improvement along a trajectory or can affect change in the *landscape* (which includes factors like cultural values, institutional arrangements, social pressures, and broad economic trends). Change at this macro (landscape) level generally involves a cascade of changes, which also affect the regime itself. The multi-level perspective has been particularly useful in understanding socio-technical pathways, which tend to be nested and interdependent across levels. It raises strategic and reflexive questions—for instance, How can we identify actions that yield structural change from individual and local to societal levels, identifying and avoiding blockages and supporting transformations towards sustainability?

System innovations and their dynamics

The *system innovation* (or 'systems of innovation') approach provides a framework for policy interventions to address not only single market failures, but also interconnected challenges through a combination of market mechanisms and policy tools (e.g. OECD, 2015). This approach emphasizes that system innovation generally requires a fundamentally different knowledge base and technical capabilities that either disrupt existing competencies and technologies or complement them. As technology innovation proceeds, it also involves changes in consumer practices and markets, infrastructure, skills, policy and culture (Smits *et al.*, 2010). A key component of innovation for sustainability is thus supportive business models (Abdelkafi & Täuscher, 2016; Bocken *et al.*, 2014; Schaltegger *et al.*, 2012; Seroka-Stolka *et al.*, 2017). Governments also have a role in supporting transitions, however, which extends beyond orchestrating and coordinating policies and requires an active management of transformative change, especially sequencing of policies with the different stages of the transition (Huber, 2008; Mol *et al.*, 2009; Seroka-Stolka *et al.*, 2017).

Learning sustainability through 'real world experiments'

Several strands of research take an approach of so-called *real world experiments* (Gross & Krohn, 2005). These action research approaches emphasize how local and regional initiatives can foster shared values among diverse societal actors (Hajer, 2011), accelerating adoption of pathways to sustainability (Geels *et al.*, 2016). These experimental approaches contribute to niche innovations that are able to challenge existing unsustainable pathways and the regimes that maintain them. Bennett *et al.* (2016) suggest that emphasizing hopeful elements of existing practice offers the opportunity to: (1) understand the values (guiding principles) and features that constitute transformative change (referred to by the authors as the Good Anthropocene), (2) determine the processes that lead to the emergence and growth of initiatives that fundamentally change human-environmental relationships, and (3) generate creative, bottom-up scenarios that feature well-articulated pathways toward a more positive future (see also chapter 2.1). In the multi-scale scenario analysis applied in this chapter, local scenarios may be most closely connected to this approach.

Synthesis

The above conceptual approaches converge on the idea that profound changes in global socioeconomic systems towards sustainability occur as transformation of nested and interlinked structures and processes across various scales. In line with *systems of innovation* approaches, *resilience thinking* and the *multi-level perspective*, we consider profound changes as structural changes. However, these changes do not happen without activating impulses of individuals, groups and organisations. Accordingly, our methods for identifying pathways for sustainable futures includes two key elements: structural analyses of alternative pathways; and cross-cutting analyses of entry points for change ('leverage points') and enabling interventions for transformations ('levers').

5.2.2 Scenarios and Pathways

This chapter mobilises two complementary types of information: scenario and pathway analysis (section 5.3) and knowledge on transformative change (section 5.4). Scenario approaches help open up thinking about the future through qualitative, storytelling approaches and through quantitative systems modelling. These approaches allow for consistent analysis of complex systems and help identify consequences of changes (e.g., technological changes, changing behaviour, alternative management regimes for natural resources). At the same time, classical model-based scenario analyses often oversimplify social realities and have little detail regarding actors, behaviours and policy implementation. Socio-technical and social-ecological pathways analysis gives much more attention to different actors and actions and to finding entry points and levers towards changing pathways. Unfortunately, these approaches often lack a forward-looking perspective (they are generally retrospective) (Turnheim *et al.*, 2015). However, taken together with cross-cutting literatures on transformative change, they can bring a much needed multi-disciplinary perspective to identify and govern pathways for transformative change.

The terms **scenarios** and **pathways** are often used interchangeably especially by the global climate and integrated assessment modeling communities (Rosenbloom, 2017; Turnheim *et al.*, 2015). Here we distinguish the two concepts. **Scenarios** are plausible stories about how the future may unfold that can be told in words, numbers, illustrations, and/or maps—often combining quantitative and qualitative elements. Scenarios are not predictions about the future; rather they are possibilities used in situations of large uncertainty, based on specified, internally consistent sets of underlying assumptions (IPBES, 2016; Raskin, 2005). The global modelling community sometimes uses the term **pathway** to describe the *clear temporal evolution of specific scenario aspects or goal-oriented scenarios* (see **Boxes 5.1-3**). The concept of **pathways** in our chapter includes—but is not limited to—this meaning. More broadly, we consider pathways as "*alternative trajectories of intervention and change, supported by narratives, entwined with politics and power*" (Leach *et al.*, 2010). Scenario exercises may represent selected pathways and their underlying narratives.

5.2.2.1 Pathways for transformative change

The concept of pathways has become increasingly popular to analyse how specific sustainability objectives can be achieved. Pathway approaches attempt to manage complexity—in a bounded, exploratory way—and illuminate new ways of achieving specific societal goals (Geels & Schot, 2007; Turnheim *et al.*, 2015). A rich set of literatures on pathways towards sustainability examines how sustainability might be achieved through different trajectories, often addressing the politics of change and seeking profound changes in global socioeconomic structures (Edenhofer & Kowarsch, 2015; Geels & Schot, 2007; Grin *et al.*, 2010; Leach, 2008; Leach *et al.*, 2018; Loorbach *et al.*, 2017; Luederitz *et al.*, 2017; Olsson *et al.*, 2014; Raskin, 2008; Rosenbloom, 2017; Scoones *et al.*, 2015; Sharpe *et al.*, 2016; Swilling & Annecke, 2012). Few analyses straddle the breadth of perspectives considered here (Loorbach *et al.*, 2017; Turnheim *et al.*, 2015).

Pathways are mostly neither deterministic nor linear, but always context-dependent and evolutionary with emergent properties (the future being shaped by the past). Different pathways achieving the same goals will have different socioeconomic and environmental implications (e.g., effects on nature and its contributions to people). These include 'distributional impacts' that raise justice issues in a given system, and in connected systems through telecouplings (i.e., socioeconomic and environmental interactions over distances). Pathways may also be characterised in other ways: speed (time to reach the goals and targets), depth (degree of differences between starting points, current development trajectories and the goals and targets to be achieved), and scope (dimensions that change to achieve the goals and targets) (Turnheim *et al.*, 2015). As one insight that emerges, pathways of fundamental reconfiguration (or system transformation) often go through distinctive phases of destabilisation → disruption → breakdown of internal structures of the old system followed by an emergence and acceleration of novel features (Loorbach *et al.*, 2017).

In this chapter, pathways refer explicitly to trajectories toward the achievement of goals and targets for biodiversity conservation and management of nature and the full array of the SDGs. Because of the transformative change required, our analysis considers the departure from existing development pathways and vested interests/structures, to make space for new and more sustainable pathways

(Loorbach *et al.*, 2017; Sharpe *et al.*, 2016). Part of this departure may occur by deepening and accelerating existing processes of change.

There are several reasons to identify and analyse alternative pathways. First, no method can identify the best feasible pathway *a priori* due to the many uncertainties, complexities, and societal perspectives in coupled human and natural systems. There is a danger of bias in selecting pathways because the "definition of the alternatives is the supreme instrument of power" (Schattschneider, 1960, p. 66). Second, presenting alternative pathways and their uncertainties may allow for constructive public discourse. It is important to think about how pathways are framed as this shapes how they are understood and addressed, structuring the possibilities and privileging certain responses (Rosenbloom, 2017). Third, presenting alternative policy pathways and their trade-offs and consequences may help avoid the misuse of expertise in policy. With several pathways, policymakers cannot legitimize policy pathways by referring to an alleged "inherent necessity" of a certain policy pathway based on an apparent scientific consensus. To avoid severe bias in the assessment, pathways thus ought to reflect several politically important and disputed objectives, ethical values and alternative policy narratives.

5.2.2.2 Scenario studies

This chapter **combines multiple scenario studies** (through an analysis of their key premises, underlying narratives and results) **and other sources to inform our understanding about possible pathways to the SDGs**, as follows:

- **Types of scenarios considered:** Following the typology of the IPBES methodological assessment report on scenarios and models of biodiversity and ecosystem servicse (IPBES, 2016), our main focus in this chapter are **target-seeking scenarios**, also known as normative scenarios. Such scenarios are built by first defining a future target and then how to get from the present to this future, through quantitative and/or qualitative backcasting (Vergragt & Quist, 2011) or scenario-discovery techniques (Gao & Bryan, 2017), for instance. Since there are relatively few target-seeking scenarios, we also included **sustainability-oriented exploratory scenarios** and **policy-screening scenarios**. The sustainability-oriented exploratory scenarios were those scenarios of evolving key drivers, based on sustainability-oriented archetypes or storylines (Hunt *et al.*, 2012; IPBES, 2016; van Vuuren *et al.*, 2012). In policy-screening scenarios (also known as *ex-ante* scenarios), we analysed specific policy options implications in relation to a reference/*status quo* scenario.

- **Spatial scales:** To extract the key elements that constitute the pathways from scenarios, we employed a cross-scale analysis. While global scenarios indicate broad pathway alternatives, scenarios at finer spatial scales provide more detail and insights in the context of local or regional conditions. We therefore enriched our analysis by bringing elements from finer scales to the pathways discussion. Global scenarios alone may not capture the difficulties of implementing certain measures at local to regional scales, or the unwanted consequences of doing so.

- **Nexus-thinking approach:** Given the inherent complexity of analyzing possible achievement of multiple SDGs, we organized our literature search and analysis using a nexus approach to explore complementary and interconnected perspectives related to terrestrial, marine and freshwater social-ecological systems.

5.2.3 Nexus Thinking, Methods of Analysis

5.2.3.1 Nexus thinking to structure the analysis

Achieving goals and targets related to nature and nature's contributions to people requires holistic approaches to integrate multiple disciplines, across space, over time, and among organizational scales. The need for integration in solving complex problems has long been recognized, leading to a variety of approaches and areas of study. In this chapter, we use a systems approach and nexus thinking to identify synergies and trade-offs when discussing pathways for achieving the SDGs—incorporating thinking across scales, domains, sectors and disciplines (Liu *et al.*, 2015b).

The word nexus (derived from the latin "*nectare*", "to bind or tie"), has long been used in multiple fields to refer to approaches that address linkages between multiple distinct entities (Liu *et al.*, 2018). In recent decades, it became increasingly popular as applied to the study of connections among water, energy and food (the WEF or FEW nexus), usually in the context of climate change, and sometimes with the addition of other issues, such as biodiversity protection and human health (Albrecht *et al.*, 2018; Hoff, 2011). We find nexus thinking a valuable approach *to avoid the natural tendency to retreat into intellectual, sectoral, and institutional silos*. This holistic approach is imperative in the context of the SDGs, given that many of the targets are interconnected (Nilsson *et al.*, 2016) and such interactions can be synergistic and/or antagonistic, involving context-dependent trade-offs (Weitz *et al.*, 2018).

For the above reasons, we use nexus thinking to frame the problem of reaching multiple SDGs together. To keep our analysis manageable and understandable in the complex context wherein everything is connected, we structure our analysis around complementary perspectives, in a multilayered approach. Each perspective can be understood as a *focus* (or lens) to view in detail particular links between terrestrial, marine and freshwater social-ecological systems without disregarding linkages to other aspects **(Figure 5.2)**.

The following six foci reflect core challenges related to conserving nature and nature's contributions to people (the mandate of the global assessment) while achieving the SDGs, given both trade-offs and synergies:

1. *Feeding humanity while enhancing the conservation and sustainable use of nature;*
2. *Meeting climate goals without incurring massive land-use change and biodiversity loss;*
3. *Conserving and restoring nature on land while contributing positively to human well-being;*
4. *Maintaining freshwater for nature and humanity;*
5. *Balancing food provision from oceans and coasts with biodiversity protection; and*
6. *Resourcing growing cities while maintaining the ecosystems and biodiversity that underpin them.*

Our analysis respects the "interconnected and indivisible nature" of the 17 goals (UN, 2015). These six foci relate to all SDGs in some way, although they are oriented around some more strongly than others. Some SDGs are easily related to several of these foci (SDG 2 – Zero hunger, for instance), but human well-being, basic needs, human rights and nature protection underlie all the lenses, including attention to their implications for Indigenous Peoples and

THE NEXUS IN THE LANDSCAPE

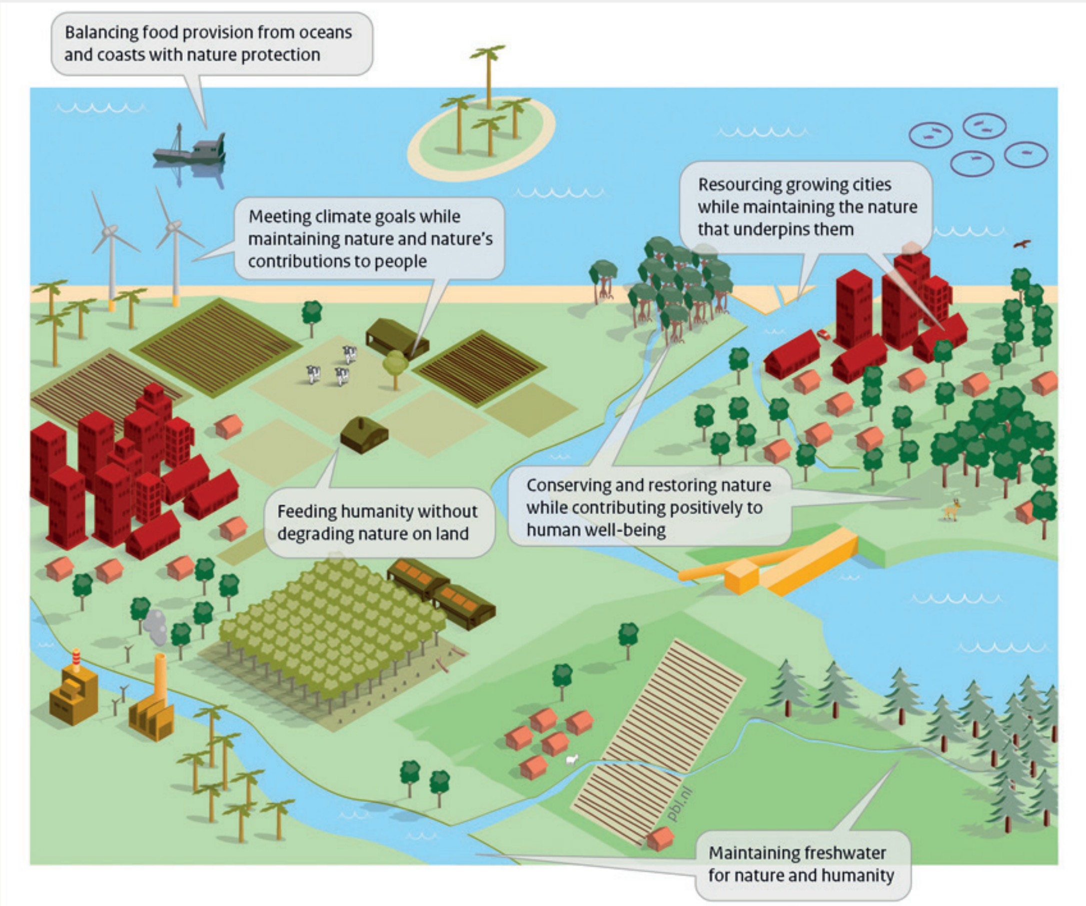

Figure 5 2 **The six interconnected foci of our nexus analysis.**

These complementary perspectives roughly followed divisions in the underlying scenario and pathways literatures addressing a variety of sustainability goals and targets (especially the UN's Sustainable Development Goals, SDGs, and the CBD's Aichi Targets). Source: PBL for this publication.

Local Communities (IPLCs), as **Figure 5.2** illustrates. The first three foci relate strongly to SDG 15 (Life on Land) and its interactions with other SDGs. The fourth addresses freshwater, connecting SDG 6 (Clean Water and Sanitation) to the first three foci through the WEF nexus. The fifth addresses marine resources, also linked to all other foci through the food system, water cycle, pollution and climate change concerns. Finally, the sixth focus addresses cities and their connection to the terrestrial, freshwater and marine resources previously discussed.

We structure our results in Section 5.3 (Pathways derived from the scenario review process) around these foci. For each subsection in 5.3.2, information is organized as follows:

- **Framing the problem**, a brief review about the current situation of the problem under analysis and major trends.
- **What do scenarios say about pathways to achieve the (relevant) SDGs?** We used the available information in the scenario literature (at multiple scales) to identify the *main measures* (actions, policies, governance premises, necessary changes) *directly or indirectly* (through quantified results or narrative premises, for instance) *underlying different scenarios in order to achieve the SDGs simultaneously*. Non-scenario literature was also used to reinforce or complement our synthesis approach.
- **Synthesis about the pathways**, we close each subsection with a synthesis of the main findings, including a diagram illustrating the pathways.

After the six subsections, we conclude 5.3 with a synthesis highlighting common threads across the six foci. We identify levers and leverage points of transformation with a focus on nature and nature's contributions to people (5.3.3). The section emphasizes core convergences and divergences across the different lenses, the synergies and trade-offs between the SDGs, and also the role nature and nature's benefits to people play in reaching the SDGs.

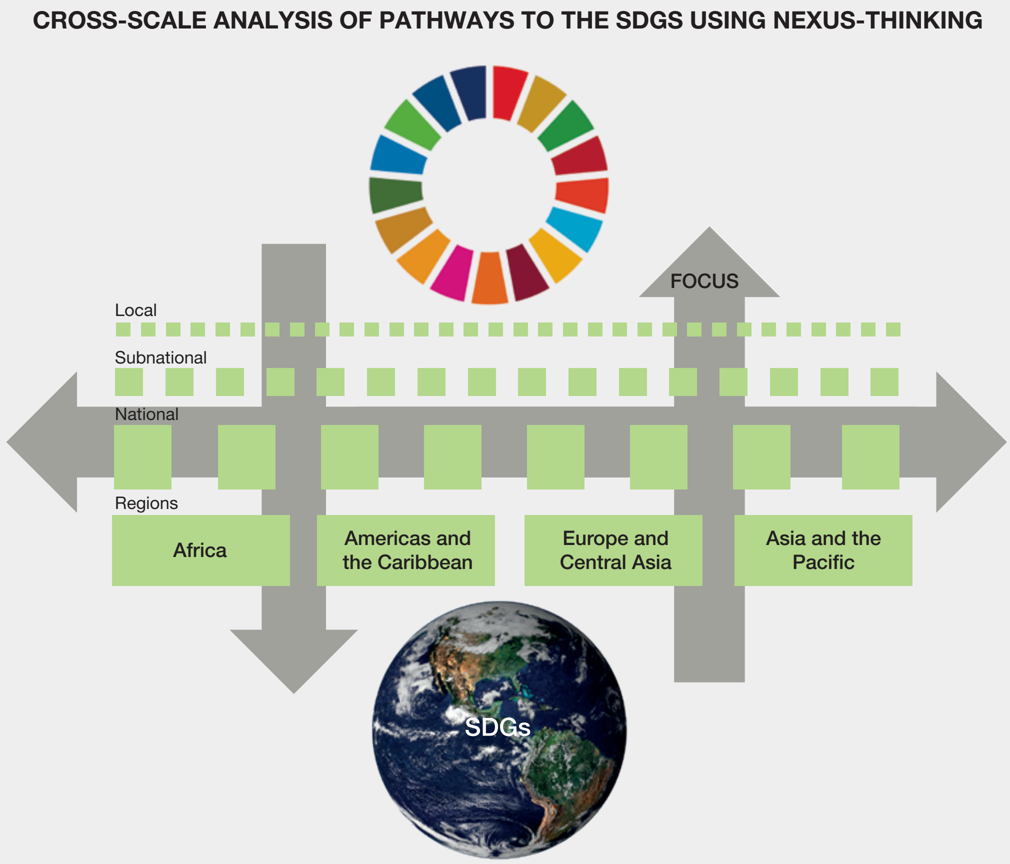

Figure 5 3 **Schematic representation of our multi-scale approach.**

The grey arrows denote the multiple foci we used to structure our analysis. For each focus, we strived to connect information across regions (horizontal arrow) and across spatial scales (vertical arrows).

5.2.3.2 Method for literature search at the global scale

Appendix 5.1 presents the basic search strings we used to select (target-seeking) global scale scenarios. Three alternative strings were used. The first one aimed to encompass all target-seeking scenarios related to nature and nature's contributions to people at the global scale, published after 2006. The second one restricts the search to the selected SDG clusters. The third one expands the selection to some key drivers of change, such as deforestation and restoration processes. To expand the set of studies underlying our analysis, we also investigated global scale exploratory and policy-screening scenario studies, which explicitly followed a sustainability focus in their storylines, with an intent to achieve the SDGs. An example is the new climate scenario SSP1 "sustainable world scenario" of the IPCC (van Vuuren *et al.*, 2017). We recorded key information for each scenario, as the basis for quantitative analysis presented in Section 5.3.1. The literature search for target-seeking scenarios at the global scale yielded 47 studies in total (see Section 5.3.1 and Table SM 5.2 B).

5.2.3.3 Cross-scale analysis

We defined a common process to incorporate information from other scales, to complement global scenarios. The initial source of information about scenarios and pathways at the sub-global scale (regional, national, subnational and local) were the fifth chapters of each of the IPBES regional assessments, which performed broad literature searches on scenarios pertaining their regions. A complementary literature search was conducted for each specific lens/perspective under analysis, similar to the one performed at the global scale. Based on the combined results from all these sources, we tabulated key information about each scenario at different scales (Appendix 5.2). We organized five tables with core information about terrestrial scenario studies (global and the four IPBES regions), and one related to marine scenarios. Each table describes the following: Scale, Region/system, Goal/vision, Type of scenario, Sectors covered, Pathway elements (measures, policies, changes), Scenario 'short name' and Complete reference. We then performed an iterative process to synthesize key information for each scale and region, related to each focus of analysis. Based on this systematization, we distilled key components of pathways projected to achieve the SDGs, which formed the basis for the subsections "What do scenarios say about pathways to achieve the SDGs?", complemented by non-scenario literature and cross-regions linkages. Although we did not adopt a typology of pathways (as in the IPBES European and Central Asia regional assessment), in 5.3 we do indicate alternative—and sometimes contrasting—pathways emerging from the literature. **Figure 5.3** depicts this process.

As mentioned before, this chapter combined methods and procedures to interpret sustainability transitions from different scientific angles. As such, it is an effort towards inter- and transdisciplinary triangulation. Combining the findings from different approaches may enable a more encompassing and more legitimate understanding of the processes, outcomes, and impacts of possible pathways to sustainability. We hope that this will in turn yield more appropriate and legitimate implications for practice and policy (as discussed in 5.4 and chapter 6).

5.3 PATHWAYS DERIVED FROM THE SCENARIOS REVIEW PROCESS

5.3.1 Results of the assessment of global scenarios

5.3.1.1 Overview

The literature search on target-seeking and policy-screening scenarios yielded 47 scenario studies with global coverage. Qualitative, storytelling ("narrative") scenarios were assessed for additional information to determine if, when and why SDGs could be achieved **(Figure 5.4 B)**. At the global scale, target-seeking scenario research is much less elaborated than exploratory scenario research (chapter 4). The IPBES methodological assessment on scenarios and models of biodiversity and ecosystem services notes that target-seeking and policy-screening scenarios have been applied to decision-making mostly at regional and local scales (IPBES, 2016), and therefore are not common at the global scale. Backcasting and scenario-discovery approaches were rare at the global scale, likely due to the inherent complexity of the task at that scale.

The scenarios evaluated consisted of target-seeking scenarios (e.g., Leclère *et al.*, 2018; PBL, 2012; van Vuuren *et al.*, 2015; see **Boxes 5.1 and 5.2**, respectively), followed by policy-screening scenario studies (e.g., Visconti *et al.*, 2016), 'sustainability' exploratory scenarios (e.g., Raskin

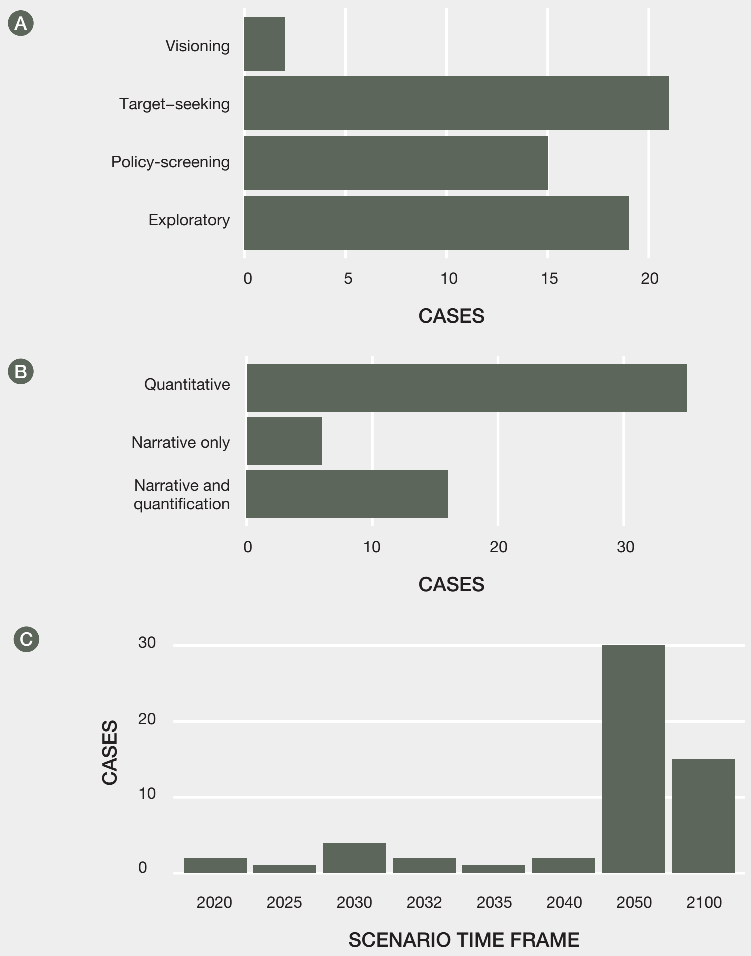

Figure 5 4 **The number of studies from the review on target-seeking scenarios that fulfill the following:**

A target-seeking scenarios, policy-screening scenarios, 'sustainability' scenarios of exploratory exercises, and visioning exercises; B using a quantitative approach, a narrative approach, or both together; and C applying different time frames of analysis (N=34; a given study could score in multiple categories for panel A).

et al., 2002) and a small number of visioning studies (e.g., WBCSD, 2010; see **Figure 5.4 A**). Visioning studies were only taken into account if they went beyond qualitative description of future trajectories for a certain sector and provided quantification and analysis of pathways to realize that vision. The analysis revealed that most selected studies include both narratives (storylines) and quantification of scenarios using models (e.g., UNEP, 2002 Sustainability First Scenario).

In most global scenario studies, biodiversity, ecosystem services (or nature's contributions to people), and implications for human well-being are a few of many aspects being analysed (e.g., PBL, 2012). Regarding temporal scale, long-term projections are most common across the selected studies (present to year 2050, **Figure 5.4 C**). This finding is in line with IPBES (2016), which states that international environmental assessments including scenario exercises typically focus on long timescales. Decision-making, however, often requires both short-term and long-term perspectives (IPBES, 2016), so considering scenarios across different temporal scales is important.

The majority of studies relied on expert knowledge. Only a few incorporated indigenous and local knowledge and perspectives or stakeholder consultations (e.g., Springer & Duchin, 2014). This finding corresponds to IPBES scenarios assessment conclusion that participatory scenario studies predominantly have a local-scale focus, while global scale scenario studies are often developed using expert-based approaches (IPBES, 2016). Participatory scenario methods enhance the relevance and acceptance of scenarios for biodiversity and ecosystem services (IPBES, 2016), and their application could be taken up more often in global-scale scenario exercises.

Sectors most commonly considered

The agricultural sector was the sector most commonly addressed in the scenarios, with 32 of the 47 studies investigating the relationships between agriculture and

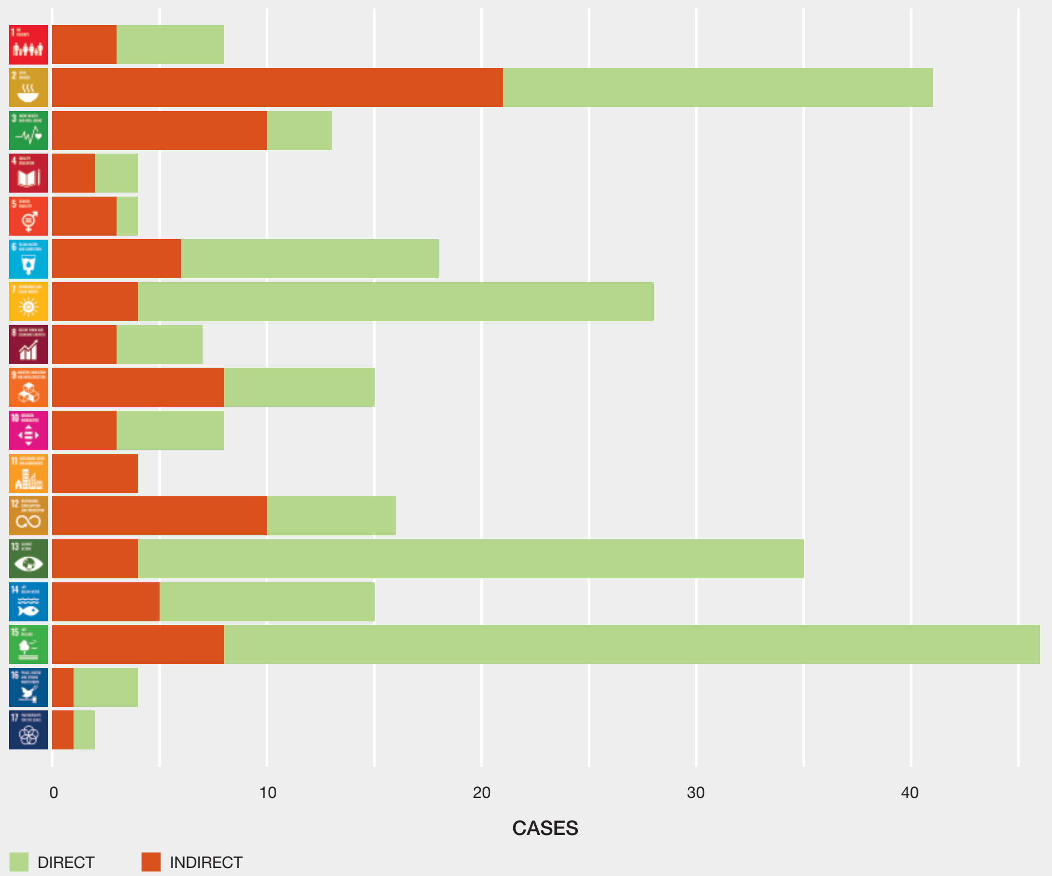

Figure 5 5 **Sustainable Development Goals in Scenarios. Green ("direct") represents scenarios that address an SDG directly; orange represents scenarios that address an SDG only implicitly ("indirect").**

other sectors and factors such as biodiversity, biofuels, deforestation, and climate change (e.g., Eitelberg *et al.*, 2016; Erb *et al.*, 2013; PBL, 2012; Smith *et al.*, 2013; van Vuuren *et al.*, 2015). Concerns ranged from feeding the growing human population to addressing threats from biofuels and managing the availability of land and water (e.g., Flachsbarth *et al.*, 2015; Odegard & van der Voet, 2014; Wirsenius *et al.*, 2010).

The second most prevalent sector was forestry, with 17 studies addressing issues such as land degradation, and competition with agricultural production (e.g., Kraxner *et al.*, 2013; Stavi & Lal, 2015; van Vuuren *et al.*, 2015). In particular, these scenarios addressed issues such as reducing carbon emissions from forest degradation, and competition between forests and biofuel crops (e.g., Smeets *et al.*, 2007; Zarin *et al.*, 2016). Energy and water sectors were considered by 17 and 7 studies respectively. In terms of water, issues addressed include river fragmentation as a threat to river biodiversity, availability of water for agricultural production (particularly emphasizing the threat of agricultural expansion for water resources), and general water efficiency measures needed to reach targets (e.g., Grill *et al.*, 2015; Springer & Duchin, 2014; WBCSD, 2010). The energy sector was addressed largely through efforts to reduce carbon emissions via clean technology, and the competition for land associated with these efforts (Prieler *et al.*, 2013; Rogelj *et al.*, 2018a; van Vuuren *et al.*, 2010, 2017).

SDGs most commonly considered

SDGs pertaining to terrestrial systems were most frequently considered. In particular, SDGs 2 and 15 were commonly investigated, analyzing trade-offs between food security and (terrestrial) biodiversity **(Figure 5.5)**. These studies provide input to investigate the foci on "*Feeding humanity while enhancing the conservation and sustainable use of nature*" Section 5.3.2.1) and "*Conserving and restoring nature on land while contributing positively to human well-being" (*5.3.2.3)*.* Also studied quite frequently were SDGs 6, 7, 12, 13 and 14. The results from the review as well as additional literature thus enables investigating foci related to *Maintaining freshwater for nature and humanity (5.3.2.4)* and *Balancing food provision from oceans and coasts with nature protection (SDG 14, 2, 12; 5.3.2.5)*. Although many studies addressed SDGs 13 and 15, including in concert, additional literature was consulted for the specific lens considering the means of "*Meeting climate goals while maintaining nature and nature's contributions to people***"** (5.3.2.2). Few target-seeking scenarios addressed SDGs 4, 5, 11, 16, and 17. Because of the undisputed relevance of an urbanizing society, however, we investigated the focus "*Resourcing growing cities while maintaining the nature that underpins them*" (5.3.2.6) based largely on secondary literature.

5.3.1.2 Core global studies: integrated pathways to achieve multiple goals

Because detailed examination of particular scenarios and trade-offs is instructive in ways that a general synopsis is not, this section reviews core global studies discussing integrated pathways for achieving multiple goals. Here we pinpoint key characteristics of the pathways discussed in these studies, which feeds into the multi-scale analysis in 5.3.2.

Roads from Rio+20 pathways: this study culminates a series of linked papers and reports (Kok *et al.*, 2018; PBL, 2012, 2014; van Vuuren *et al.*, 2015). It used a backcasting approach to explore the level of effort needed to achieve selected SDGs (accounting for feasibility constraints). **Three alternative pathways were quantified and compared to the 'trend' scenario; each achieved the goals despite variation in management and behaviour change**. The goals align closely with the SDGs (they were based on internationally agreed goals and targets prior to the SDGs) and involve provision of energy and food while mitigating climate change (2 degrees), providing clean air and halting biodiversity loss. The study also examined some related issues including nitrogen, water, and health in the context of population, economic growth, energy and land use. The scenarios were quantified using an integrated assessment model framework IMAGE in combination with related models for biodiversity, human health and climate policy (GLOBIO, GISMO and FAIR, respectively) to provide a global overview while differentiating between world regions (see the IPBES regional assessments for region-specific results). **Box 5.1** synthesizes how the three pathways differ and some key quantitative results in relation to biodiversity.

Alternative pathways to the 1.5 degrees target based on the Shared socioeconomic pathways (SSPs). The SSPs represent five different development trajectories: i.e., sustainable development (SSP1), global fragmentation (SSP3), strong inequality (SSP4), rapid economic growth based on a fossil-fuel intensive energy system (SSP5) and middle of the road developments (SSP2; all are used extensively by the Intergovernmental Panel on Climate Change (IPCC)). Each of the SSPs portrays a storyline quantified using models. These storylines can be combined with different assumptions about climate policy to form a larger context of socioeconomic development and level of climate change (mitigation scenarios, c.f. Riahi *et al.*, 2017; Rogelj *et al.*, 2018b). The sustainable development scenario (SSP1) combined with stringent climate policy is a scenario exploring the route towards a more sustainable world, although the SDGs were not targeted in its development. Mitigation scenarios that achieve the ambitious targets included in the Paris Agreement typically rely on greenhouse gas emission reductions combined with net carbon dioxide removal from the atmosphere, mostly accomplished through

Box 5 1 Roads to Rio+20 Pathways.

Several key **premises** underlie the alternative pathways (Figure Box 5.1.a) and their achievement of sustainability goals (Kok *et al.*, 2018; Table SM 5.3.3):

The **Global Technology pathway** assumes that sustainability objectives are pursued mainly by large-scale application of technological solutions. A high level of international coordination through—for example—trade liberalization and the expansion of global markets drives these responses in all world regions. In terms of land use, sustainable intensification in agriculture may lead to a "land sparing" effect, i.e., efficient use of some lands for production would allow sparing other land from conversion to agriculture and/or dedicate them to conservation (Balmford *et al.*, 2005). The protected area system focuses on continuous natural areas away from existing agricultural land to minimise conflict with agricultural expansion, but large natural areas are not necessarily connected.

The **Decentralized Solution pathway** consists of solutions and technologies that can be implemented on a smaller scale resulting in multi-functional mosaic landscapes and regional diversity, in line with regional priorities. Local and regional markets drive demand. Ecological innovation in mixed land-use systems where natural elements and production landscapes are interwoven may result in a "land sharing" effect (Balmford *et al.*, 2005). Agricultural intensification is achieved by using ecological techniques, such as intercropping, agroforestry, and natural pest control, in combination with natural corridors interwoven with agriculture to enable the extensive use of ecosystem services (Pretty, 2008; Tittonell, 2014). In this pathway, agricultural landscapes comprise at least 30% of natural elements acting as corridors between natural areas, hence reducing fragmentation and providing ecosystem services.

The **Consumption Change pathway** starts from implementing a set of behavioural changes in favour of less resource-intensive consumption. These include ambitious efforts to reduce waste, increase recycling in production chains, reduced energy- and material- intensive lifestyles and a shift towards moderate consumption of meat and dairy, in line with health recommendations. Alongside land "sparing" and "sharing" pathways above, this is the "caring" pathway, reflecting the importance of personal behavioural and consumption choices. This pathway assumes a reduction of 50% in food waste and losses, equalling 15% of the production (IMECHE, 2013). Increases in agricultural productivity are only slightly higher than in the 'trend' scenario. Food consumption change is derived from the Willett diet, characterized by a low meat and egg intake (Stehfest *et al.*, 2009; Willett, 2001).

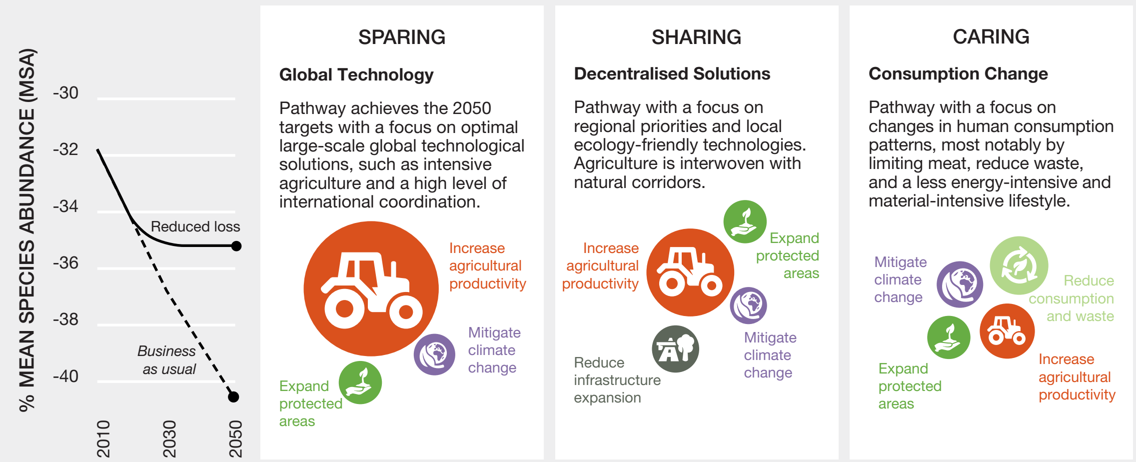

Figure 5 1 A Schematic representation of three alternative pathways to reduce biodiversity loss represented in the Roads to Rio+20 study (see Table SM 5.3.1/5.3.2 for comparison of premises).

Source: PBL (2017).

Results

According to the study, all pathways achieve the assumed 2050 targets (Table SM 5.3.1) and would reduce biodiversity loss in the coming decades (avoided Mean Species Abundance (MSA) loss is 4.4-4.8% MSA, compared to 9.5% MSA loss in the 'trend' scenario **(Figure Box 5.1.b)**. Under the Global Technology pathway the most important contribution by far comes from increasing agricultural productivity on highly productive lands. Under the Consumption Change pathway, significant reduction in consumption of meat and eggs as well as reduced waste means that less agricultural production would be required, thus reducing associated biodiversity loss. Under the Decentralised Solutions pathway, a major contribution comes from avoided fragmentation, more ecological farming and reduced infrastructure expansion. Under all scenarios, climate change mitigation, the expansion of protected areas and the recovery of abandoned lands also significantly contribute to reducing biodiversity loss. Further positive results could be achieved by combining various options from the pathways, especially by increased consumption changes in the other pathways. This would result in reversing trends of biodiversity loss (see **Box 5.3** on Bending the curve).

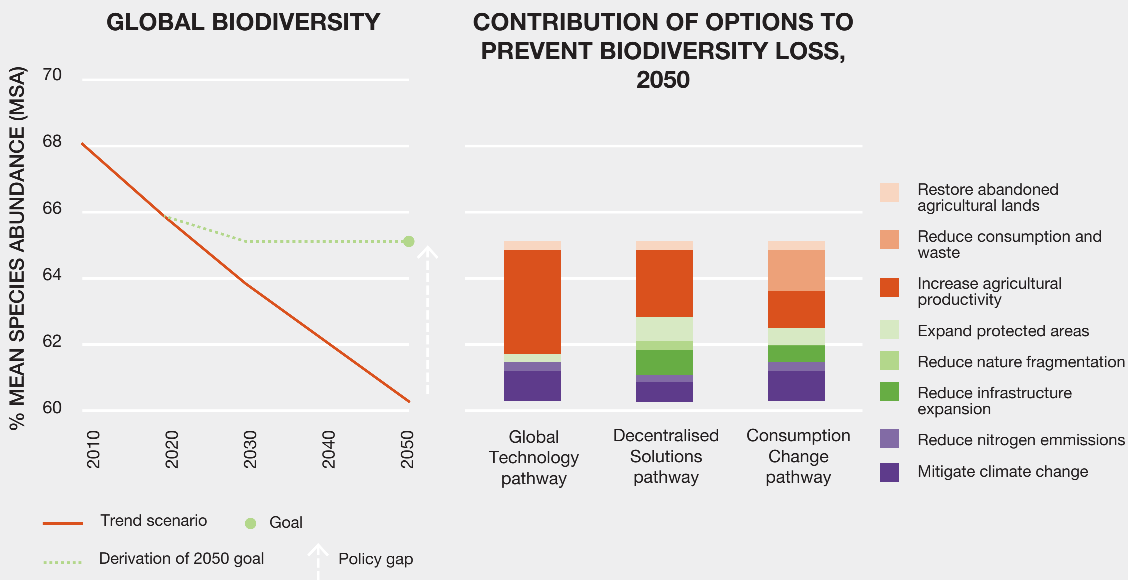

Figure 5 1 B **Measures in the alternative pathways that contribute to biodiversity goals.**

The Rio+20 scenarios have also been used to explore the impact of alternative pathways on extinction risk and abundance of large mammals, revealing that both bottom-up behavioural change (Consumption Change) and top-down technology and policy changes (Global Technology) can reverse global biodiversity decline in the short term, but the onset of delayed climate change impact may require further mitigation strategies.

This study was also one of first to discuss synergies and trade-offs among food, biodiversity, energy, health and climate targets (see Table SM 5.3.3), some of which were explicit in the models. However, some potential trade-offs remain unquantified, such as the use of pesticides and their impacts on health and biodiversity. Source: PBL (2012).

The following publications contain more details (Kok *et al.*, 2018; PBL, 2012, 2014; van Vuuren *et al.*, 2015; Visconti *et al.*, 2016), and there is discussion about their regional results in each IPBES regional assessment.

large-scale application of bioenergy with carbon capture and storage, and afforestation (Doelman *et al.*, 2018; Rogelj *et al.*, 2018a). Using the IMAGE integrated assessment model, van Vuuren *et al.* (2018) explored the impact of **additional measures (beyond SSP mitigation scenarios)** that also include lifestyle change, additional reduction of non-CO_2 greenhouse gases and more rapid electrification of energy demand based on renewable energy (see **Box 5.2** for more detail).

Alternative pathways for bending the biodiversity curve: the 'Bending the Curve' study (Leclère *et al.*, 2018) quantitatively modelled ambitious target-seeking scenarios aiming at reversing biodiversity trends in the 21st century from negative to positive (Mace *et al.*, 2018). This interdisciplinary effort between different modelling communities focuses on biodiversity as affected by human land use and relies on: a) spatially explicit datasets of biodiversity, modelled impacts of land use on biodiversity, and existing scenario frameworks (e.g., SSPs and representative concentration pathways, RCPs); b) integrated assessment models, in particular their spatially explicit land-use modeling components; c) global spatially explicit biodiversity models (also used in chapters 2 and 4) assessing an array of biodiversity impacts from land-use changes. The storylines of existing SSP/RCP scenarios were enriched with more ambitious conservation storylines and quantified via additional datasets generating new scenarios of future trends in land use. These new scenarios considered further actions for biodiversity, such as increased conservation efforts (increased extent and management efficiency of protected areas, increased restoration and landscape-level conservation planning), but

Box 5 2 Alternative pathways to the 1.5 degrees target.

Compared to the default SSP2 1.9 and 2.6 (radiative forcing level of 1.9 and 2.6 W m–2 in 2100, respectively), alternative scenarios to achieve the 1.5 degrees goal are built using the following premises (van Vuuren *et al.*, 2018):

- Rapid application of best available technologies for energy and material efficiency in all relevant sectors in all regions;
- Higher electrification rates in all end-use sectors, in combination with optimistic assumptions about integration of variable renewables and costs of transmission, distribution and storage;
- High agricultural yields and application of intensified animal husbandry globally;
- Implementation of best available technologies for reducing non-CO_2 emissions and full adoption of cultured meat in 2050;
- Consumers change their habits towards a lifestyle that leads to lower GHG emissions (less meat-intensive diet, less CO_2-intensive transport, less intensive use of heating and cooling and reduced use of several domestic appliances);
- Lower population growth (compatible with SSP1);
- The combination of all options described above.

Results

Although the alternative options explored greatly reduce the need to actively remove atmospheric CO_2 to achieve the 1.5 °C goal, nearly all scenarios still rely on bioenergy with carbon capture and storage and/or reforestation (even the hypothetical combination of all alternative options still captured 400 $GtCO_2$ via reforestation). Although not directly estimating impacts on biodiversity targets, these results are important due to the large-scale reforestation process envisioned in the mitigation scenarios. The set of alternative scenarios suggests a diversity of possible transition pathways, including via changing consumption patterns.

The results point out the need for a more diverse portfolio of options than currently discussed in the mitigation scenarios and an open debate concerning their contributions. This could provide more flexibility to ensure that goals are reached. However, it is important to note that the adoption of alternative pathways also might convey substantial regional impacts. To illustrate, **Figure Box 5.2** compares the spatially explicit results of SSP1 and SSP1 1.9, as implemented by the IMAGE model in Doelman *et al.* (2018).

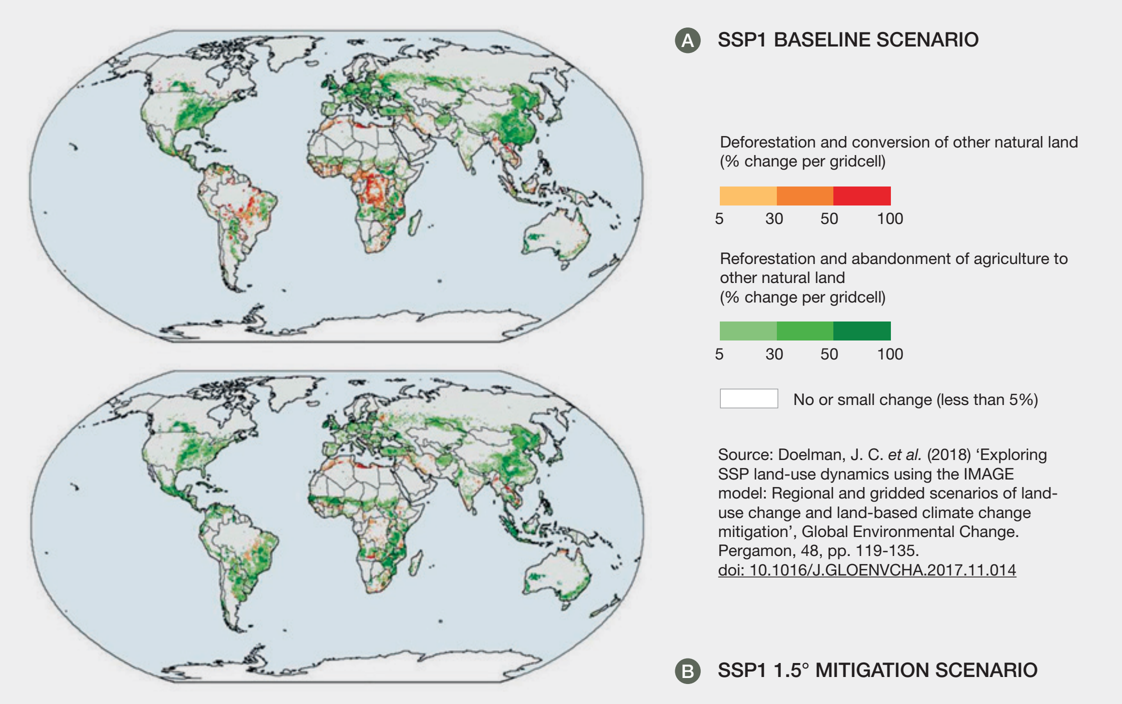

Figure 5 2 **Change in land use (percentages of grid cells) between 2010 and 2100; deforestation and conversion of other natural land to agriculture (red) and reforestation and abandonment of agriculture to other natural land (green) for SSP1 baseline scenario and SSP1 1.5 °C mitigation scenarios (1.9 W/m²).**

Source: PBL for this publication.

Box 5 3 Bending the curve scenarios: towards pathways for ambitious biodiversity targets.

In addition to a baseline (BASE) scenario (based on the "Middle of the Road" SSP2), this study considers six "wedges scenarios" in which various efforts are implemented in order to "bend" the curve of biodiversity loss. The scenarios do not assume strong climate mitigation efforts, nor do they account for future changes in climate or any threat to biodiversity other than habitat loss. The **premises** underlying the six wedge scenarios are as follows:

Increased conservation efforts ("C scenarios"):

a) Increasing protection: any change in land use detrimental to biodiversity (according to PREDICTS' Biodiversity Intactness Index (Hudson *et al.,* 2017)) is ceased from 2020 onwards for all areas identified by the potential protected areas layer (see sections 4.1 and 5.2 in Leclère *et al.*, 2018).

b) Increasing restoration and landscape-level conservation planning: over the entire land area, incentives are gradually put in place to favor land-use changes resulting in biodiversity improvements from 2020 onwards. The net impact on biodiversity (gain or loss) of a particular land-use change is based on PREDICTS' Biodiversity Intactness Index for the two land uses, while the relative importance (for biodiversity) of a given parcel of land derives from the regional restoration priority layer (see sections 4.3 and 5.2 in Leclère *et al.*, 2018).

Demand-side efforts beyond SSP1 ("DS scenarios"):

a) Shifting towards healthier diets: dietary preferences evolve towards 50% less meat compared to the baseline scenario, linearly between 2020 and 2050 (the corresponding animal calories are replaced by plant-based calories) except for regions with low shares of meat in diets like Middle-East, Sub-Saharan Africa, India, Southeast Asia and other Pacific islands (where dietary preferences follow the reference scenarios)..

b) Reducing waste throughout the food supply chain: total waste (losses in harvest, processing, distribution and final household consumption) decreases by 50% by 2050 compared to the baseline, linearly between 2020 and 2050.

Supply-side efforts ("SS scenarios"):

a) Sustainably increasing productivity: crop yields develop following SSP1, assuming in particular a rapid convergence of land productivity in developing countries to that of developed countries.

b) Increasing trade in the agricultural sector: trade of agricultural goods develops according to SSP1, with a more globalized economy and reduced trade barriers.

Combined efforts scenarios: the above efforts are combined by pairing increased conservation and supply-side efforts in the C+DS scenario, increased conservation and supply-side efforts in the C+SS scenario, and all efforts together in the integrated action portfolio (IAP) scenario.

Results show that bending the curve is possible within the 21st century for several feasible driver scenarios. **Figure Box 5.3** shows that combining different action wedges allow biodiversity trends to be reversed before 2050 (IAP scenario), instead of continuing declines for BASE scenario. This predicted reversal of trends is similar across all metrics, indicating that future land-use scenarios can be robustly favorable to biodiversity.

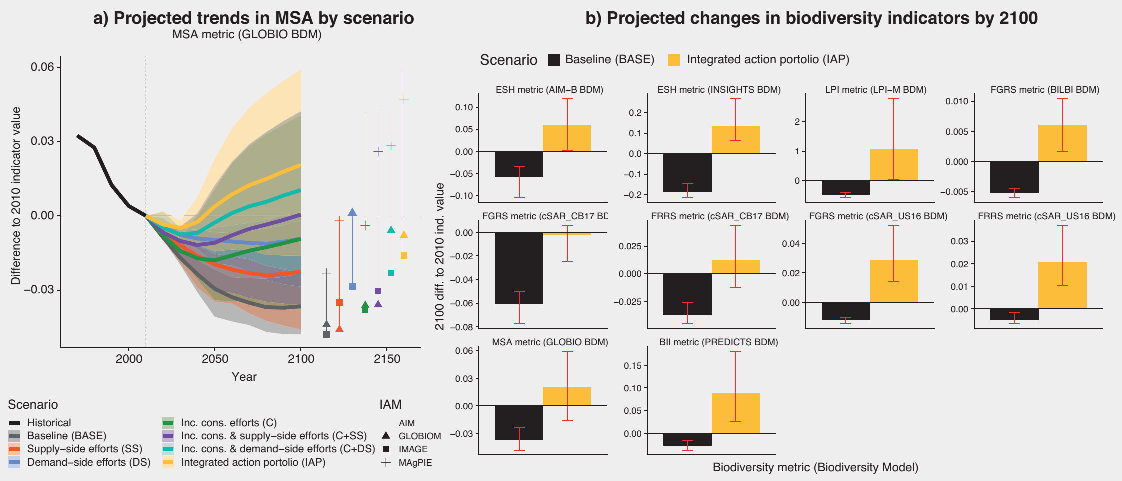

Figure 5 3 **Illustration of results from the Bending the Curve fast-track analysis results.**

The left panel illustrates the estimated change in GLOBIO's Mean Species Abundance index (MSA) from 2010 to 2100 (as compared to 2010) for the land-use component of four integrated assessment models (AIM, GLOBIOM, IMAGE and MAgPIE; the range across IAMs is depicted by ribbons, the average by lines) and 7 scenarios between a business as usual

(BASE) and an Integrated Action Portfolio (IAP) scenario cumulating all efforts to reverse biodiversity trends. The right panel presents the change in various biodiversity indicators estimated by 2100 as compared to 2010 for 2 scenarios (BASE and IAP): BILBI and countryside Species Area Relationship models provide measures of extinctions (the Fraction of Regionally/Globally Remaining Species FRRS & FGRS); GLOBIO and PREDICTS both provide measures of ecosystem integrity through the Mean Species Abundance (MSA) index and the Biodiversity Intactness Index, (BII) respectively; INSIGHTS and AIM-Biodiversity provide a measure of habitat changes through the Extent of Suitable Habitat (ESH) index; and wildlife population density trends are estimated through the Living Planet Index (LPI). The bars indicate the average across IAMs, while red error bars indicate the dispersion across IAMs.

The multi-model assessment framework allows for quantitative assessment of uncertainties associated with land-use projections and their underlying drivers. The contribution of individual drivers and combinations of drivers to stepwise biodiversity improvements has also been quantified. For example, although larger conservation and restoration efforts are key to halting loss and engaging biodiversity onto a recovery path, such a reversing of global biodiversity trends will only be possible by 2050 if our food system achieves a feasible but ambitious transformation.

also demand-side (shift in diets towards less meat, reduced waste) and supply-side efforts (crop yield improvement and reduced trade barriers). Scenarios were fed into the integrated assessment models to generate land-use change projections. Finally, biodiversity models were used to assess whether these spatially explicit land-use change projections over the 21st Century are able to reverse biodiversity trends on a multitude of biodiversity indicators. **Box 5.3** describes measures embedded in the pathways and synthesizes core results.

Two core conclusions can be drawn from the analysis of these studies:

1. **Pathways and narratives:** Different pathways can potentially yield achievement of the same sustainability goals, sometimes with contrasting narratives.**Recognizing the existence of alternative narratives, including their complementarities and tensions, is central to advance the discussion of necessary transformations**, as alternative pathways pose different challenges, trade-offs and synergies among targets (Leach *et al.*, 2010; Luederitz *et al.*, 2017; **Boxes 5.1-3**). For instance, focusing on lifestyle change may greatly decrease the need for future choices related to resource use. Different narratives also uncover power structures and winners and losers of anticipated transformations. Reduced meat production may have implications for economies of producing countries. System lock-ins may be reinforced by certain pathways. Relying only on land-sparing pathways may have positive implications for large-scale industrial agriculture while undermining small-scale farmers. In the following sections, alternative narratives and pathwaysare recognized and highlighted through examples.

2. **SDGs and the Paris Agreement goals:** Scenarios consistent with the Paris goals to reduce GHG emissions include options such as switching to zero- and low-carbon energy options, increasing energy efficiency, using carbon capture and storage (CCS), reducing non-CO_2 GHG emissions, eliminating emissions related to land-use change and stimulating afforestation. Van Vuuren *et al.* (2018), for instance, concluded that GHG targets can be achieved through reduced production of meat and dairy products and intensification of agricultural production, together limiting conversion of unmanaged land. Such a pathway may also promote land-use changes that minimize releases of carbon stored in vegetation and soils, thereby potentially preserving some biodiversity-rich areas. However, mitigation scenarios may also rely on development of short-rotation bioenergy plantations—increasing pressure to convert unmanaged land—and afforestation of non-forested areas for both carbon sequestration and extractive use.

These climate mitigation scenarios suggest four key points: (a) the **biodiversity impacts of afforestation** will depend on where afforestation occurs and how the resulting plantations and forests are managed; (b) such pathways indicate a **land-constrained scenario for food production** due to competition with large-scale reforestation and biofuels; (c) a key underlying premise of the SSPs pertains to population size and ensuing consumption trends. The population dynamics for the different SSPs (Abel *et al.*, 2016) range from a very high global population of almost 13 billion by 2100 down to just 7 billion in SSP1—a shade lower than the current population of 7.6 billion. Therefore, **the feasibility of the options discussed above depends on reduced population growth, and consequently a considerably lighter pressure on resources** (energy, land, water)(see 5.4.1.2). Finally, (d) **such studies assume appropriate, timely and effective governance of such large-scale transformations** in different geographic contexts (see 5.4.2.1-5).

5.3.2 How to achieve multiple SDGs: a cross-scale analysis using nexus thinking

5.3.2.1 Feeding humanity while enhancing the conservation and sustainable use of nature

Framing the problem

Today, agriculture accounts for 38% of Earth's terrestrial surface (Foley *et al.*, 2011) and produces enough calories for all people in the world (Ramankutty *et al.*, 2018). Many millions of people have been lifted out of hunger but food security continues to be a major challenge globally (Godfray *et al.*, 2010). The Food and Agriculture Organization (FAO) reports that the number of undernourished people increased to 821 million in 2017. Similarly, stunting and wasting continue to affect children under the age of five, with more than 150 million and 50 million children affected in the same year, respectively. At the same time, obesity is rising, affecting more than 670 million people worldwide (FAO, 2017).

There are many reasons for the mismatch between the increased availability of food and the continued existence of undernourishment. On the supply side, food production is not evenly distributed globally, and regions differ in terms of yield, irrigation, nutrient application and climate impacts, among other factors (Lobell *et al.*, 2011; Monfreda *et al.*, 2008; Mueller *et al.*, 2012; Ramankutty *et al.*, 2018; Searchinger *et al.*, 2013). Consumption is further impeded in some places by access, affordability, and poverty. Added to this is increasing food waste across the food value chain from production to consumption (Gustavsson *et al.*, 2011; Odegard & van der Voet, 2014; Smith *et al.*, 2013), market influences on food price (Headey & Fan, 2008; O'Hara & Stagl, 2001) and other factors affecting the distribution of food. Besides, in many regions the expansion of industrial agriculture–via incentives from trade agreements, government subsidies, and global mergers of large agribusinesses corporations–threatens small-scale agriculture, still a significant and in many countries the main contributor to food production and food security (IPES-Food, 2016). Beyond agriculture, hunting, gathering, and herding systems continue to be crucial for locally appropriate food security, and such systems have sometimes suffered at the expense of subsidies for and externally imposed notions of appropriate nutrition and food production (Council of Canadian Academies, 2014; EALLU, 2017). Despite their importance, these non-agriculture food systems represent an important gap in literatures on scenarios and pathways (except for fishing, see 5.3.2.5 and also 5.3.2.4); accordingly, our focus in this section is largely on agriculture.

Agriculture is a fundamental driver of global biodiversity loss through its area expansion and the increase of pollutants and of resources used in production (including irrigation water, fertilizers and pesticides) (see chapters 2, 3). Meanwhile, agriculture depends strongly on healthy ecosystems for a diversity of supporting ecosystem processes, including nutrient remineralization, soil health, insect pollination, and biological pest control (Power, 2010; Seppelt *et al.*, 2017). **The core question addressed here is whether and how agriculture and associated food systems will be able to meet the needs of the global population in the coming decades, without further degrading natural resources (and possibly even restoring some).** Addressing this question requires consideration of the globalization of food systems and the varying contributions and roles that different regions play in food production **(Figure 5.6)**.

We organize the discussion about pathways in relation to agricultural production, the supply chain and consumers. While much of the literature has focused on reconciling agricultural production and conservation, other issues also need attention. These include food distribution systems, waste, poverty, inequality and personal food preferences, all of which provide direction for tackling hunger and malnutrition, and ultimately, environmental degradation (Bennett, 2017; Cassidy *et al.*, 2013; Tilman & Clark, 2014). It is also critical to reflect on current trends of global food production systems becoming more capital-intensive. The concentration of food production in fewer hands, and the centralized control of inputs pose a significant threat to small-scale agriculture (FAO, 2017).

What do scenarios say about how to achieve these goals?

Agricultural production pathways

Considerable debate addresses how best to balance food production and nature conservation, minimizing land clearing and biodiversity loss (Balmford *et al.*, 2005; Bruinsma, 2011; Erb *et al.*, 2016; Foley *et al.*, 2011; Kok *et al.*, 2014; Phalan *et al.*, 2011; Smith, 2018; Smith *et al.*, 2013; Tscharntke *et al.*, 2012). Two interconnected aspects are key: (1) where food is produced and nature is conserved (spatial distribution of nature and agricultural lands), and (2) how and by whom food is produced.

Some argue that achieving this balance requires land sparing (intensification of agriculture for high yields and the setting aside areas for conservation—a binary approach), while others argue for land sharing (integrated approaches where these two forms of land-use are blended and wildlife-friendly techniques are applied). Based on different approaches, scholars independently come to the conclusion that agricultural yields can be increased substantially without further expansion of agricultural area (Delzeit *et al.*, 2018; Erb *et al.*, 2016; Mauser *et al.*, 2015) but with intensification of land use. In the extreme, biologist E. O. Wilson has called for protecting “half Earth” (Wilson, 2016), producing more and healthier food through sustainable intensification on existing farmland, and returning the other half of land to nature. Lately, many authors have argued that this simplified dichotomy (“land sparing” vs. “land sharing”) limits future possibilities (Kremen, 2015). A stringent application of one of the two strategies everywhere is undesirable, as what is optimal may strongly differ regionally based on socioeconomic, cultural and ecological characteristics—and the region’s role in global food systems **(Figure 5.6)**.

This leads to another important debate regarding the nature and scale of agricultural systems. Agro-industrial systems, consisting of input-intensive monocultures and industrial-scale feedlots currently dominate farming landscapes (FAO, 2017; IPES-Food, 2016). The uniformity at the heart of these systems, and their reliance on chemical fertilizers, pesticides and preventive use of antibiotics, systematically yields negative outcomes and vulnerabilities, which might lead to system lock-ins (Geiger *et al.*, 2010; Hunke *et al.*, 2015; Wagner *et al.*, 2016). To avoid such problems, there is a need to scale up sustainable practices, including agroecology (FAO, 2017; IPES-Food, 2016; Muller *et al.*, 2017; Rockström *et al.*, 2017). A recent study explored the role that organic agriculture could play in sustainable food systems (Muller *et al.*, 2017). These authors showed that—in combination with reductions of food waste and food-competing feed, with correspondingly reduced production and consumption of animal products—organic agriculture could feed the world using less land than the reference scenario, and that it could also bring several environmental benefits, including a decrease in pesticide use.

Agroecology practices can play a key role. Applied to small-holders they can boost food security; smallholders rather than large-scale farming are the backbone of global food security efforts, given that 80% of the hungry live in developing countries and 50% are smallholders (Tscharntke *et al.*, 2012). The move towards sustainable agriculture may include the adaptation and transfer of agroecological practices and technologies to areas and nations with relatively low yields (‘bridging the yield gap’; Pradhan *et al.*, 2015). Such efforts could enable more efficient nutrient use worldwide, but they are no substitutes for regional strategies to achieve food security. Payment for ecosystem services (PES) programs are frequently mentioned in regional to local scenarios (SM 5.2) as an important complementary measure to help facilitate the transition (e.g., Kisaka & Obi, 2015; see 5.4.2.1 about incentives).

The majority of current integrated global scenarios largely rely on a land sparing/intensification approach (see Section 5.3.1.2, SM 5.2.B), allocating food production across the globe to the most suitable lands, and envisioning extensive land restoration. The Roads to Rio+20 is an exception, also representing a land sparing pathway **(Box 5.1)**. Regional to local scenarios (SM 5.2.C to F) tend to explore multiple pathways, detailing the challenges and opportunities of such pathways, and in some cases contrasting perspectives. Regional to local scenarios highlight the following as core pathway elements to achieve the goals of food production and nature conservation: spatial planning; strengthened protected areas; measures to avoid the social and environment rebounds of agricultural intensification; resolution of land tenure issues; routine law enforcement; participation in strengthened governance structures. The importance of international cooperation and cross-national governance structures has been stressed by several scenario studies given the globalization of production and the need to upscale local innovations (Geels *et al.*, 2016; PBL, 2014; Pouzols *et al.*, 2014; van Vuuren *et al.*, 2015).

Consumer pathways: changes and diets and pressure for certified products

Consumers can influence supply chains and agriculture production through consumption choices, including changes towards healthier and environmentally friendly diets. The heterogeneous trends of population growth and urbanization across different regions, and different countries’ positions as consumers or producers in the globalized food system, underlie such discussions.

At the global scale (Table SM 5.2 B), several authors have discussed the impacts of alternative diets on land-cover change and, consequently, on biodiversity loss (Delzeit *et al.*, 2018; Erb *et al.*, 2016; Popp *et al.*, 2010; Schader *et al.*, 2015; Stehfest *et al.*, 2009). For instance, Stehfest *et al.*’s (2009) four scenarios of dietary variants—all of which reduce meat consumption (ranging from partial to complete elimination of meat from global diets)—lessened projected land-use change (and impacts on ecosystem services more broadly) and emissions. Potential instruments discussed in such studies include regulation, economic incentives, and information campaigns.

Regional to local scenarios focused less on consumption and diet changes, except in the US and EU. In the **United States**, for instance, Peters *et al.* (2016) evaluated ten alternative diet scenarios (varying the content of meat and dairy consumption) based on projected human carrying capacity (persons fed by unit land area). Their results indicate that: (a) diet composition greatly influences overall land footprint, and imply very different allocation of land by crop type; (b) shifts toward plant-based diets may need to be accompanied by changes in agronomic and horticultural research, extension, farm operator knowledge, infrastructure, livestock management, farm and food policy, and international trade; and (c) diets with low to modest amounts of meat outperform a vegan diet, and vegetarian diets including dairy products performed best overall.

In meat producing countries like **Brazil**, recent scenario studies tend to focus on measures to transform cattle ranching (see for example MCTI, 2017; Strassburg *et al.*, 2014; see Table SM 5.2.C). These studies argued that even with current trends in meat consumption, a boost in the current low productivity of the sector—combined with adequate measures to avoid social and environmental rebounds of intensification—could decrease deforestation and even liberate area for restoration. In contrast, global scenarios, particularly recent ones aligned to 1.5°C targets (see **Box 5.2 and 5.3**), tend to consider a reduction in meat consumption as a necessary measure, given competition for land (biofuels and reforestation), emission and pollution concerns.

Finally, consumer pressure for goods produced in an environmentally friendly and socially just manner is a strong mechanism for transforming food systems. Certification programs are often mentioned as an important pathway element in scenarios at all scales (SM 5.2), as further discussed below (and in 5.4.3.2; chapter 6).

Supply chain pathways

Supply chains link producers and consumers via local to global networks of processors, traders, retailers, investors and banks. The relatively small number of actors (compared to producers and consumers) provides opportunities for levers of transformation, as such key actors may influence decisions made by primary producers and others throughout supply chains (Kok *et al.*, 2014). Partnerships between public and private actors involved in supply chains seem promising for mainstreaming biodiversity protection and engaging multiple levers of change.

A good example of supply chain initiatives is the Soy Moratorium in Brazil's Amazon, a production system telecoupled via global markets (see also chapter 6). This Moratorium was the first voluntary zero-deforestation agreement implemented in the tropics and set the stage for supply-chain governance of other commodities, such as beef and palm oil (Gibbs *et al.*, 2015). In response to pressure from retailers and nongovernmental organizations (NGOs), major soybean traders signed the moratorium, agreeing not to purchase soy grown on lands deforested after July 2006 in the Brazilian Amazon. A monitoring system verifies individual producers. Although few integrated quantitative scenarios represented such measures explicitly, qualitative scenarios often mentioned them as key elements, tied to other governmental and civil society measures (for instance, Aguiar *et al.*, 2016).

The trend of concentration of food systems in few companies also tends to create major asymmetries in economic and power relations. Such asymmetries must also be addressed to ensure fairness and underpin necessary changes regarding food waste, distribution, and more sustainable and healthier practices (IPES-Food, 2016). One core example is the vested interests of large companies that produce pesticides and chemical inputs.

5.3.2.2 Meeting climate goals while maintaining nature and nature's contributions to people

Framing the Problem

Under a business-as-usual scenario, global demand for land is projected to increase substantially. An expansion of agricultural land and bioenergy plantations may leave little room for preserving natural habitats and biodiversity (Secretariat of the Convention on Biological Diversity, 2014). Many more stringent climate mitigation scenarios (reaching 450 ppm but also 550 ppm CO_2eq concentrations by 2100) rely on large-scale deployment of bioenergy with carbon capture and storage (BECCS) (Rogelj *et al.*, 2018b; Smith *et al.*, 2014). The bioenergy crop area required by 2100 is estimated at 150 to 600 Mha (Rogelj *et al.*, 2018a). Potential implications for biodiversity have been explored (Meller *et al.*, 2015), but only a few global bioenergy scenario studies explicitly addressed biodiversity targets and SDGs (e.g., Beringer *et al.*, 2011; Erb *et al.*, 2012; Heck *et al.*, 2018; Leclère *et al.*, 2018; see also 5.3.1.2). It has also been suggested that freshwater biodiversity is severely threatened by ongoing and future development of hydropower (Hermoso, 2017), but we are not aware of any global hydropower scenarios that explicitly address impacts on biodiversity and ecosystem services.

Global energy production from various bioenergy systems in 2018 generates about 50 EJ per year. In some regions, bioenergy production generates substantial economic benefits for states and increases employment and individual incomes (Smith *et al.*, 2014). Bioenergy production in scenarios reaching the 1.5° C target range from 40 to 310 EJ per year (Rogelj *et al.*, 2018b). Major bioenergy systems include industrial organic residues, forest and agricultural residues, dedicated biomass plantations and optimal forest harvesting. Dedicated biomass plantations include annuals (e.g., corn and oil crops), perennials (e.g., sugarcane, oil palm and perennial grasses) and wood-based systems such as short rotation woody crops (see Creutzig *et al.*, 2015; Smith *et al.*, 2014 for a more detailed classification.

Substantial climate mitigation potentials could also be generated by reducing demand for traditional biomass, which until recently accounted for ~80% of current bioenergy use and helps meet the cooking needs of

~2.6 billion people (Chum *et al.*, 2011; IEA, 2012). Ecosystem-based non-bioenergy climate mitigation also has substantial potential without adverse effects on biodiversity and food security. So-called 'natural climate solutions' include a wide range of measures, such as reforestation and changes in forest management, fire management, changes in fertilizer use in grasslands as well as coastal and peat restoration (Griscom *et al.*, 2017). But all such solutions have adverse effects, so scenarios are key for considering trade-offs in context.

Land-based climate mitigation scenarios achieving multiple sustainability goals

Global bioenergy potentials and scenarios are commonly generated with Integrated Assessment Models (IAMs), which explicitly account for competing land demands (Rogelj *et al.*, 2018b), and are consistent with estimates from other global biophysical modelling approaches (Beringer *et al.*, 2011; Erb *et al.*, 2012; Heck *et al.*, 2018; Kok *et al.*, 2018; Meller *et al.*, 2015). BECCS from dedicated plantations in accordance with SSP2 and RCP2.6 would most likely lead to a further transgression of planetary boundaries for land-system change, biosphere integrity and biodiversity, and biogeochemical flows (Heck *et al.*, 2018). So-called second- and third-generation bioenergy systems (IEA & FAO, 2017), such as the use of agricultural residues, and biofuels produced from lignocellulosic ethanol and algae, often have a lower impact on biodiversity and the environment in general. An interpretation of the SSPs with five IAMs with distinctive land use models suggests substantial potential for climate mitigation through improved agricultural management and second-generation bioenergy crops in combination with BECCS, while preserving or even enhancing the extent of natural ecosystems and carbon stocks, in particular in an SSP1 world (Popp *et al.*, 2017).

However, in current models for large-scale scenarios, biodiversity targets have only been included in rather simplistic ways, such as an additional constraint for land allocation, e.g., excluding protected areas from bioenergy or food production (Beringer *et al.*, 2011; Erb *et al.*, 2012; Meller *et al.*, 2015). The global pathways (SSPs) and associated models still lack many processes important to quantify changes in habitat quality and biodiversity (Harfoot *et al.*, 2014; Meller *et al.*, 2015), particularly at local scales (Kok *et al.*, 2017), implying high uncertainty in future impacts of large-scale deployment of bioenergy systems on biodiversity and ecosystem services (Meller *et al.*, 2015).

Griscom *et al.* (2017) estimated that 'natural climate solutions' can provide 37% of the climate mitigation needed until 2030 for a better-than 66% chance of reaching the 2 degrees Celsius target, without adverse effects on biodiversity and food security, and with likely co-benefits for biodiversity. Carbon storage, climate mitigation effectiveness and biodiversity can, for example, be promoted if trees are allowed to grow older in certain temperate forests (e.g., Law *et al.*, 2018). Results from a global analysis, however, suggest that optimal forest harvest ages in terms of climate mitigation efficiency (including life-cycle analyses) often deviate from those ages that promote biodiversity the most (Oliver *et al.*, 2014) and high biodiversity is often found in low-biomass systems (Bond, 2016; Myers *et al.*, 2000). Abreu *et al.* (2017), for example, found strong negative effects of fire suppression on plant and ant richness in the savannahs of the Brazilian Cerrado, a global biodiversity hotspot, where carbon storage was increased by fire suppression. Nevertheless, a recent study with a global integrated energy-economy-land-use modelling system including a wide range of climate mitigation activities suggested that it is feasible to reach the 2 degree Celsius and even the 1.5 degree Celsius target of the Paris Agreement, with co-benefits for air quality, food and energy prices, and without substantial negative effects on biodiversity (Bertram *et al.*, 2018). These outcomes were achieved via a reduction of agricultural trade barriers, no further increases in first-generation biofuels, an increase in the protected forest area and an increase in carbon pricing (Bertram *et al.*, 2018). 'Bending the curve' scenarios also suggest substantial potential for improved land management and synergies between climate mitigation and biodiversity, but also trade-offs (see section 5.3.1.2, **Box 5.3** and Kok *et al.*, 2018).

Synthesis and open questions about climate mitigation pathways

Different bioenergy systems can have very different impacts on biodiversity and ecosystem services (Meller *et al.*, 2015). Intensively managed bioenergy monocultures, such as sugarcane, maize/corn, soybeans, and oil palm have roughly similar negative impacts as other forms of intensive agriculture on biodiversity and ecosystem services more broadly, which raises concerns about their future deployment. The global potential of second- or third-generation bioenergy systems is more uncertain than the above first-generation systems. Alternatively, establishing bioenergy systems that integrate multiple functions can also promote biodiversity (Creutzig *et al.*, 2015; Meller *et al.*, 2015). For example, when combined with agroforestry or installed on degraded land, oil palm plantations can generate co-benefits on food production, carbon storage and biodiversity (Creutzig *et al.*, 2015; Smith *et al.*, 2014). It has also been suggested that marginal and degraded lands, currently not used for food production, might have a substantial potential for bioenergy production. However, how much land is available or unused has been debated (Creutzig *et al.*, 2015), and many areas considered marginal in terms of their agricultural or forestry potential harbour rich biodiversity (Bond, 2016; Myers *et al.*, 2000). Also, 'low-input high-diversity' (LIHD) mixtures of native grassland perennials, for example, can have higher energy yields than monocultures, increase carbon storage in soils, benefit biodiversity and ecosystem services, and they can be grown on agriculturally degraded soils (e.g., Tilman *et al.*, 2006b). Even for the European Natura2000 protected area network, a large potential of low-input high-diversity bioenergy production has been suggested (Van Meerbeek *et al.*, 2016). However, intensively managed monocultures often have higher yields and are, therefore, favored by current price and policy incentives, even though they perform poorly when considering multiple ecosystem services (e.g., Werling *et al.*, 2014). Forest residue use also has large potential, but it can also decrease old-growth forest structures, such as deadwood, which are important habitats for many species (Meller *et al.*, 2015).

Large-scale deployment of intensively managed first-generation monoculture bioenergy crops would have profound negative impacts on biodiversity and many ecosystem services but a comprehensive quantification of such effects at the global scale is missing. A recent study concluded that a low-emission scenario with BECCS might affect global vertebrate diversity as negatively as a high-emission scenario with stronger climate change but without BECCS (Hof *et al.*, 2018). Nevertheless, substantial additional potential for bioenergy exists without compromising biodiversity and ecosystem services, but the implications of different bioenergy systems for a variety of ecosystem services and sustainable development are often poorly captured in scenario studies.

Other ecosystem-based climate mitigation activities surely also have large potential for sequestering carbon cheaply while providing multiple ecosystem services, and boosting biodiversity (Griscom *et al.*, 2017). It is, however, difficult to generalize under which conditions certain management actions preserve biodiversity and achieve an optimal supply of several ecosystem services. Optimal approaches (balancing trade-offs of production and conservation) are region- and ecosystem-specific and include considerations of both biological and livelihood diversity. For instance, among the guiding principles proposed to maximize carbon storage and commercial forestry in landscape restoration schemes in the tropics is that afforestation should not replace native grasslands and savannahs (Brancalion & Chazdon, 2017).

The reviewed literature suggests that governance and shifted economic incentives will be necessary to promote the development of those land-based climate mitigation activities that secure multiple ecosystem services (Grubler *et al.*, 2018; IEA & FAO, 2017; van Vuuren *et al.*, 2015; Werling *et al.*, 2014). Demand-side climate mitigation measures, e.g., reduced waste or demand for energy and livestock products, are often more likely to achieve multiple goals, such as greenhouse gas emission reduction, food security and biodiversity protection than bioenergy plantations (Grubler *et al.*, 2018; Smith *et al.*, 2013). Low energy demand pathways, with reduced or no reliance on BECCS, would likely result in significantly reduced pressure on food security (Roy *et al.*, 2018). Some demand-side changes will require life-style changes, which can take more time than supply-side measures and pose challenges to influence by policies (Smith *et al.*, 2013; see also section 5.3.2.1 and 5.4.1.2 on consumption). However, current observable trends suggest a substantial potential to decrease the global energy demand despite rises in population, income and activity. A global scenario study based on these trends suggest that the 1.5 degrees Celsius target and many SDGs could be met without relying on negative emission scenarios (Grubler *et al.*, 2018), but most global studies concluded that some negative emissions might still be necessary even with optimistic assumptions concerning, e.g., lifestyle changes, reforestation and energy transitions (e.g., van Vuuren *et al.*, 2018). Further transdisciplinary research and improved models for ecosystem management and bioenergy scenarios are, however, necessary to close the knowledge gaps outlined above.

5.3.2.3 Conserving and restoring nature on land while contributing positively to human well-being

Framing the problem

The concept and practice of protected areas (PAs) has been at the heart of conservation policy since its inception in the 19th Century. Traditionally, PAs were implemented by governments using strict conservation approaches, which treated biodiversity protection as incompatible with social-cultural practices and benefits. By the 1980s, classic conservation models evolved towards more participatory management and inclusive conservation approaches. The Convention of Biological Diversity (CBD) called for the protection of at least 17% of terrestrial and inland water by 2020, especially areas of particular importance for biodiversity and ecosystem services (a target nearly met, although with limited spatial and ecological representativeness; chapter 3).

Existing PAs suffer from several challenges. Isolated areas can lack functional connectivity for species. Some authors argue that biodiversity within PAs continues to decline, questioning the effectiveness of current conservation management approaches (Coad *et al.*, 2015), while other studies document the effectiveness of PAs, at least relative to other land uses (Gray *et al.*, 2016). Today's PAs are likely not adequate to conserve many species whose distributions will shift due to climate change (Secretariat of the Convention on Biological Diversity, 2014); they may also suffer from additional degradation (e.g., increased fire risk). In this context, to protect habitats and species and maintain connectivity, attention has been directed towards biodiversity-rich land under **private** ownership and under the governance and management of IPLCs, who already contribute to the management of around 40% of PAs globally (Drescher & Brenner, 2018; Garnett *et al.*, 2018; Kamal *et al.*, 2015; Maron *et al.*, 2018; Paloniemi & Tikka, 2008; Tikka & Kauppi, 2003).

In addition to conservation, **restoration** of ecosystems and landscapes (although in its early stages) is rapidly becoming a new major driver of changes in nature and NCP (Aronson & Alexander, 2013). Aichi Biodiversity Target 15 together with the "Bonn Challenge"—a global restoration initiative—have established a goal of restoring 150 million hectares of deforested and degraded land globally by 2020. The New York Declaration on Forests expanded this goal to 350 million hectares restored by 2030 (Chazdon *et al.*, 2017). In addition, several large-scale restoration initiatives have recently emerged around the world (Latawiec *et al.*, 2015).

What do scenarios say about how to achieve these goals?

Sustainability-oriented global scenarios usually consider the maintenance or expansion of protected areas (PA) networks as central. For instance, the Rio+20 target-seeking scenarios implemented three different assumptions regarding the extent and distribution of PAs. The Global Technology pathway, reflecting a land-sparing approach, explores the expansion of agricultural areas close to existing agricultural areas, and assumes that 17% of each of 7 biodiversity realms will be protected in PAs situated far from agriculture. In the Decentralized Solutions pathway, production areas are shared with nature elements covering at least 30% of landscapes to reinforce PAs, which cover 17% of all 779 ecoregions. As previously discussed, Kok *et al.* (2014) show that both strategies may reduce biodiversity loss, but the biodiversity preserved, and the spatial distribution of losses differ greatly (see **Box 5.1**).

Any approach entails international cooperation including funding from different sources (e.g., Global Environment Facility, Butchart *et al.*, 2015) to facilitate and scale up protected areas. This is especially true in developing regions facing challenges to effective protection in current and future protected areas. Scenarios at local and national scales emphasize, as a critical element of pathways, the improvement of monitoring systems and the enforcement (and protection) of environmental legal frameworks (Aguiar *et al.*, 2016).

Also, at local to regional scales (Appendix 5.2), scenarios show that **existing protected areas are at risk**, mostly due to political changes, incomplete implementation and institutional weaknesses (see chapter 3 for a discussion). In Latin America, for instance, the network of PAs and indigenous lands is one of the most important factors managing the Amazon deforestation frontier (Aguiar *et al.*, 2007; Pfaff *et al.*, 2015; Soares-Filho *et al.*, 2010). However, these areas suffer the impacts of illegal logging and fires, and are threatened—above all—by political and economic pressure to give way to agricultural expansion, major infrastructure and natural resource extraction projects (Aguiar *et al.*, 2016; Ferreira *et al.*, 2014).

The **expansion of protected areas networks** faces competition with other land uses. In a global analysis, Venter *et al.* (2018) found that both old and new protected areas did not target places with high concentrations of threatened vertebrate species, but instead appeared to be established to lessen conflict with agriculturally suitable lands. In Africa, for instance, although the need for expanding protected area networks is great, some authors argue that improved governance of existing PAs may provide more biodiversity benefits (Costelloe *et al.*, 2016).

Local scenarios propose a combination of protected areas and land-sharing approaches through landscape planning. The 'land sharing' strategy has the potential to improve connectivity between natural areas by boosting natural elements within the agro-ecological matrix. Meanwhile, increasing productivity reduces the land area needed for agricultural production and consequently reduces biodiversity loss. But the sustainability of that intensification depends on reserving large areas within the agro-ecological matrix for natural elements (Perfecto & Vandermeer, 2010).

The **spatial arrangement** of protected areas and natural elements also matters, as explored by landscape planning to meet human needs via multiple ecosystem services while maintaining biodiversity in functioning ecosystems. This can be done on private lands, optimizing trade-offs between environmental, social and economic benefits (Kennedy *et al.*, 2016; Seppelt *et al.*, 2013). Such planning can also consider the importance of mosaics of diverse governance types and the overlap of PAs with Indigenous lands and community-governed conservation areas that can enhance opportunities to meet human needs and ecosystem function. In the Andes, for instance, the spatial and temporal organization of farms and agricultural practices at multiple scales—including some agroforestry practices—could improve yield and boost ecosystem services (Fonte *et al.*, 2012).

Restoration

Ecosystem restoration can also deliver multiple benefits to people and help achieve multiple Sustainable Development Goals (Possingham *et al.*, 2015). Successful cases of restoration are found all over the world (see Fisher *et al.*, 2018). Achieving these targets would ease pressing global challenges such as climate change mitigation (Chazdon *et al.*, 2016) and adaptation (Scarano, 2017), and biodiversity decline (Crouzeilles *et al.*, 2017). Large-scale restoration may play a critical role in enhancing nature's contributions, but it represents yet another competing use of already scarce land resources with potential impacts on local livelihoods (Adams *et al.*, 2016; Hecht *et al.*, 2014).

Box 5 4 Restoration experiences in Brazil.

Brazil provides valuable case studies for understanding potential solutions and challenges of accommodating new restoration areas where land is an increasingly limited resource (Latawiec *et al.*, 2015). The State of Espírito Santo government, supported by both agricultural and environment departments, has been promoting large-scale forest restoration and conservation programs through the 'Reforest' Program ('Reflorestar' in Portuguese) with a total goal of approximately 236 000 ha between 2005 and 2025. At the same time, the State's development plan aims to expand agricultural areas by 284 000 ha and forest plantations by 400 000 ha. The current pasture productivity in the State is less than one third of its potential (Latawiec *et al.*, 2015). Pasturelands therefore provide an opportunity to accommodate both intensified but non-confinement-based cattle ranching activities and restoration, through land sparing **(Figure Box 5.4.A)**.

A second example is from the state of Sao Paulo, where the Rural Landless Workers' Movement redistributed more than 3000 families to settle in the Pontal do Paranapanema in 1942, in the Reserva do Pontal area designated to protect the highly threatened Atlantic Forest ecosystem and the endangered endemic black lion tamarin (Hart *et al.*, 2016; Valladares-Padua *et al.*, 2002). A concerted effort by a range of stakeholders supported rural livelihoods through landscape-level coordination, developing sustainable agroforestry initiatives and creating ecological corridors to connect forest fragments (Wittman, 2010). Diversified agroforestry created a buffer for wildlife reserves and improved agricultural productivity, increasing incomes for local communities (Cullen *et al.*, 2005). This example demonstrates that implementation of a landscape approach wherein a participatory approach can facilitate forest conservation and restoration. Such integrated landscape management approaches have gained prominence in the search for solutions to reconcile conservation and development (Sayer, 2009), particularly if they consider nonlinear ecosystem dynamics and climate change (Sietz *et al.*, 2017).

Figure 5 4 A **An example of land sparing.**

An increase in pasture productivity in areas suitable for cattle ranching (left) allowed a farmer to set aside marginal areas with rocky soils (right) for forest restoration in the Atlantic Forest in Brazil (Latawiec *et al.,* 2015). Photo credit: Veronica Maioli.

These examples reveal several essential conditions for land sparing to occur, such as covering implementation costs, providing technical assistance, and setting up rigorous monitoring to avoid leakage and rebound effects. It is also paramount to protect local livelihoods involved in other farming activities that may be less profitable but key to meeting local and regional food security needs (e.g., production of staple crops such as black beans, in the case of Brazil). As illustrated by first São Paulo example, sometimes leakage might be best avoided by diversifying production systems through land sharing (Perfecto *et al.*, 2009).

Demand for agricultural land and land for restoration will continue to grow for several decades, putting pressure on scarce land resources (Smith *et al.*, 2010). This pressure can be mitigated, however, through solutions promoting more sustainable and inclusive land management. In particular, integrated land-use planning that takes into account conservation and restoration priorities with priorities for increased agricultural production (Margules & Pressey, 2000; Strassburg *et al.*, 2017) might play a key role in reconciling competing demands.

Conservation and restoration scenarios and IPLCs

Few of the aforementioned scenarios directly address the interplay between human well-being, nature conservation and restoration goals. It is primarily at local scales that studies suggest that engaging meaningfully with IPLCs—whose lands hold much of the world's biodiversity—is one of the most effective ways to secure biodiversity conservation and sustainable use (FPPIIFB & SCBD, 2006). The global importance of IPLCs is treated in chapters 1, 2, and 3.

Empowering IPLCs as central partners in conservation and climate-change mitigation has allowed many people to gain access to land and citizenship rights (chapters 3 and 6; Kohler & Brondizio, 2017), but this has provided limited improvements in access to social services and economic opportunities. On the other hand, Kohler and Brondizio (2017) suggest that public policies and conservation programs should not delegate responsibility for managing protected areas to IPLCs without considering local needs, expectations and attitudes toward conservation.

It is primarily at local scales that scenarios explicitly consider land tenure rights, economic incentives and alternatives, and vulnerability of IPLCs (living inside or outside protected areas and other special units; e.g., Folhes *et al.*, 2015). For example, in **China**, Cotter *et al.* (2014) considered a GoGreen scenario that embedded the MAB (Man and the Biosphere Programme) principles of conservation and sustainable livelihoods while introducing Traditional Chinese Medicine agroforestry. This GoGreen scenario enabled protection of forests while sustaining rural livelihoods. Similarly, Suwarno *et al.* (2018) concluded that the current forest moratorium policy (BAU) is not effective in reducing forest conversion and carbon emissions. Furthermore, they suggested that a policy combining a forest moratorium with livelihood support and increases in farm-gate prices for forest and agroforestry products could increase local communities' benefits from conservation (including via certification schemes for cocoa production). Elsewhere, Mitchell *et al.* (2015) employed social-ecological modelling and scenario analysis to explore how governance influences landscape-scale biodiversity outcomes in the **Australian Alps**. Their study highlighted the importance of shared values and attitudes supportive of conservation, as well as political will and strategic direction from local governments.

Finally, some scenarios also explicitly mention the importance of **using biodiversity products to create economic alternatives** for IPLCs and regional economies (Aguiar *et al.*, 2016; Folhes *et al.*, 2015). A recent paper (Nobre *et al.*, 2016) brings a broader proposal: a new development paradigm that transcends reconciling conservation with intensification of agriculture, moving towards biomimicry-based development—a "Fourth Industrial Revolution" that could benefit IPLCs and the world at large.

Synthesis and open questions about conservation and restoration pathways

The expansion of the current PA network is necessary to ensure that PAs are ecologically representative and connected, including in light of climate change. However, to accommodate conservation and restoration where land is increasingly limited, the reviewed literature points out that **participatory spatial planning based on a landscape approach** is key. The landscape approach aims to allocate and manage land to achieve social, economic, and environmental objectives in landscape mosaics where multiple land uses coexist. Such integrated management should also include the urban-rural interface, and the importance of locally desirable livelihood activities less profitable than industrial agriculture, but key to meeting local and regional food security needs.

On the other hand, many existing PAs are not effectively managed or adequately resourced. The review of the current scenario literature, especially at local to national levels, underlines the need to **protect the protected areas**, including by enhancing monitoring systems and legal frameworks.

Sustainable-use protected areas (and other special areas, such as indigenous lands) will rest upon **appropriate governance mechanisms and collaboration with IPLCs.** This would begin with recognition of IPLC knowledge and leadership including via novel compensation-oriented payments for ecosystem services programs (5.4.2.1), but it also might involve economic alternatives, technological innovations, and access to markets and basic services (education, health, etc.). On the other hand, IPLCs should not be seen as "traditional environmentalists" to whom the responsibility to manage protected areas is delegated, but rather an opportunity to co-govern with those who have intimate and ancestral-derived knowledge and practices, but also varying needs in different contexts. Finally, innovations related to the benign industrial use of biodiversity could benefit local populations and regional economies, and contribute to conservation.

Mechanisms to facilitate and scale up international **financing of protected areas** are also essential, especially in developing regions. However, funding is not enough, as weak governance and power structures in different regions need to be taken into account. **Power asymmetries**, especially in developing countries, threaten not only legal frameworks (for instance, regarding protected area networks), but also the possibility of implementing integrated management processes.

5.3.2.4 Maintaining freshwater for nature and humanity

Framing the problem

Maintaining freshwater for nature and humanity is an urgent challenge, with an estimated 1.8 billion people likely to live under conditions of regional water stress (Schlosser *et al.*, 2014). The diversion of freshwater for human use has been characterised by an incomplete appreciation of freshwater ecosystems and the services they provide. Aquatic ecosystems in some cases have been losing species up to 5 times faster than other ecosystems (Ricciardi & Rasmussen, 1999), and the situation is set to worsen as anthropogenic pressures on water resources increase (Darwall *et al.*, 2008; Dodds *et al.*, 2013; Dudgeon *et al.*, 2006). Anthropogenic land-cover change is a more dominant driver of hydrological impacts than climate change (Betts *et al.*, 2015), and global-scale population and economic growth variables have greater effects on projected water supply-demand relationships than does mean climate (Vörösmarty *et al.*, 2000). Climate change is a major driver of agricultural water demand, however, primarily through increased temperature, which increases the transpiration demand; effects due to changes in precipitation and runoff are variable and uncertain (Turral, 2011).

Around 2010, food production accounted for 70-84% of global water consumption, and dominated projected consumption (FAO, 2016; Secretariat of the Convention on Biological Diversity, 2014). Implementation of the OECD baseline scenario for 2050 in modelling biodiversity "intactness" of freshwater ecosystems (Janse *et al.*, 2015) indicates further global declines in aquatic species richness, particularly in Africa. In 2014, freshwater fish (a major livelihood component and economic sector) constituted 12.7% of the global capture fishery, and 64% of aquaculture fish (FAO, 2016; McIntyre *et al.*, 2016). Access to fish by IPLCs is being eroded by changing legal frameworks and commodification (Allison *et al.*, 2012; Beveridge *et al.*, 2013), as well as pollution and overfishing. Freshwater and associated fish are critically limiting resources on many small island nations. In the Polynesian islands, as one example, major threats to freshwater biodiversity relate mainly to alteration of natural flow regimes (barriers and abstraction of water), plus overharvesting, alien species and climate change (Keith *et al.*, 2013).

Water for energy production accounted for approximately 15% of global withdrawals in 2010 (Flörke *et al.*, 2013). Fricko *et al.* (2016) found that "once-through" cooling was the dominant source of withdrawals, and of thermal pollution in thermal power generation. Meeting targets for a stable global climate through the development of renewable energy puts additional stress on freshwater systems, because hydropower is considered a major renewable energy source. Changes in river flood pulses (sensu Junk, 1989) and water quality induced by dams have had adverse effects on biodiversity, ecological productivity (e.g., Abazaj *et al.*, 2016; Arias *et al.*, 2014) and sediment transport, by decreasing wet season flows, increasing dry season flows, impeding movement of aquatic life, and trapping sediments.

Changes in land cover in catchments affect river flow characteristics. Evidence for increased run-off from deforestation is clear (Zhang *et al.*, 2017), whereas the effects of afforestation are ambiguous (Jackson *et al.*, 2013; Vanclay, 2009). Clearly there are important trade-off implications for the carbon mitigation potential of afforestation. Land and terrestrial water management also poses a serious threat to the freshwater-marine interface (Blum & Roberts, 2009). Lotze *et al.* (2006) analysed 12 temperate estuaries and coastal seas, and found that about 40% of species depletions and extinctions could be attributed to habitat loss, pollution, and eutrophication. Other important consumers of water are industries, of which mining is particularly important in terms of demand and impacts (pollution, sediment load; Azapagic, 2004; Vörösmarty *et al.*, 2013; chapter 2).

Here we summarise characteristics of pathways towards resolving these tensions and challenges at global, regional and local levels, and draw out commonalities and differences across these scales. People use water to supply domestic and urban needs, to produce food, and to produce energy. These uses consume water, change its quality, and change associated contributions to people. Most normative scenarios relating to water have focused on improving water supply and quality for human purposes. In recent years, freshwater policies "have begun to move away from a riparian rights focus … towards efficiency improvements and river basin management" (UNEP, 2002). At the global scale, this shift is reflected in the global scenario analyses, as outlined below.

What do scenarios say about how to achieve these goals?

The GEO-3 "Policy First" scenario (UNEP, 2002) emphasizes using top-down governmental policy and institutional instruments to create integrated resource management approaches, including increased environmental stewardship. This scenario also invests in governance focused on social environmental policies, and enables greater participation from the private sector. The "Sustainability First" scenario describes pathways grounded in both government and civic society taking action against declining global social, economic and environmental indicators. The pathways incorporate greater collaboration between actors, with initiatives from society pushing sustainability. They also rest on positive media engagement, incorporation of research and analysis, and increased accountability and transparency. Greater integration of regional policies related to water management and other transboundary issues are envisioned.

The GBO-4 (CBD, 2014) re-assessment of the PBL (2012) Roads from Rio+20 used the same 3 scenarios designed to attain SDG targets, but with metrics addressing Aichi Biodiversity Targets relating to inland waters. Elements of all three scenario pathways address the maintenance of freshwater ecosystems and their multiple contributions. Aside from the systemic integration of freshwater nature into planning, development and communications, GBO-4 pathways include national accounting of water stocks. Specifically, in these pathways IPLCs are involved in creating and governing protected areas (PAs), PA networks are expanded to be more representative of freshwater ecosystems, and protection is enhanced for river reaches upstream and downstream of terrestrial PAs to maintain connectivity. These pathway elements were echoed strongly by Harrison *et al.* (2016). GBO-4 included a range of other elements, including management of pulsed systems that protects refugia for aquatic biota, identification of systems important for providing multiple ecosystem services (including disaster risk reduction); reduction of pressures on wetlands, river and mountain areas, and restoration of degraded systems. Policy instruments include the enforcement of environmental regulations for development projects, and new market instruments (wetland mitigation banking, payments for ecosystem services).

Pathways for food and freshwater

Pathways towards sustaining freshwater ecosystems and their multiple contributions rest on addressing **land use**, **eutrophication** and **hydrological disturbance**. The World Water Vision (Cosgrove & Rijsberman, 2000) identified two critical pathway elements: 1) limiting expansion of agricultural land area (requiring improved water use efficiency and agronomy) and 2) increased storage, through a mix of groundwater recharge, wetlands, alternative storage techniques employing ILK, and dams that minimize disruption of flow regimes and impacts, including on IPLCs.

Pathways for energy, climate and freshwater

Fricko *et al.* (2017) found significant potential gains from technological improvements in cooling. Transitioning toward air and sea-water cooling over the period 2040-2100 could reduce cumulative freshwater withdrawal by 74%, consumption of freshwater by 19% and thermal pollution by 41%. In addition, a rapid scale-up of non-water based renewable energy generation (wind, solar) could generate multiple co-benefits, including climate stabilisation, reduced water demand, improved water quality and a reduction in hydrological disturbance, sustaining fluvial ecosystems. In the Gulf States, cogeneration (using thermal energy from electricity generation to desalinate seawater) is responsible for about 85% of desalination (El-Katiri, 2013).

Flow alteration and barriers were not explicitly addressed in the global scenario pathways assessed here. At local and regional scales, studies suggest that improving environmental legislation (Fearnside, 2015), enhancing existing infrastructure (Zwarts *et al.*, 2006), and implementing operating procedures to minimise downstream ecological impacts (Kunz *et al.*, 2013) are critical pathway elements for conserving freshwater systems and their contributions. Demand management (advocated in GEO-3 and other meta-analyses) is also a central recommendation, including improved water use efficiency, pricing policies and privatisation.

In freshwater system pathways, there are some synergies between conserving nature and NCP and mitigating climate change: restoring and avoiding further conversion of peatlands is an important pathway element (Griscom *et al.*, 2017).

Regional and local perspectives

Sub-Saharan **Africa** is expected to experience one of the largest increases in point-source pollution of freshwater due to increasing urbanization and slow development of sewage treatment (Nagendra *et al.*, 2018). Investment in wastewater treatment is crucial to complement improved sewage reticulation (van Puijenbroek *et al.*, 2015), while investment in distribution infrastructure and improved regulation of access are pathway elements to ensure equitable access to water (Notter *et al.*, 2013).

Improvement of infrastructure across the continent is needed to increase agricultural production, while improved irrigation efficiency needs better enforcement of regulations (AfDB, 2015; Notter *et al.*, 2013). In the Inner Niger Delta, Zwarts *et al.* (2006) found that improving efficiency of existing water infrastructure, instead of building new dams, would improve conservation of ecosystem services and economic growth. In southern Africa a number of studies indicate that participatory approaches to water resource planning and environmental flows could enable equitable trade-offs between water users (Brown *et al.*, 2006; King *et al.*, 2014, 2003). Operating procedures for existing hydropower dams can be optimised to reduce biogeochemical impacts downstream (Kunz *et al.*, 2013).

In the Americas, issues arising from hydropower developments have identified elements of pathways towards sustainability (Moran *et al.*, 2018). In the Brazilian Amazon, unrepealed legacy legislation has allowed the overriding of environmental licensing laws; institutions and legal instruments, and full disclosure and democratic debate on river basin development plans are critical pathway elements, especially for transboundary river systems (Fearnside, 2015; Latrubesse *et al.*, 2017). At the local level in the Brazilian Amazon, key pathways include strengthening the capacity of local communities to negotiate with developers and develop management skills for collective projects (Folhes *et al.*, 2015).

Social-ecological systems modelling by Mitchell *et al.* (2015) in south-eastern Australia in the **Asia and the Pacific** region indicates that conservation of alpine lakes, fens and bogs would be enhanced by adoption of a long-term governance regime immune to short-term political agendas.

In **Europe and Central Asia**, a participatory backcasting scenario planning process for Biscay in the Basque Country found that water supply and water regulation could be optimised under their “TechnoFaith” scenario—one which prioritizes technological solutions. The “Cultivating Social Values” scenario achieved almost the same results through participatory decision-making, emphasis on local government, responsible consumption, and a proactive society (Palacios-Agundez *et al.*, 2013).

Synthesis about freshwater pathways

The scenarios literature reviewed above coupled with broader literatures on freshwater systems and management suggest the following key elements of sustainable pathways. A central cross-cutting conclusion is that sustenance of freshwater ecosystems and their contributions requires healthy catchment areas, careful allocation of water rights and maintenance of hydrologic variability (Aylward *et al.*, 2005; Dudgeon, 2010; Durance *et al.*, 2016; Harrison *et al.*, 2016; Kuiper *et al.*, 2014; Poff, 2009; Postel & Thompson, 2005). **Foremost among pathway elements is the importance of dynamic and iterative deliberations among stakeholders** in identifying desired futures and policy to achieve these (Tinch *et al.*, 2016).

Freshwater production as an ecosystem service: The pathways reviewed secure sustained supply of good quality water sufficient for human and environmental needs. This requires protection of upstream catchment areas, middle-reach floodplain systems (Green *et al.*, 2015) and often land rehabilitation to reinstate storage and reduce erosion and sediment transport. Such efforts can be broadened to regional and continental institutional arrangements to address the impacts of land-use change at basin scales (Ellison *et al.*, 2017). Explicit recognition of the provisioning function of upstream catchments is crucial for land-use planning, a central element of sustainable pathways. Design strategies for forested catchment land cover, such as (re)planting water courses with indigenous species can also produce natural hydrographs and high-quality water (Ferraz *et al.*, 2013; Vanclay, 2009). Integration of surface and groundwater management (Giordano, 2009) reduces the need for dams. Catchment protection (e.g., limiting mining and industry) can reduce pollution of water-producing areas.

Freshwater systems: There is strong consensus that variability in hydrological regime is crucial for maintaining freshwater ecosystems and their contributions to society, as central in sustainable pathways (e.g., Annear *et al.*, 2004; Biggs *et al.*, 2005; Bunn & Arthington, 2002; Poff *et al.*, 1997, 2010; Postel & Richter, 2003). Sustainable pathways maintain or re-instate flow variability, quantity, timing and quality needed to sustain healthy freshwater systems. Pathway element include: i) slowing and reversing catchment land cover transformations (deforestation, intensive cultivation); and ii) minimising disruption of flow regimes by using fewer, smaller dams.

Agricultural production: Attaining ambitious pathway targets for agricultural production (see section 5.3.2.1 Feeding Humanity) without damaging freshwater nature entails a broad set of actions. Optimising water use for agricultural production rests on sustainable intensification, improved management through technology, better agronomy, and improved hydrological governance, including implementation of “green water” techniques (Bitterman *et al.*, 2016; Pandey *et al.*, 2001; Rockström & Falkenmark, 2015). Also important are improved management to reduce non-point source pollution (e.g., Hunke *et al.*, 2015) and sediment input to freshwater systems, and enforcement of standards and allocations.

Energy production: The production of hydropower—central to many sustainable pathways—carries many impacts which cannot be mitigated (e.g., Fearnside, 2015; Kling *et al.*, 2014). Reductions in variability, discharge and changes in biogeochemistry are among these. Alternative sources of renewable energy are implementable with present technology. Management regimes of existing hydropower dams can be optimised by integrating ecological requirements of variability and water quality into standard operating protocols (Kunz *et al.*, 2013).

Supply chains: Sustainable pathways require that supply chains secure sufficient water to meet environmental demands, human rights and needs. This can be achieved by a combination of improved valuation of the resource (demand management), involving stakeholders inclusively, and investment in infrastructure, such as dual reticulation systems for urban supply, treatment systems for urban waste water and agricultural waste water. Dedicated institutional arrangements for managing river basins are seen as a critical component for managing supply chains.

Consumer actions: Reduction of consumption and waste as a key pathway element can be achieved by optimising efficiency in urban use, agricultural use (precision irrigation, improved agronomy, reduced waste flows), industrial/mining use (tertiary treatment of waste, increased regulatory oversight) and the energy sector (transition to alternative renewables, and cooling systems). Such actions are not likely to be made without changing incentives (including water pricing) (5.4.1.1, 5.4.2.1), encouraging behaviour change including through infrastructure (5.4.1.3), and increasing awareness and knowledge among consumers (5.4.1.8).

5.3.2.5 Balancing food provision from oceans and coasts with nature protection

Framing the Problem

Seafood from fisheries and aquaculture is an integral part of the global food system, supplying approximately 17% of all animal protein consumed by humans and providing a suite of micronutrients important for human nutrition (FAO, 2016). The dietary importance of seafood is pronounced in many food-insecure regions (Béné & Heck, 2005; FAO, 2016). Demand for seafood is predicted to grow substantially in coming decades, potentially at a higher rate than other major sources of animal protein (Tilman & Clark, 2014), and failing to meet that demand may affect the health of millions of people (Golden *et al.*, 2016).

Broad limits to global marine fisheries production have been reached (Worm & Branch, 2012), while aquaculture production of aquatic animals has steadily increased over the past four decades. As of 2013, 31.4% of fish stocks evaluated by the FAO were determined to be overfished and 58.1% were fully fished (FAO, 2016); the former yield less food than is theoretically possible, and the latter cannot yield additional food without becoming overfished. While marine fisheries landings reported by the FAO have remained relatively steady since the mid-1990s, at ~80 million metric tons, aquaculture production increased from less than 10 million tons in 1985 to over 70 million tons, or 44% of the world's total seafood production, in 2014 (FAO, 2016). A recent reconstruction of global catches (including catch types excluded from the FAO data) indicate that the mid-1990s global maximum in catches was higher, and that the decline in the subsequent years has been more severe, than observed in the FAO data alone (Pauly & Zeller, 2016). While aquaculture avoids some of the ecological concerns of fisheries, concerns involve the conversion of coastal wetlands, particularly mangroves, for aquaculture (Ottinger *et al.*, 2016), and the use of the majority of the world's fish oil and fishmeal production for aquaculture feeds (Tacon & Metian, 2015).

Safeguarding and improving the status of biodiversity will entail reducing intensity of seafood production to levels that allow for sustainable use of living marine resources (Sumaila *et al.*, 2015; Worm *et al.*, 2009). Some efficiency improvements are possible, however, such as ensuring that food-grade fish are used for direct human consumption rather than for aquaculture or livestock feed (Cashion *et al.*, 2017). While indirect drivers such as demographic changes and consumption patterns increase pressures on marine biodiversity, these drivers also exacerbate other factors such as poor governance and poverty (Finkbeiner *et al.*, 2017). When fisheries resources are overexploited, actions to improve conservation status can also increase sustainable seafood production. However, conservation and fisheries rebuilding may affect the availability and access to living marine resources by specific human communities in the short-term, although effectively managed marine ecosystems can support long-term sustainable development (Costello *et al.*, 2016; Jennings *et al.*, 2016; McClanahan *et al.*, 2015). Involvement and participation of stakeholders and local communities and consideration of local traditions in decision-making and implementation of resource management and biodiversity conservation policies could help reduce trade-offs between seafood provision and biodiversity conservation (Berkes, 2004; Christie *et al.*, 2017; Uehara *et al.*, 2016). Meeting food provisioning objectives appears to entail conservation and/or restoration of marine ecosystems, reduction of pollution, management of destructive extractive activities, strong progress toward climate change targets, elimination of perverse subsidies, education and other aspects of capacity builiding (Teh *et al.*, 2017).

What do scenarios say about how to achieve these goals?

Available scenarios for marine biodiversity and ecosystem services focus on identifying and exploring pathways to achieve biodiversity conservation and sustainable seafood production goals across multiple spatial scales (Table SM 5.2.A). Specifically, these scenarios explore options for marine protected areas and fisheries management such as spatial planning and control of catches or fishing effort. Climate change and its effects on marine biodiversity and ecosystems are included in a few cases to examine how regional conservation and fisheries management goals can be achieved under global changes.

Marine pollution is a cross-cutting issue that is often implicitly included in scenarios related to multiple economic sectors. Some of these sectors are sources of marine pollution. Marine spatial planning processes are central, managing activities such as shipping and coastal development. With recent focus on plastic waste in the ocean (e.g., see chapter 4), scenarios have been developed for waste management to achieve targets for marine plastic waste (Löhr *et al.*, 2017). A variety of telecouplings were explored particularly in management of transboundary fish stocks (Carlson *et al.*, 2018). For example, different fisheries management measures in the high seas on straddling fish stocks were examined to investigate their effectiveness in reducing climate risk on coastal fisheries and biodiversity (Cheung *et al.*, 2017).

Regional to global scale scenarios often focus on examining a specific policy pathway, while multiple pathways are more commonly considered at subnational to national scales (Table SM 5.2.A and Figure SM 5.2.A). At large spatial scales, existing scenarios explored different extents and configurations of marine protected areas and their effectiveness in protecting biodiversity from impacts of multiple human activities, or management of fishing effort to maximize sustainable seafood production. Although these scenario pathways are not considered simultaneously, they may indeed be mutually compatible in comprehensive pathways to sustainability. In contrast, scenarios for smaller spatial scales often examine pathways to specific national or regional policy frameworks such as the Marine Strategy Framework Directive in the Europe Union or, more generally, ecosystem-based management. These policy frameworks involve multiple policy goals, e.g., biodiversity conservation, economic benefits, sustainable food production, and the viability of specific industries or sectors. Examining a portfolio of pathways and options to achieve these multiple policy objectives and their associated interactions and trade-offs could help inform ecosystem-based management of the ocean.

One of the linkages between marine biodiversity and sustainable food production goals that is most commonly explored in existing scenario analyses (specifically target-seeking/policy-screening) is pathways to achieve Maximum Sustainable Yield (MSY) and the implications for biodiversity (see 5.3.2.5). Although direct utility of MSY as a target for fisheries management has been widely criticized (Berkes *et al.*, 1998), MSY is explicitly stated as an aspiration in important international agreements and national policies such as the United Nations Law of the Seas and and the European Common Fisheries Policy. However, achieving ecosystem-level long-term average maximum production may lead to overexploitation or depletion of relatively less productive or less valuable populations (e.g., through bycatch), which has been suggested in scenario assessments at global, regional and local scales (Cheung & Sumaila, 2008; Walters & Martell, 2004; Worm *et al.*, 2009). In some heavily exploited systems, achieving maximum sustainable yield may require restoring ecosystems and rebuilding fish stocks, which would have co-benefits for biodiversity conservation (Cheung & Sumaila, 2008; Pitcher *et al.*, 2000). In some specific cases, overexploitation has resulted in structural change in fisheries social-ecological systems, resulting in more intense trade-offs between maximizing sustainable yield and improving biodiversity status (Brown & Trebilco, 2014; Hicks *et al.*, 2016). For example, in eastern North America, the rise of invertebrate fisheries (e.g., shrimp) after the collapse of Atlantic cod may be due to a shift from a predator-controlled system to a prey-controlled system (Baum & Worm, 2009). Because of the high productivity and economic value of the invertebrates, rebuilding of cod fisheries (a potential biodiversity or ecosystem target) may lead to reduced fisheries profits (a sustainable food production target).

Achieving marine protected area (MPA) targets should contribute positively to both biodiversity conservation and sustainable food production, although the extent of co-benefits would depend on timeframe, site selection, and design and effectiveness of the protected areas. Scenario modelling efforts for MPA targets focus strongly on site selection with a primary objective of biodiversity conservation. Across many contexts, scenario and modelling studies that evaluate different MPA designs and the pathway to achieving MPA targets generally suggest that MPA networks would benefit both biodiversity and fisheries in the long-term, particularly in overexploited ecosystems, in part because of demonstrated spillover effects by which effectively-managed MPAs boost fisheries in surrounding waters (Gill *et al.*, 2017). However, trade-offs often exist in the short-term because of the time lag in biological responses to protection relative to the immediate cost of losing resource use opportunities (Brown *et al.*, 2015). The degree of such trade-offs and co-benefits is shown to be sensitive to ecosystem and MPA attributes such as mobility of organisms, dispersal of the populations, size of and connectivity between protected areas (Gill *et al.*, 2017). In addition, scenario analysis, particularly those with stakeholders participation, often reveals trade-offs and conflicts between different sectors and communities in identifying pathways to achieve the MPA targets (e.g., Daw *et al.*, 2012). Climate change may further complicate the trade-offs between MPA designation and different sectors as range-shifts and habitat changes driven by climate change may add additional constraints on the design of

MPA network or require bigger MPAs (Fredston-Hermann *et al.*, 2018). On the other hand, scenario analysis at multiple scales could also help identify pathways to reduce or resolve such trade-offs (IPBES, 2016).

Scenario research has also identified co-benefits from addressing other non-fishing drivers such as climate change (and ocean acidification) and habitat degradation. Given the increased focus on ecosystem-based fisheries management (Link, 2010), recent scenario analyses explored multiple drivers that cut across marine biodiversity and sustainable food production, including environmental change drivers (e.g., climate, pollution and habitat degradation). Overall, clear co-benefits exist in addressing drivers of environmental change for both biodiversity conservation and fisheries production globally (e.g., Cheung *et al.*, 2016) and regionally (e.g., Ainsworth *et al.*, 2012; Sumaila & Cheung, 2015). Specifically, climate change is likely to trigger species turnover and decreased potential fisheries catches, which compromises both biodiversity conservation and food production (Cheung *et al.*, 2009; Worm *et al.*, 2009).

Resolving apparently competing targets in sustainability pathways appears to require other actions with co-benefits for each. For instance, addressing perverse incentives associated with subsidies is a key element of sustainable pathways, given its co-benefits for biodiversity and long-term food provision (Pauly *et al.*, 2002; Sumaila *et al.*, 2010). Outside of fisheries management, organic and inorganic pollution are doubly harmful, often leading to hypoxia and increased harmful contaminants in seafood (e.g., mercury). Thus, achieving targets that address these climate and pollution drivers is an important element towards achieving both biodiversity and food security targets. However, few scenario analyses explore the contributions of mitigating these drivers for achieving biodiversity and fisheries targets. This is particularly relevant for climate change mitigation given that reducing biodiversity loss and/or ensuring sustainable food production (e.g., by eliminating overfishing, protecting habitat, and protecting local access to seafood) could be cost-effective means to reduce the impacts of climate change (Gattuso *et al.*, 2015).

Synthesis and open questions about pathways for oceans

Conservation and restoration of marine ecosystems can contribute positively to meeting food security goals in the long-term (Singh *et al.*, 2018). Marine conservation includes effective management of fishing and other extractive activities, consideration of climate change mitigation and adaptation, and reduction of pollution and other human pressures on marine ecosystems. International conventions and agreements exist to facilitate the development of specific actions at regional and national levels to achieve specific conservation targets and goals (Rochette *et al.*, 2015). Ultimately, a portfolio of measures is often key to reduce pressures on marine ecosystems (Edgar *et al.*, 2014).

Scenarios rarely consider explicitly the co-benefits and interactions between meeting conservation and food security goals, particularly for vulnerable coastal communities (McClanahan *et al.*, 2015). Recent studies, mainly at regional to local scales, have started to explore conservation-food security interactions using scenario analysis **(Table SM 5.2 A)**. Initiatives are underway to further develop capacity for scenarios and models for marine biodiversity and ecosystem services, including collating global and regional datasets for drivers such as fisheries catch and oceanographic changes, e.g., the Fisheries and Marine Ecosystems Impact Model Intercomparison Project (Tittensor *et al.*, 2018). Specific actions being considered in pathways to achieve both conservation and food security goals include, for example, elimination of perverse subsidies, reduction in fishing capacity, alternative fisheries management, designation of marine protected areas and climate mitigations. However, given the increasing focus of international conservation efforts on large marine protected areas or co-management of natural resources beyond national jurisdictions, linking scenario exercises with global scale pathways would help elucidate co-benefits and trade-offs of conservation efforts with food security issues locally, nationally and globally.

5.3.2.6 Resourcing growing cities while maintaining the nature that underpins them

Framing the problem

Urbanization rates, while relatively stable within developed country contexts, are increasing at an unprecedented scale within developing countries of the Global South (CBD, 2012; Nagendra *et al.*, 2018). Urbanization is both the movement of people from rural to urban areas, and a function of population increases within these regions. Urban dwellers now exceed 50% of the global population, and by 2050, there will be 2 to 6 billion more of them (UN, 2012). Urbanization will drive land-cover change both within defined city boundaries and in the broader surrounding landscapes from which cities are resourced. City expansion into surrounding areas is happening more rapidly in developing countries, and population growth appears to be a key driver here. In developed country contexts urban growth and expansion is slower and more strongly correlated with GDP measures and economic growth (Seto *et al.*, 2011). Cities are major consumers of natural resources and are highly reliant on regulating functions provided by ecosystems. These resource and ecosystem dependencies can stretch over extensive areas and form the basis of telecoupled systems where trade flows of resources connect distant regions (Fang *et al.*, 2016). And despite trade flows, cities face real challenges to maintain crucial resources, including clean water (Schlosser *et al.*, 2014).

Rapid urbanization is driving extensive changes in land cover and land use. This landscape fragmentation alters biodiversity patterns and ecosystem functions (Aronson *et al.*, 2014; Foley *et al.*, 2005; McKinney, 2006; Miller & Hobbs, 2002). Growth within and on the margins of cities can overlap with areas of rich biodiversity and natural resources (Chapin III *et al.*, 1997; McDonald, 2008; Ricketts & Imhoff, 2003). Rapidly urbanizing cities in biodiversity hotspots (such as Cape Town, South Africa) are particularly vulnerable to extinction and loss (Holmes *et al.*, 2012; Seto *et al.*, 2012a).

There is a pressing need to understand the implications of loss of species and habitats in and around cities (Grimm *et al.*, 2008), in terms of ecosystem services, human well-being and equity issues. How cities are provisioned with ecosystem services now and in the future relates to the success reaching the SDGs, particularly SDG 11 (to make cities inclusive, safe, and resilient and sustainable) and SDG 15 (protecting, restoring and promoting the sustainable use of terrestrial ecosystems).

What do scenarios say about how to achieve these goals?

Local scenarios and pathways related to nature, urbanization and sustainable development

A wealth of biodiversity can exist in cities (CBD, 2012), which is important for human health and well-being, livelihood opportunities, heat mitigation, and spiritual and cultural values. Developing in a manner that secures this can be extremely difficult to achieve in cities with high levels of endemic biodiversity and pressing social needs, such as housing (e.g., Cape Town, South Africa; O'Farrell *et al.*, 2012). Informality, witnessed through sprawling collections of informal dwellings, is one such key issue and characterises rapid urbanization observed across the Global South. The widespread presence of informality highlights the local realities of poverty, a lack of urban planning and the limited capacity to shape local landscape outcomes. Schneider *et al.* (2012) note the importance of understanding local ecology in determining the role and the impact of urban form both within the city and beyond it. Their work speaks specifically to urban density, water and food relationships, and shows the negative impacts of urban sprawl for biodiversity, productivity, and local ecology. Güneralp *et al.* (2013) note the local impacts of shifting towards meat-based diets within urbanizing areas.

The Cities and Biodiversity Outlook (CBD, 2012) highlights the importance of local knowledge in underpinning urban planning and resource management. Ahrends *et al.* (2010) produced models that demonstrate the role of markets on the degradation of resources within an African city context. Weak governance fails to secure the integrity of local biodiversity resources, allowing continued erosion of public goods. Detailed place-based knowledge and modelled futures around urban projections (Güneralp & Seto, 2013) can be used to inform appropriate local policy development pathways towards sustainable futures. These should include a detailed understanding of infrastructure, incentives and disincentives to promote benign development patterns that simultaneously promote conservation. Contemporary local form in many cities presents opportunities for land managers and decision-makers to improve urban design. Combined with a systemic understanding of nature and its contributions to people, this will allow for effective sustainable planning.

One pivotal policy domain with likely long-term impact on future scenarios relates to the initial choice about local and regional road network structures (Barrington-Leigh & Millard-Ball, 2017; Marshall & Garrick, 2010; Seto *et al.*, 2014). This choice about the configuration and location of road networks is a near-permanent commitment, as compared with other aspects of physical urban form and urban land use. Road networks underlie and constrain all other aspects of urban form, which in turn affect GHG emissions, energy intensity, community activities, and resource use through travel, consumption, extraction and home production patterns (Barrington-Leigh & Millard-Ball, 2015). In addition, high-connectivity, grid-like road networks are conducive to high-density settlement, while low-connectivity road networks are highly resistant to densification. Ensuring all new road networks are highly connected will impact the extent of habitat loss during late phases of urbanization. Prominent ongoing trends in transportation infrastructure present both threat and promise for resource impacts of cities. The electrification of transport promises higher efficiency (lower resource use) but possible rebound (more travel and sprawl). Automation of transport may exacerbate preferences for low-connectivity street-network sprawl, but may also encourage vehicle sharing and free up the large fraction of city space currently used for parking, providing opportunities for improving and reimagining use of urban space.

Regional scenarios and pathways related to nature, urbanization and sustainable development

Regional trends and informants: While urban land-cover area is set to increase, how and where urban areas will expand remains unclear. Work by Seto *et al.* (2012a) on regional influences shows that population growth, international capital flows, informal economies, land use policies, and transportation costs are all important driving factors. These influencing factors vary regionally with variable outcomes, however the regions of greatest anticipated urban expansion are Africa (particularly sub-Saharan), Asia and Latin America. Regional understandings show some shared trends, but also regional variance. Expansion in Africa is likely to emerge in the form of growth in smaller towns, while Asia shows tight coupling between urban expansion and economic shifts, and in Latin America urbanization is characterised by persistent socio-economic disparities (CBD, 2012). In contrast some regions of the Global North are experiencing urban depopulation. In their analysis of national and regional models relating to food production and urban expansion, Nelson *et al.* (2010) found variable impacts on biodiversity and ecosystem services, with various influences and trade-offs at different scales, highlighting the need to consider regional effects in local decision-making and vice versa.

Regional threats to biodiversity

Scenario modelling exploring the relationship between urbanization and protected areas and biodiversity hotspots shows alarming encroachment by cities into these key biodiversity areas, with regional variation. Güneralp and Seto (2013) tracked and modelled urban growth and demonstrate that urban areas are increasing in proximity to protected areas. McDonald *et al.* (2008) reiterate this finding and serve to refine the distances and related impacts between growing cities and adjacent, previously distant, protected areas. The most rapid urban expansion in relation to adjacent protected areas is found in China, while in South America rapid urban expansion also threatens biodiversity hotspots (critical biodiversity areas without formal protection status). Forecasts consistently show overlaps between predicted areas of rapid urban expansion and intact natural habitat and biodiversity, with protected natural assets experiencing increased pressure (McDonald *et al.*, 2008). Also evident here is the variation in regional conservation approaches. Landscape perspectives are required and in this respect we can learn much for scenario modelling from both agriculture and conservation science (Schneider *et al.*, 2012).

Global scenarios and pathways related to nature, urbanization and sustainable development

Linking urban form to sustainable development

Modelled urban scenarios show likely global trends where urban land cover expansion exceeds urban population growth, highlighting the importance at the global scale of considering biodiversity management as an imperative in urban planning. Scenarios by Fragkias *et al.* (2013) suggest that between 2000 and 2030 a 70% increase in urban population will be matched by a startling 200% increase in urban cover, and that 50% – 60% of the total urban cover in 2030 will be built post-2000. McDonald (2008) makes the incontrovertible connection between urban form and per capita resource consumption, demonstrating that urbanization has profound and prolonged implications for oil consumption and climate change, such that new urban design is critically important. Ever-improving understanding of the relationships between existing urban forms and biodiversity can be effectively used to guide future urban design and development for improved sustainability.

Economic flows and telecouplings

It is increasingly recognized that global economic forces play a significant role in determining local urban form and land-cover change. In their footprint analysis, Folke *et al.* (1997) demonstrate how Baltic cities are embedded in a web of connections that stretch far beyond their own immediate environment. These cities from the Global North import and consume from distant regions without a sense of the associated ecological impacts. Folke *et al.* (1997) go on to argue that the economic forces that govern these telecouplings fall beyond the sphere of influence of ordinary citizens. Telecouplings between cities and other areas are very common, as through the provision of water and other resources (Deines *et al.*, 2016; Liu *et al.*, 2015b; Seto *et al.*, 2012b; Yang *et al.*, 2016). The flow of financial capital itself in the form of tax havens is responsible for fuelling much distant environmental degradation, including illegal fishing (Galaz *et al.*, 2018). Understanding telecouplings can help develop appropriate policies that are more equitable and just towards pathways for sustainability (Schröter *et al.*, 2018).

Synthesis and open questions about pathways for cities

The scenarios literature reviewed above coupled with broader literatures on city impacts and ecosystem services suggest the following key elements of sustainable pathways. A central element of sustainable pathways for cities (as in SDG 11) is maintaining nature and its contributions to people within cities and their broader regions (Folke *et al.*, 2009; Russell *et al.*, 2013), and broad access to those contributions, recognizing the multiple and diverse values of city residents (Pascual *et al.*, 2017a). To achieve sustainable development objectives within cities and ultimately develop sustainable cities requires critical engagement across multiple sectors, and a keen understanding of the challenges and action required at local, regional and global scales (Schröter *et al.*, 2018).

At local scales, city-specific thresholds are crucial for retaining species and ecosystem, and for pathways to achieve acceptable levels of urban transformation (CBD, 2012). This is especially difficult in biodiversity-rich areas in developing city contexts (O'Farrell *et al.*, 2012). Linked to this are the needs to strengthen local governance in order to secure public goods, and to enable transdisciplinary planning at local levels such that sectors and departments are bridged and society and businesses are engaged. Such engagements appear fundamental to shaping sustainable urban areas and guiding local-level resource consumption patterns (CBD, 2012).

Facilitating the local realization of global targets for sustainable urban development entails recognizing the emergent differences between and within regions, and the drivers of these (Seto *et al.*, 2012a). Several drivers are key: economic policy and processes, financial underpinnings, infrastructure, investment, and population growth (Seto *et al.*, 2012a). An understanding of how these key drivers impact biodiversity areas (such as protected areas) would be instructive. In particular, cities can work to ensure that biodiversity areas do not become isolated through incompatible surrounding land uses, and that city expansion considers the degree to which encroachment towards these key regional biodiversity sites can be tolerated (Güneralp & Seto, 2013).

Cities play a central role in global pathways because increasing urban land cover affects consumption of resources, including fossil fuels, which in turn propel climate change (Fragkias *et al.*, 2013). Efforts to follow sustainable development pathways within urban areas will thus benefit from a clearer understanding of telecouplings that drive patterns of production, consumption, transportation and disposal, which in turn create and entrench the spatial and social configurations of our cities. This global understanding can then in turn be used to guide local level policy formulation where negative effects are countered and where functioning ecosystems are enhanced alongside their contributions to people (Schröter *et al.*, 2018).

5.3.3 Conclusions from the scenario review

The nexus-based analysis has revealed that no single strategy will yield sufficient transformation to sustainable development and achieve multiple SDGs. All foci suggest that successful pathways entail various measures and instruments applied in concert at local, regional and global scales. All six foci involve trade-offs between sectors and groups, such that compromises are inevitable as conflicting objectives are balanced. However, the six foci also identify potential synergies where some actions have benefits across multiple objectives and for many groups. Here we synthesize five cross-cutting insights from the scenario review, which structure section 5.4 on constituents of pathways to sustainability and are taken up also in the discussion of policy options in chapter 6.

Consumption patterns are a fundamental driver of material extraction, production, and flows, but they too are driven—by worldviews and notions of good quality of life. Addressing aggregate consumption is a central theme in pathways for all foci, but some aspects are more explicit in some than others. For example, although it is aggregate consumption that drives resource extraction and production, research on scenarios and pathways more commonly addressed per capita consumption and waste than population. Similarly, scenario studies quite commonly mentioned the preferences, value systems, and (less often) collective notions of a good quality of life as drivers of consumption, but these aspects were generally not modelled explicitly (See 5.4.1.1 about visions of a good quality of life, and 5.4.1.2 about consumption).

Behaviour change pervades all aspects of transformative change—supply chains and their ecological degradation, but also conservation and restoration. Consumption is effectively a problem of habits and behavioural norms, but so too are changes in practices of production (e.g., agroecological practices in farming), conservation and restoration. All six foci identified such behaviour change as central, but scenario studies varied greatly in the detail with which they envisioned enabling this change. Many studies appealed to a combination of incentives and awareness raising, even though the latter is generally regarded to be a weak enabler of behaviour in relation to infrastructure and consistency with value systems (See 5.4.1.3 about values, agency, and behaviour).

Inequalities and inclusiveness are key underlying problems—good planning helps, but power disparities remain an issue. Across the six foci, many studies highlighted the crucial importance of addressing inequalities and involving people in participatory planning, including the urban poor and Indigenous Peoples and Local Communities. But only a few really addressed the barriers to transformative change that arise from substantial inequities in power, e.g., in the food system, where studies highlighted the difficulties posed by corporate control of seeds, agricultural inputs, and food distribution. The same issues are likely equally important in other foci, e.g., industrial fishers and seafood distributors, but were not discussed explicitly in the studies we found (See 5.4.1.4 about inequalities, and 5.4.1.5 about inclusiveness in planning and conservation).

Larger structural issues underpin all of the above factors—telecouplings, technology, innovation, investment, education and knowledge transmission. Key elements of these structural factors were often largely implicit in pathways analyses, despite their fundamental importance to behaviour change, the dynamics of global social-ecological systems, and the SDGs. The distant effects of local actions caused by telecouplings were central to the cities focus, and implicit in all of the others (e.g., via spatially disjunct supply and demand). Many studies across several foci discussed the potential gains from the spread of beneficial technologies (e.g., the climate mitigation focus), but fewer directly addressed the challenges posed by spread of harmful technologies, or the importance and design of innovation systems that encourage benign technology. Education and knowledge transmission were often addressed in scenarios directly in the form of awareness raising for particular behavioural changes or technology transfer, leaving mostly implicit the crucial roles of education systems for ensuring well-functioning participatory processes (including political ones), and of the transmission of ILK for maintaining local capacities for stewardship (See 5.4.1.6 about telecoupling, 5.4.1.7 about technolgy, innovation and investment, and 5.4.1.8 about education and knowledge transmission).

Sustainability pathway analyses indicate the importance of governance instruments and approaches such as incentives, adaptive management, law and its enforcement. There was near universal acknowledgement of the importance of several governance instruments and approaches, but much more attention to some aspects than others. For example, many studies across all foci appealed to the importance of economic incentives, but generally from a simple behaviourist perspective (as in psychological approaches) without explicit recognition of how incentive programs also effect change by articulating values (as noted in broader social science approaches). Management and governance approaches were commonly discussed as managing several sectors together (integrated management), but much less frequently discussed for early action to address emerging threats (precaution) or managing for resilience and adaptation (these are more explicit in the freshwater realm). Many studies across all foci identified particular environmental regulations, but fewer explicitly considered consistency of monitoring and enforcement although this is often crucial and implicit in scenarios (See 5.4.2.1 about incentives, 5.4.2.2 about integrated management, 5.4.2.3 about precaution, 5.4.2.4 about governing for resilience, and 5.4.2.5 about law and its enforcement).

5.4 KEY CONSTITUENTS OF PATHWAYS TO SUSTAINABILITY: ADDRESSING THE INDIRECT DRIVERS OF CHANGE

The scenario analysis in 5.2 and 5.3 demonstrated that pathways to achieve SDGs and biodiversity targets imply fundamental changes from current trends in all of the world's regions. They are in one sense extremely ambitious, while also necessary and apparently feasible. This scenario analysis also provides key insights about the pathways to realizing the full suite of goals for biodiversity and ecosystem services, but it is not a sufficient source for such insight. Our analysis revealed that some of the issues considered in the literature as central to social-ecological transitions and transformations were largely implicit or even absent in many of the target-seeking and sustainability-oriented scenarios we consulted, such as the role of formal and informal institutions, and other indirect drivers (chapter 2). Following this insight and to characterize the constituents of sustainable pathways comprehensively, the sections below interweave evidence from the scenario analysis (5.3) with evidence from diverse literatures (including those discussed in 5.2.1).

We organize this synthesis of key constituents of pathways to sustainability via eight points of leverage for social-ecological change, and five types of interventions or 'levers' of institutional change for sustainable pathways. These key points of intervention in social-ecological systems can be thought of as 'leverage points' (Abson *et al.*, 2017; Meadows, 2009), while 'levers' are management or governance interventions to effect the transformative change that achieves the collectively agreed-upon objectives for nature and its contributions to people. Note that we use the notion of 'lever' metaphorically, recognizing that global systems—as complex social-ecological systems—cannot be manipulated as neatly as can a boulder with a stick. Rather, we use 'lever'/'leverage point' to illustrate only that these levers and leverage points offer crucial opportunities to engender changes in economies and societies towards achieving shared goals.

Second, levers and leverage points are independently important: the five levers pertain more broadly than the eight leverage points, and other tools may be needed to achieve desired changes in the leverage points. The pathways we identify involve considerable flexibility in *how* to, for instance, promote positive changes in leverage points such as consumption or inequalities. Chapter 6 provides the needed account of policy options for intervention at these specific points. Our five levers, meanwhile, are intended to suggest general and systemic interventions; they are policy tools or governance approaches that are themselves key constituents of social-ecological transitions, to be considered broadly, simultaneously addressing many leverage points and social variables. There are no governance panaceas for social-ecological sustainability (Ostrom, 2007).

Change in any of these levers and leverage points may appear difficult to achieve, but we argue that many are easier to achieve in sets. Change in one aspect may enable change in others (5.4.3 details several nation-scale case studies). For example, changes in laws and policies will enable and underpin changes in management, consumption, and other aspects of behaviour. The reverse is also true: changes in individual and collective behaviours and habits can facilitate changes in attitudes, policies, and laws. Because of these bidirectional influences, there is no one way to order the levers and leverage points. Here we present the leverage points in an order that proceeds clockwise around the outside of the IPBES conceptual framework, spiralling into institutions at the end; levers are ordered from most labile to most lasting and structural (i.e., incentive programs are most easily changed, law hardest) **(Figure 5.7)**.

The analyses of leverage points and levers are organized into three sections. The first section examines each of the identified leverage points as they relate to important dimensions of global social-ecological systems (5.4.1), while the second section discusses levers of change (5.4.2). Each subsection within starts with a statement of the leverage point or lever, followed by any needed *Background*, *Evidence* and a brief discussion of *Possible points of action* (with more detail found in chapter 6). The last section provides examples illustrating leverage points and levers in action, both via national case studies and potential alternative routes that proceed from the bottom up (5.4.3).

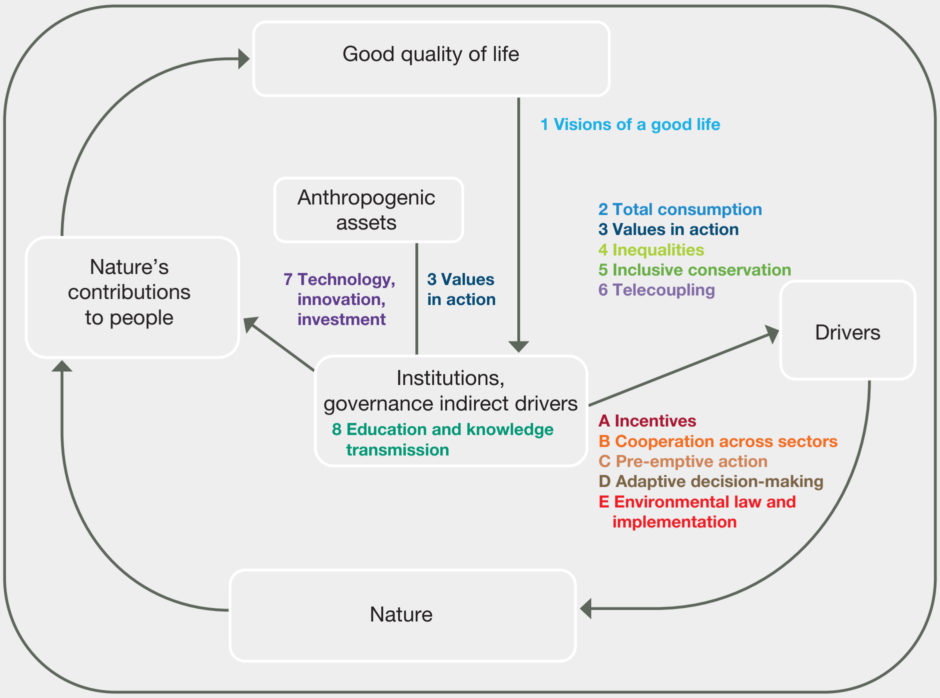

Figure 5 7 **Eight featured leverage points and five levers of transformative change toward sustainable pathways, overlaid on a simplified version of the IPBES Conceptual Framework.**

The leverage points (numbers) and levers (letters) vary in many dimensions, but each has the property that a relatively small change could effect a large change in outcomes for nature and its contributions to people. Change in one leverage point or lever can in many cases also help change others e.g., a change in visions of good quality lives (1) could greatly enable changes in consumption (2). All pertain somewhat to human formal and informal institutions, and in most cases the relationships of these institutions with other elements of the conceptual framework (in particular all five levers could be situated within the Institutions bubble, but they do pertain especially to direct drivers). Figure text for levers and leverage points differs slightly from the subsection headings, for brevity.

5.4.1 Leverage Points for Pathways to Sustainability

5.4.1.1 Visions of a good quality of life and well-being

One of the key drivers of the overexploitation of nature is the currently popular vision that a good life involves happiness associated with material consumption (5.4.1) and success based largely on income and demonstrated purchasing power. However, as communities around the world show, a good quality of life can be achieved with a significantly lower impact on natural resources and ecosystems. Alternative conceptions of a good life can be promoted without paternalism, by valuing and providing the personal, material, and social conditions for a good life with a lower material impact, and leaving to individuals the choice about their actual way of living. In this respect, the renaissance of more relational notions of well-being may be key to achieving nature-based targets. By highlighting the importance of relations to other human and non-human others for a good life we might not only contribute to decoupling consumption and well-being, but also enhance quality of life.

Background

In the academic literature, different terminologies are used to address well-being, happiness, and the good life. In general, 'happiness' refers to self-reported assessments, in which people are asked to articulate via qualitative or quantitative surveys their satisfaction with their own life. 'Quality of life' usually refers to objective indicators (such as the HDI—Human Development Index) that aggregate different data about some essential components of a dignified human life (such as life expectancy, morbidity, education & literacy, inequality). The term 'good life' is more comprehensive and includes the ancient concepts such as "eudaimonia" or "buen vivir", implying in their own way satisfaction with one's own living conditions, aspirations, and meanings, while considering collective and personal principles and virtues (see chapter 1). All these concepts (or philosophies) refer to 'agency', i.e. the ability to decide about how to live according to one's own core values (Sen, 2009). Other than preferences, which are often arbitrary and causal, core values based on deeply held beliefs and guiding principles operate as the basic points of orientation for actions and decisions. Core values can be articulated and justified to others. The concept of a 'good life' is thus linked to forms of justification and claims of justice and goes beyond immediate preferences or feelings of satisfaction.

Approaches to assessing well-being through only objective or subjective measures have generally suffered from criticism. Focusing only on resources underplays the fact that availability of resources does not ensure that they are converted into actual well-being (Nussbaum, 2003). Not only personal differences, but also environmental, institutional, and cultural conditions influence the way in which resources contribute to a good life. Focusing only on self-reported assessments gives insight into what people subjectively consider important for happiness (Layard, 2005), but, if not combined with objective indicators (Happy Planet Index; Bhutan Gross Domestic Happiness Index), it neglects the influence of external factors in determining self-assessment; it might also overlook forms of oppression (self-reported happiness can derive from ignorance of possible alternatives or entitlements, or as a coping strategy under distress). Moreover, people can decide to act according to other motives (altruism, care, etc.) against their personal happiness or advantage, thus following core values in the sense described above.

It is contested how material wealth and growth per capita correlate with (subjective or objective) well-being. While some studies show that, after a certain threshold additional wealth yields diminished happiness returns or decouple from quality of life (Binswanger, 2006; Easterlin *et al.*, 2010; Helliwell *et al.*, 2012; Jackson, 2009; Layard, 2005; Max-Neef, 1995), other recent studies contest these findings (Ortiz-Ospina & Roser, 2017; Veenhoven & Vergunst, 2014). Relative to average or aggregate income, inequality seems to have a larger negative impact on subjective and objective well-being (Oishi & Kesebir, 2015; Wilkinson & Pickett, 2010). It is widely agreed that there is no automatic or obvious correlation between wealth and well-being, but that it depends strongly on institutional, social, and cultural settings that guarantee essential conditions to achieve a good life.

Given the great diversity of conceptions of a good life and well-being, it is important to focus on the *conditions* for leading a good life rather than on the ways in which people actually (choose to) live their lives (Nussbaum, 2000, 2003; Sen, 1999). Such a focus on conditions avoids problems of paternalistic intervention (influencing or forcing people into choosing a specific conception of a good life). A plurality of options for actualization is available once the basic conditions for a good life are guaranteed. Attention can then focus on what process, group, or institution has the legitimate authority to decide what people have reason to value (Deneulin & Shahani, 2009), and to the substantial conditions for participation, including domination structures, actual access conditions, and effective 'power' to be heard and make a difference. Institutions play a key role in framing enabling conditions for a good life. Experiencing life in an environment devoid of dangerous impacts such as those associated with global warming, can be considered a 'metacondition' ('ecological functioning capability'; Holland, 2008; Page, 2007).

Conditions can be *subjective* (preferences), *objective* (material or institutional), and *intersubjective* (social or cultural) (Muraca, 2012). For example, affording shoes can be considered as a subjective condition for happiness (if one loves shoes, collects them, etc.), as an objective condition for being, say, healthy (especially in cold countries), and/or as an intersubjective condition for leading a good life in the face of others in a society, in which wearing shoes is considered a symbol for decency and reliability (Sen, 1987).

When addressing policy interventions about well-being, intersubjective conditions are often neglected, although they play a crucial role especially for change in consumption patterns. Overconsumption is often not only a result of subjective preferences, but also of infrastructural or cultural conditions. For example, if everyone else drives a sports utility vehicle (SUV), driving a small car on the highway is not only a matter of social status but also of personal safety. Having a smartphone up to date is increasingly a necessity for work, but also for access to health services or for social interactions. Such social conditions depend on cultural patterns that influence and are influenced by institutional framing.

Evidence

The orientation towards ways of living based on high material and energy flows is supported by shared values that promote happiness as based on material consumption and success demonstrated mainly via purchasing power and economic status. This model supports what has been termed an 'imperial mode of living' that arguably stabilizes the economies of developed nations while offering a hegemonic orientation to developing countries (Brand & Wissen, 2012).

Since concepts of the good life are influenced by institutional settings and social expectations, social and institutional change can foster alternative conceptions of a good life and guarantee prosperity (Jackson, 2009) with lower material impacts on resources and ecosystems (Røpke, 1999) if combined with the promotion of the fundamental conditions for guaranteeing flourishing (Jackson, 2009; Nussbaum, 2000, 2003). As evidence suggests, competition, inequality, and acceleration of the pace of life—essential components of the idea of a good life based on material consumption—in the long run lead to dissatisfaction (Binswanger, 2006; Easterlin *et al.*, 2010).

A promising path is offered by a widespread renaissance of more relational notions of well-being embodied in various initiatives, social movements, and social groups also in developed countries (see for example the Convivialist Manifesto: http://dialoguesenhumanite.org/sites/dialoguesenhumanite.org/files/meetuppage/103/convivialist-manifesto.pdf; the European Degrowth movement (D'Alisa *et al.*, 2014); or the Transition Town movement (Hopkins, 2008). In Latin America, the promotion of the old concept of "Buen Vivir" also embodies collective deliberations on the conditions of a good life for all, including the rights of nature and ecosystems to flourish. Increasing evidence also supports the conclusion that significant relationships with nonhuman nature are constitutive of a good life for many people both in developed and developing countries (Arias-Arévalo *et al.*, 2018; Chan *et al.*, 2016; Kohler *et al.*, 2018; Muraca, 2016). The use of concepts such as 'relational values' help articulate a more adequate language for why people are willing to invest time and attention to the care of ecosystems (Chan *et al.*, 2016; Muraca, 2016; also see chapter 1).

The notion of a good life that most Indigenous Peoples share is deeply relational: the relation to the land with all its interconnected human and nonhuman inhabitants constitutes their collective self-understanding as community. Livelihoods sovereignty is an essential condition to keep this bond. In Ecuador, the rights of Mother Earth (Pachamama) to preserve its condition of regeneration (a different language for biodiversity and ecosystem services) are considered as inseparable from the conditions for a good life of the people and are protected by the Constitution. The Bolivian Constitution includes the consideration of diversity not only ecologically, but also culturally, affirming the rights of the different and diverse indigenous communities in the conception of a plurinational State. These contributions of nature to notions of a good life may be under threat as access to nature—or key components of nature—are lost (Chan & Satterfield, 2016; Garibaldi & Turner, 2004; Kohler *et al.*, 2018; Louv, 2008; Miller, 2005; Nabhan & St Antoine, 1993).

Possible points of action

Governments and other institutions are responsible for enabling subjective, objective, and intersubjective conditions for a good life. Successful policies would generally target the different drivers that affect the desirability and burden of alternative ways of being: socioeconomic (such as competition-driven investment in innovations and the need for new market opportunities), structural (dominant understandings that equate economic growth with well-being), and socio-psychological and cultural (including the social relations in which humans are embedded) (Røpke, 1999).

Promoting alternative conceptions of a good life does not require paternalistic interventions: if the material, social, and personal conditions for a good life are sustained in ways that do not require a high material and energy flow, individuals have the freedom to choose alternative modes of living without significant impairing their quality of life. In this case, sufficiency would not only be an individual choice of voluntary simplicity, but also the legitimate entitlement to a sufficient lifestyle, i.e., the right to have less, to have a slower pace of life, to escape the escalating competition for success and enhancement ('hedonic treadmill'; Binswanger, 2006), without suffering a significant lack in the conditions for a meaningful and dignified life (Winterfeld, 2007). For example, if access to essential services (such as communicating with one's physician or buying a bus ticket) requires specific up-to-date technology, choosing not to use them heavily impacts access to health and mobility. Institutional framing can make the choice of a sufficient and low-impact lifestyle achievable for a large majority of the population, by eliminating burdens or negative incentives.

Improving affordable, spatially inclusive and comprehensive public transport infrastructure would expand fundamental entitlements to mobility, enabling people to embody more collective notions of a good life without substantial compromise to security, comfort and efficiency.

Regulation of planned obsolescence for technological products would shift innovation towards ecological design and long-lasting, modular products, thus increasing the freedom of choice of consumers while improving the social and environmental conditions under which electronic devices are produced. It would also in the long run affect the cultural understanding of innovation and originality while significantly reducing environmental impacts (e.g., through rare earths mining).

Expectations of increasing speed in social interactions often correlate with increasing impact on nature due to associated infrastructural needs. Policies and programs that counteract acceleration tendencies and promote spaces for solidarity, care, creativity, and democratic participation might enable the achievement of essential features of a good life and expand freedoms. Technological innovation can significantly contribute to reframing the conditions of acceptability of social behaviours as well (e.g., the "do not disturb while driving" feature on recent smartphones might reduce the expectation of immediate response to messages).

Such interventions would foster a shift—in the long run—from the role of consumers to that of users (Lebel & Lorek, 2008) without significantly impairing the capabilities of people to achieve valuable doings and beings. Supporting alternative modes of production based on peer-to-peer processes would increase local resilience, make technologies accessible and decentralized, and promote the autonomy and self-determination of local communities (Kostakis & Bauwens, 2014).

Ultimately, a fundamental condition for a good life is the possibility of deliberation and negotiation within a society. Participatory parity (Fraser, 2007) is key. This entails different social groups being able to speak in their own terms and language about their understanding of a good life and enabled to participate in the framing of its conditions (Fraser, 2007).

5.4.1.2 Aggregate consumption (a function of population, per capita consumption and waste)

Beyond improved efficiencies and enhanced production, all pathways to reducing biodiversity loss entail reducing or reversing the growth of aggregate consumption, as a function of population size and per capita consumption and waste. Per capita consumption tends to rise as income rises, putting further pressure on biodiversity. Upward trends in population growth have and will lead to further biodiversity loss and increasing numbers of threatened species. The need for transformative changes in consumption patterns is particularly pertinent for wealthier nations and people.

Background

Across 114 nations, the number of threatened species in the average nation is expected to increase by 14% by 2050 (McKee *et al.*, 2004); and increased efficiency in food production is unlikely to compensate sufficiently for the negative impact of human population growth and increasing per capita consumption on biodiversity (Crist *et al.*, 2017). Expected changes in population and income between 2010 and 2050 suggest that the environmental effects of the food system, as one example, could increase by 50–90% without substantial technological changes and dedicated mitigation (Springmann *et al.*, 2018a). Globally, decreases in consumption are thus critical, recognizing that there are significant inequalities within and between countries in consumption related to food, energy, water, and other natural resources (O'Brien & Leichenko, 2010).

Aggregate consumption is a function of population size *and* per capita consumption. An example of these effects at a fine scale is that households with fewer members tend to have higher per capita consumption, with consequences for biodiversity, especially in biodiversity hotspots (Liu *et al.*, 2003). Cities are more efficient resource-users per capita than sparsely populated areas due to economies of scale, in particular with infrastructure (EEA, 2015). On the other hand, urbanization has also been found to increase consumption at the household scale. Specifically, the ecological footprints (an index of major consumption categories at the household level; see chapters 2 and 3) of nineteen coastal cities across the Mediterranean reveals that per capita footprints are larger on average than parallel rural populations. The main drivers were found to be food consumption, transportation and consumption of manufactured goods (Baabou *et al.*, 2017). In general, the co-benefits of urban systems as both source and solution of environmental effects are not well studied.

Evidence

Aggregate consumption (the product of population size and per capita consumption and waste) is undisputably a key driver of environmental degradation (Dietz *et al.*, 2007; Ehrlich & Pringle, 2008; Rosa *et al.*, 2004). As one prime example, food consumption drives the agricultural sector (which covers 38% of Earth's surface), and is as a primary source of environmental degradation and GHG emissions (both drivers of biodiversity loss). Seventy-five per cent of that agricultural land is used for livestock production (Foley *et al.*, 2011). In particular, demand for animal source foods has more than tripled over the past 50 years due to population growth and dietary change (Delgado, 2003; Thornton, 2010). Livestock production (grazing and feedstock) is the single largest driver of habitat loss, a pattern increasing in developing tropical countries where the majority of biological diversity resides. The projected land base required by 2050 to support livestock production in several megadiverse countries exceeds 30–50% of their current agricultural areas (Machovina *et al.*, 2015). Some reduction in biodiversity loss can be offset through technological gains such as yield gains in agriculture due to intensification (Wirsenius *et al.*, 2010), but these do not yet keep pace with simultaneous growth in population and income (West *et al.*, 2014).

Changes in consumption patterns are among the most prominent elements in storylines used in scenarios that lead to achieving SDGs, including all three elements (population size, per capita consumption, and waste). The core global studies (Roads to Rio+20, Pathways to the 1.5ºC target, and Bending the Curve—5.3.1.2) all assumed relatively low stabilized global population sizes and various scenarios of reduced overconsumption and waste. More specifically, Stehfest *et al.* (2009) showed that four scenarios of dietary variants, all involving reduced meat consumption yielded diminished land-use change (and associated, non-modelled, benefits for BES) and reduced emissions and energy demand. Meanwhile, energy scenarios suggest that focusing on the energy use of sectors, not people, would lead to substantial reduction in energy demand (see McCollum *et al.*, 2012's energy efficient pathway).

These patterns in scenarios contain some important complexities but lack others. One key missing nuance in large-scale scenarios is the minimal representation of rebound effects (Jevons paradox), by which consumption often tends to increase in response to gains in efficiency in production or resource intensity, erasing some or all of the gains (e.g., LED lighting may be more efficient but enable much more lighting in total; more abundant energy may encourage greater consumption) (Alcott, 2005). Accounting for these rebound effects would make the case even clearer that ***increased production and efficiency are not sufficient, without also addressing consumption itself***. In terms of food consumption, modelled patterns often somewhat underrepresent variation within agricultural systems, and the important role dairy and foods of animal original play in childhood, maternal (during pregnancy) and elderly nutrition (FAO, 2016)(). For instance, few scenarios account for feedbacks between changing availability of protein affects local hunting or fishing (Brashares *et al.*, 2004), where wild-based and so small-scale economies, such as bushmeat provisioning, have also been identified as an important driver of biodiversity loss (Fa *et al.*, 2005; Nasi *et al.*, 2008). Terrestrial wildlife, especially ungulates, are a primary source of meat for millions globally. Wild meats are however an important source of childhood nutrition, without which an estimated 29% increase in children suffering from anemia would occur, leading to health, cognitive and physical deficits in poor households (Golden *et al.*, 2011). Virtually all models do include some level of meat and fish derived proteins. Furthermore, all models related to the role of dietary changes recognize that dietary changes, such as lowering animal protein consumption do not apply to undernourished and vulnerable populations. The general point is that lowering consumption of animal protein is important; and that variation aside, even the lowest impact of animal protein production typically exceed the impact of plant-based options (Clark & Tilman, 2017; Poore & Nemecek, 2018).

Waste is equally key. A large amount of food, including animal products, is wasted worldwide, e.g., roughly 30% in the U.S. when accounting for production through household waste (Nellemann, 2009). Wasting 1 kg of feedlot-raised boneless beef is estimated to have ~24 times the effect on available calories as wasting 1 kg of wheat (~98,000 kcal versus ~4000 kcal) due to the inefficiencies of caloric and protein conversion from plant to animal biomass (West *et al.*, 2014). Waste varies greatly between countries: food loss in India for vegetables and pork is <3 kcal per person day−1, versus ~290 kcal per person day−1 for beef in the United States. Approximately 7 to 8 times more land is required to support this waste in the United States than in India (Machovina *et al.*, 2015). Overall, because waste in the production cycle is so variable, even for the same food types and classes, producer-level monitoring and mitigation will be key to achieving more sustainable pathways (Poore & Nemecek, 2018).

Overproduction (when not discarded to prop up prices) and associated marketing can also drive consumption: if subsidies or other forces yield an oversupply of a commodity or good, this will lower prices, and consumption of those goods and their embodied resources will tend to rise. Producers can boost these effects strongly through advertising, which can yield self-reinforcing dynamics in consumer culture (Berger, 2015; Isenberg, 2017; Philibert, 1989).

Possible points of action

It is estimated that countering these driving forces would require incentives for increases in the efficiency of resource use of about 2% per year (Dietz *et al.*, 2007), and no single measure or action will be sufficient. Intensification will offset some effects of consumption in the agricultural sector, but much gain would accrue via reduction in meat consumption through demand reduction and dietary shifts (Foley *et al.*, 2011). As with all efficiencies, some rebound effects are to be expected and addressed (e.g., increased demand that follows initial gain through efficiency) (Alcott *et al.*, 2012).

An estimated 1.3 to 3.6 billion fewer people could be fed if diets shifted to lessen reliance on animal products, particularly resource-demanding ones (while maintaining the relative contribution of grazing systems) (Davis & D'Odorico, 2015). Some analyses suggest that targeting Western high-income and middle-income countries would yield the largest potential gain and focus for the environmental (and health) benefits of dietary changes at a per capita level (Springmann *et al.*, 2014). Improvements in consumption patterns can likely be achieved by reducing subsidies for animal-based products, increasing those for plant-based foods, and replacing ecologically inefficient ruminants (e.g., cattle, goats, sheep) (Machovina *et al.*, 2015). Research and development of plant-based meat substitutes is also a growing phenomena and potential solution (Elzerman *et al.*, 2013; see also Poore & Nemecek, 2018; Springmann *et al.*, 2014, 2018b).

Significant targeting of waste is also an important policy target; well tested approaches include regulations for Extended Producer Responsibility whereby producers manage the waste generated by their products (OECD, 2016).

Given the central role of advertising and marketing in boosting production, policies might seek to rein in the reach of advertising, particularly to children and for resource-intensive products. Lastly, broader changes in consumption could be triggered by promoting alternative models of economic growth (e.g., as proposed by the World Business Council for Sustainable Development, WBCSD, 2010), which may also offer higher likelihood of achieving SDGs 2, 6, 15.

5.4.1.3 Latent values of responsibility and social norms for sustainability

Sustainable trajectories are greatly enabled by context-specific policies and social initiatives that foster social norms and facilitate sustainable behaviours. An important step toward this goal would be to unleash latent capabilities and relational values of responsibility (including virtues and principles; 5.4.1.1). Such values may often be strongly held in relevant populations, but not manifest in large-scale action due to a lack of enabling conditions, including infrastructure and institutional arrangements. Because communities, the values they hold, and barriers to enacting values are all diverse and multifaceted, social norm-shifts and widespread action are most likely to stem from locally tailored programs, policies and investments.

Evidence

There is strong evidence that many populations already express values consistent with sustainability, such as pro-environmental values (e.g., Dunlap & York, 2008) and relational values (Klain *et al.*, 2017). These values manifest differently in different places (Chan *et al.*, 2016). For example, Haidt & Graham (2007) document a striking difference in moral foundations between progressive and conservative voters in the USA, and the World Values Survey reveals two major axes of difference (traditional vs. secular-relational values and survival vs. self-expression values) (World Values Survey, 2016). In both of these frameworks, values on either end of these spectra could support sustainability.

Ample evidence supports that the expression of such values is currently impeded by insufficient infrastructure and social structures (Shove, 2010). This 'social practice' strand of research demonstrates the need for explanations of collective action (e.g., issues involving greenhouse gas emissions) to go beyond the aggregate of individual people operating independently. This research suggests that the focus on individual attitudes, behaviours, and personal choice needs to be expanded to include systemic considerations, such as the role that governments play in "structuring options and possibilities" (Shove, 2010). As one important possibility, sometimes norms can be promoted in new contexts by foregrounding existing widely held norms and values, and their applicability to the issue at hand via a process called 'normative reframing' (Raymond *et al.*, 2013). Thus, notions of justice or fairness can be applied in new environmental contexts, either through normative reframing or even the creation of new norms in 'normative innovation' (Raymond *et al.*, 2013).

Extensive work on barriers to pro-environmental behaviour, which originates from an individual-focused paradigm, also often discusses two main realms of barriers: personal and collective. This work provides evidence that individual-level factors (e.g., disposition) play a role in behaviour, and it also confirms the importance of factors external to the individual (Darnton & Horne, 2013; Kollmuss & Agyeman, 2002). In short, though individual motivation is important, the problem is sometimes or often not that individuals lack motivation for action (e.g., on climate change), but rather that current infrastructure, habits, and norms are outdated and insufficient to express values already present. An example from the United States relates to personal transportation, many people report wanting a lower carbon alternative to personal vehicle travel, but their communities are designed in such a way that make other options prohibitively inconvenient and/or unappealing (Biggar & Ardoin, 2017b, 2017a; Shove & Walker, 2010).

Related to the point above, but stemming from a parallel literature, extensive behavioural economics and psychological research suggests that human decisions are heavily impacted by context and structures. There is strong evidence from a range of studies and a larger body of social sciences literature that replacement or evolution of infrastructure and social structures could nudge change in individual behaviour and also contribute to the formation of pro-sustainability habits and norms (Pallak *et al.*, 1980; Thaler & Sunstein, 2008). A fundamental idea underlying this philosophy, which has been called "liberal paternalism" because it allows free choice (liberal) but guides people (paternalistic), is that people often want to act differently than they do, and would often appreciate a "nudge" to help them act in accordance with their deeper values. One specific example would be that people wanting to purchase sustainable seafood have benefited from a green-yellow-red signaling system, especially when those signals are displayed beside the products in stores and restaurants. A more general example would be that people wanting to donate more to charity generally give more with automatic payment plans.

Additional evidence suggests that despite the responsiveness of human behaviour to existing contexts, moral belief and conviction already do transcend purely selfish action and/or more mechanical responses (e.g., of the type described by moral psychology or behavioural economics) (Damon & Colby, 2015). Learning can help people develop these responses based on morals and conviction, especially when that learning employs dialogue, reflection, reasoned argumentation, and deliberation (all of which practices are increasingly recommended by education scholars; see 5.4.1.8). A cornerstone of much moral philosophy is the idea that people can engage with complex situations and, through conscious deliberation and moral judgement, change behaviours and lifestyles. Acknowledging the aforementioned substantial impact of sometimes minor situational and contextual variables, it is helpful to also consider research into human moral choice, and how morality and moral decisions come about. Much research in this realm highlights the importance of intentional effort, deliberative discussion and thought (including in education), not as an alternative to 'nudge' approaches but as a complement (John *et al.*, 2009; Reed *et al.*, 2010).

Fifth, the burgeoning science of norms offers important insight into how to change behaviour. The science of norms considers the interplay of proximate contextual factors (e.g., what people around us are doing) and more deeply rooted social, collective understandings of "how things should be." Norm-based interventions are some of the most prevalent and effective means of changing behaviour (Miller & Prentice, 2016). As one example, household use of electricity decreases following messages about neighbors who use less electricity (the addition of a message conveying social approval/disapproval further strengthens the change; Schultz *et al.*, 2007). Norms interventions, particularly related to environmental issues, are less common in developing countries; an example from the health field is that decreases in female genital mutilation followed interventions that attended to social norms along with other aspects of local context (Cislaghi & Heise, 2018). Research on the dynamics of norms (i.e., how norms change) focuses on the need to change expectations, both about what others will do and what others think people should do (Wegs *et al.*, 2016). Legislation can affect these changes under specific conditions (e.g., when policies are not too far from aligning with existing social norms) (Bicchieri & Mercier, 2014). For most cases, however, interpersonal interaction is central to changing norms. Discussion can encourage prosocial behaviour by signalling and emphasizing desirable behaviours and norms (Balliet, 2009; Sally, 1995). Discussions also help people understand why others feel as they do and allow people to grapple with disagreement. In some situations, for instance those in which people need to be convinced, argumentation may be required (Bicchieri & Mercier, 2014). Work from a variety of fields confirms the importance of interpersonal interaction and discussion; one study, for instance, found time spent with neighbors to be strongly correlated to "environmental lifestyle" and "willingness to sacrifice", emphasizing the importance of non-kin social relationships and interactions (Macias & Williams, 2014).

For IPLCs, values of all kinds (e.g., instrumental, intrinsic, relational) are deeply intertwined with cultural and environmental contexts, and value systems are often represented in and reinforced by language. The loss of language may be associated with value deterioration or change. Many (if not all) languages codify values related to the ability to coexist with surrounding environments for hundreds or thousands of years (Davis, 2009; Maffi, 2001). These sustainability-related values may be particularly common in Indigenous and other long-standing local communities, with their strong traditional beliefs, laws, customs, culture, and affections towards nature (e.g., sacred trees, sacred animals, totems) (e.g., McGregor, 1996; Turner, 2005). As such, the loss of languages is potentially a major problem for value diversity and authenticity. In many regions, community values that support sustainable trajectories using indigenous knowledge are at risk of extinction, which results in the loss of biodiversity (Unasho, 2013). Loh and Harmon (2014) note that one in four of the world's 7000 languages are at current threat of extinction, confirming a simultaneous decline in linguistic diversity and biodiversity – approximately 30% since 1970. Extinction statistics tell the story: 21% of all mammals, 13% of birds, 15% of reptiles, 30% of amphibians and 400 languages have gone extinct (Loh & Harmon, 2014). In this sense, the value of the knowledge-practice-belief complex of Indigenous Peoples relating to conservation of biodiversity are central to the sustainable management of ecosystems and biodiversity.

Possible points of action

A particular challenge faces people participating in global supply chains (e.g., through their purchasing of goods and services), because although there might be broad and strong agreement with the notion that we humans have a responsibility to account for our impacts on the environment (Klain *et al.*, 2017), there are a dearth of options for people to do so easily, enjoyably, and affordably (Chan *et al.*, 2017b). That is, the primary option available to consumers is the purchase of certified products (e.g., Marine Stewardship Council seafood, forest-stewardship council wood products, organic food), but these are inevitably costly, limited, and complex (few consumers can keep track of and come to trust more than a few of the plethora of competing labels). Because the costliness stems partly from inefficiencies in these niche supply chains, there is potential to enable widespread action in accordance with values of environmental responsibility via credible non-tradeable offsets that enable organizations and individuals to mitigate their impacts on nature (Chan *et al.*, 2017a). A legitimate and trusted system of such offsets does not yet exist, but there are important developments and novel efforts (e.g., the Natural Capital Project's Offset Portfolio Analyzer & Locator, Forest Trends' Business & Biodiversity Offsets Programme, CoSphere).

Offsets have a potentially important role to play because they could enable people and organizations to enact values of environmental responsibility that are currently suppressed by disabling conditions, but which could potentially yield new social norms. However, to achieve that, it will be crucial that offsets avoid the problems and associated negative reputation that has plagued carbon offsetting, such that offsets convey the real and socially legitimate mitigation of diverse impacts on nature and its contributions to people (Chan *et al.*, 2017a).

5.4.1.4 Inequalities

Inequality often reflects excessive use of resources or power by one or more sectors of society at the expense of others. As societies develop and aim to 'catch up' in economic growth, inequality often emerges through control and appropriation of unequal shares of finite resources with implications for both creating unjust social conditions and loss of nature and its contributions. Therefore, addressing societal inequities is not only important for its own sake and for moral reasons, but as leverage to facilitate achievement of biodiversity goals.

Background

The world is currently experiencing increasing levels of inequality in many sectors of society, including between, within countries and across countries (Stiglitz, 2013). Although assessments of inequality often focus on income, there are many dimensions of societal inequalities such as distributive, recognition, procedural and contextual inequities (Leach *et al.*, 2018). Distributive equity refers to the distribution of costs and benefits, and questions of who gains and who loses. This is very applicable for example to the climate discussion where questions are raised about who bears the responsibility for or burdens of climate impacts (Collins *et al.*, 2016; Dennig *et al.*, 2015). This may also include discussion about unequal access to health across and within countries (Costello & White, 2001; Joshi *et al.*, 2008) or inequality in access to energy (Lawrence *et al.*, 2013; Pachauri *et al.*, 2013) and inequalities in income distribution (Alvaredo *et al.*, 2018; Piketty & Saez, 2014; Ravallion, 2014). Procedural equity refers to access and participation in decision-making processes and applies to discussion about gender inequality and representation in governance structures, education, and other spheres of society (McKinney & Fulkerson, 2015). Recognition equity refers to accounting for stakeholders' knowledge, norms and values, and this is the main driving force behind IPBES and other organisations' calls for including indigenous and local knowledges, expanding the values base and opening up to multiple forms of evidence (Díaz *et al.*, 2015; Nagendra, 2018; Pascual *et al.*, 2017a; Tengö *et al.*, 2017). Finally, contextual equity refers to deep rooted social conditions, such as gender, social structure, discrimination and historical legacies that help to explain why inequality is perpetuated and reproduced over time (Martin *et al.*, 2016; McDermott *et al.*, 2013). All these different dimensions of inequities and inequalities can apply variously to gender equity, equity between specific groups, or between vulnerable groups and between different segments of society (Bock, 2015; Daw *et al.*, 2015; Keane *et al.*, 2016; Terry, 2009).

Evidence

Global inequalities, between and within countries, include inequities in income and wealth, inequities in access to resources and other benefits, as well as inequities in who bears the brunt of global change.

Globally, income inequality is increasing while biodiversity loss continues apace (Butchart *et al.*, 2010; Dabla-Norris *et al.*, 2015). Although the mechanisms of how income inequality affects biodiversity loss are not yet articulated comprehensively, there is some indication that income inequality is positively correlated with biodiversity loss. Inequality has been associated with an increasing number of social and environmental problems (Islam, 2015; Jorgenson *et al.*, 2017; Wilkinson & Pickett, 2010). Several studies suggest some initial hypotheses for the observed negative coarse-scale correlations between biodiversity and inequality (Holland *et al.*, 2009; Mikkelson *et al.*, 2007; Mikkelson, 2013). Here income inequality, measured using the Gini index, is correlated positively with threatened species, suggesting that inequality may exacerbate biodiversity loss. It also appears that a psychological acceptance of inequality (as measured by the social domination orientation) is negatively correlated with a variety of environmental actions and behaviours, and that this negative relationship is stronger in nations characterized by societal inequality (Milfont *et al.*, 2017).

More broadly however, inequality is seen as resulting from broader structural issues. In this way, unequal access to incomes, resources, consumption and other forms of inequality are symptoms of larger structural configurations related to power asymmetries and political influence (Cushing *et al.*, 2015; Pieterse, 2002). Some of explanations of this assertion include the existence of phenomenon such as 'ecologically unequal exchange', which is a structural mechanism allowing for more developed countries to partially externalize their consumption-based environmental impacts to lesser developed countries (see chapter 2.1; Jorgenson *et al.*, 2009). While there are some nuances to this suggestion (Moran *et al.*, 2013), there is evidence showing unequal consumption patterns between developed and developing countries (Wilting *et al.*, 2017), and 'trade of biodiversity' from developing countries to developed countries (Lenzen *et al.*, 2012). For example, there is evidence suggesting inequalities in access to health (Costello & White, 2001; Joshi *et al.*, 2008), energy access (Lawrence *et al.*, 2013; Pachauri *et al.*, 2013), climate change and other environmental burdens and responsibility (Collins *et al.*, 2016; Dennig *et al.*, 2015), income distribution (Alvaredo *et al.*, 2018; Piketty & Saez, 2014; Ravallion, 2014), between countries, individuals, genders and other socially differentiable segments of society (Aguiar & Bils, 2015; Bebbington, 2013; Chaudhary *et al.*, 2018; Lau *et al.*, 2018; Piketty & Saez, 2014).

Possible points of action

There are increasing numbers of suggestions and solutions for addressing inequality in society. For example, the concept of 'common but differentiated responsibility' has taken root in multinational agreements, is now a principle within the United Nations Framework Convention on Climate Change (UNFCCC). It acknowledges the different capabilities and differing responsibilities of individual countries in addressing climate change (Rajamani, 2000; Stone, 2004). Given different countries' historically different responsibilities and benefits in use of and access to resources, this principle could be applied more broadly to other spheres of biodiversity management.

Within nations, there are other solutions to inequality such as United Nations Development Programme's Inclusive Growth (UNDP, 2017). Others still advocate for universal provision of services including universal health care, universal education, basic social services, and regressive taxation. One of these universal provisions that is gaining traction is universal basic income (Lowrey, 2018).

5.4.1.5 Human rights, conservation and Indigenous Peoples

Sustainable trajectories that achieve biodiversity and Sustainable Development Goals need to maintain or enhance ecosystem services on which livelihoods depend as concerns Indigenous Peoples and land-based (and often poor) people living in or adjacent to all classes of protected areas. Achieving large-scale engagement of Indigenous Peoples and Local Communities (IPLCs) in protected areas governance entails (a) recognition of and compensation for historical wrongs and transgressions of rights in conservation contexts; (b) IPLC-led planning, decision-making and consent (which is significant and robust); and (c) connection of local efforts with larger connected landscapes/seascapes to enable the continued benign use of ecosystem services in broader landscapes and seascapes. Human rights are linked to but not inclusive of the rights of nature across these considerations.

Evidence

Some conservation efforts have led to Indigenous Peoples and Local Communities being displaced from traditional territories and deprived of access to resources essential to their livelihood (Agrawal & Redford, 2009; West & Brockington, 2006; see also chapters 3 and 6). This was true across many colonial administrations wherein reserves were often created as hunting reserves or settler communities (Griffiths & Robin, 1997; Neumann, 1998). These reserves impinged upon forest and land-dependent communities (Duffy *et al.*, 2016). There are also reports of similar patterns of restrictions and conflicts with contemporary pastoralists (Holmern *et al.*, 2007) and swidden agriculturalists (Harper, 2002). As conservation efforts have escalated in the contemporary period, this pattern has continued, with some exceptions (Davies *et al.*, 2013). International organizations in the last two decades have come to recognize that the involvement of local people is an essential prerequisite of any attempt to achieve better conservation and natural resource management (Kakabadse, 1993; McNeely, 1995). However, there have been ongoing reports of violent and militarized conservation actions including shoot-to-kill orders issued for poachers (Lunstrum, 2014). Recent examples come from the USA, Cambodia and southern African countries (Ramutsindela, 2016), including cases where relocation has failed and violence has escalated as a partial consequence (Hübschle, 2016).

In many countries, both in Global North and South, the processes of allocating land rights are still a work in progress. People with legitimate and historical rights to territorial use and jurisdiction have often had difficulty gaining recognition of these rights in processes of land allocation. Misidentifying people as stakeholders rather than rights-holders has often enabled human rights abuses by lessening the obligations of duty bearers (those responsible to protect and enable viable conditions such that human rights are ensured) (Alcorn & Royo, 2007). Failure to recognize the presence and role of historical wrongs has often deepened or exacerbated tensions about or the creation of just forms of conservation (Chan & Satterfield, 2013). This has included histories of displacement often linked to 'fortress conservation' (Büscher, 2016), forced relocation and loss of livelihoods (Brockington & Igoe, 2006), colonial legacies, transgression of treaty rights, and failed restitution for historical losses (Colchester, 2004). The designation of protected areas without meaningful involvement of those most affected (Hockings *et al.*, 2006) has been widespread, so much so that some populations are not aware that they are living within a designated protected area and that conditions of use have thus changed (Sundberg, 2006).

Pressure from national and international organizations related to human rights and to conservation has placed pressure on policymakers in countries with rich biodiversity, sometimes with undesirable effects. Even attempts to achieve conservation through community-based management have not always fully addressed the fundamental rights of local people, even in better designed systems such as those known as community-based conservation (Berkes, 2004; Campbell & Vainio-Mattila, 2003). Cernea and Soltau (2006) have documented cases where conservation has deepened poverty and food insecurity as a result of restrictions imposed on resource use, most acutely in cases of forced relocation or involuntary resettlements. Sachs *et al.* (2009) have documented cases where a disproportionate conservation burden has been placed on already poor and marginal communities thereby increasing transitions into more severe forms of poverty.

The loss or degradation of social status has also accompanied conservation activities, often due to the relocation of peoples to hostile host communities (Martin, 2003) or the stigmatizion of some peoples because their land-use practices are deemed destructive by conservation agents (Bocarejo & Ojeda, 2016). Compensation for losses directly attributable to conservation (e.g., due to loss of lands, or loss of resources or income as the result of human-wildlife conflicts) have often been insufficient (Cernea & Schmidt-Soltau, 2006) or have failed to recognize losses most meaningful to impacted communities (Witter & Satterfield, 2014). Communities have often waited far too long in far too compromising circumstances for promised relocation packages when being moved to improve the status of parks and protected areas (Hübschle, 2016). Lastly, when conservation efforts have been poorly executed due to problems of governance, corruption, or in areas with histories of war and armed conflict, violent and militarized conservation has often ensued and harmed human and nonhuman communities (Smith *et al.*, 2015).

Given the vast lands over which IPLCs exercise traditional rights, recognizing land rights and partnering with Indigenous Peoples could greatly benefit conservation efforts (Garnett *et al.*, 2018). According to Garnett et al. (2018), Indigenous Peoples either traditionally own, manage, use or occupy at least a quarter of the global land area, constituting approximately 40% of land that is currently protected or ecologically intact. IPLCs frequently have a rich set of relational values regarding nature and their interactions with it, and some of these are consistent with conservation, although often not as it has been practiced historically (through exclusion) (Chan *et al.*, 2016; Pascual *et al.*, 2017a). Involving IPLCs justly and appropriately in conservation could help them manage other pressures, such as resource extraction, in a way that meets both local and global needs.

Possible points of action

Recent innovation among conservation organizations has seen investments in engaging local communities in exploring future scenarios to achieve conservation and development, thus involving communities at an early stage of conservation and sustainable development programs (Boedhihartono, 2017; Clarke, 1990; Curran *et al.*, 2009; chapter 6).

Needs remain, however, for measures to directly and indirectly address enduring negative consequences of conservation for local and Indigenous Peoples. Improved forms of community-based conservation might ensure that the rights of nature do not supersede human rights (Hockings *et al.*, 2006). For instance, conservancies established in southern Africa have enabled local decision-making to be sustained across decades (Boudreaux & Nelson, 2011; Tallis *et al.*, 2008). Many countries are beginning to return land and forests to local communities and indigenous groups. Notable successes have been achieved in the last decade, and wider adoption of such programs for forests and biodiversity conservation could address the issues raised here (Adams, 2001; Boedhihartono, 2017; Sayer *et al.*, 2017).

Adaptive management (5.4.2.4) is viable when people are well integrated into the social-ecological system being conserved, and distribution of economic and social benefits contribute to improve the lives of IPLCs (Berkes, 2004; Infield & Namara, 2001). There are examples of successful action drawing on traditional ecological knowledge and practice, which have been combined with western concepts of conservation to produce multi-disciplinary management outcomes (Gadgil *et al.*, 2000; Huntington, 2000).

Enabling local definitions and targets for nature's contributions to people is also key, especially those that go beyond market measures and enhance well-being (Sandifer *et al.*, 2015). Working with locally-defined compensation and resettlement planning can help improve or restore livelihoods and development opportunities (Bennett *et al.*, 2017; Vanclay, 2017). Compensation for crop losses can also improve support for conservation initiatives and is being widely used, though challenges remain (Karanth & Kudalkar, 2017; Nyhus *et al.*, 2005).

In the rare instances where relocation appears necessary, fairness might dictate the suspension of processes if they cannot be realized well and fairly in an appropriate time frame (Hübschle, 2016). Strong stances against militarized and armed conservation will help restore deeply eroded people-park relations and 'de-criminalize' livelihoods (Duffy *et al.*, 2015).

Schemes such as payments for ecosystem services (PES) are most likely to succeed in conditions where livelihoods are already relatively secure, and payments are supplemental and not a replacement for income or food security (Pascual *et al.*, 2014).

The social complexities of landscapes can be integrated when designing compensation schemes for conservation at community levels (Wunder *et al.*, 2008). It is inevitable that trade-offs will occur between biodiversity and ecosystem service goals (chapter 2.3), but these trade-offs can be made fairly if addressed explicitly and democratically (Borrini-Feyerabend *et al.*, 2013).

Last, Indigenous Peoples and Local Communities can be integrated, along with other actors, in landscape-level governance through the recognition of both ancient practices and innovative mechanisms. The relationship between human activities and the environment also creates unique ecological, socioeconomic, and cultural patterns, and governs the distribution and abundance of local species, which are often described as cultural landscapes in western society (Farina, 2000; Plieninger & Bieling, 2012). Exemplar practices exist in other parts of the world that represent harmonious interactions between humans and the nature such as Satoyama and Satoumi of Japan, Pekarangan (homegarden) of Indonesia, Chitemene of Zambia, Malawi, and Mozambique, and are now collectively described as 'Social-Ecological Production Landscapes and Seascapes (SEPLS)' (Gu & Subramanian, 2014; Takeuchi, 2010). Similarly, the framework and designation of the Globally Important Agricultural Heritage Systems (GIAHS) by FAO since 2002 and the International Partnership for the Satoyama Initiative (IPSI) since 2010 (Box 3.1, chapter 3 for more detail) aims to identify and improve recognition about remarkable land-use systems and landscapes that have long provided various ecosystem services while contributing to biodiversity conservation and maintenance of Indigenous and local knowledge (FAO, 2010; Lu & Li, 2006; Nahuelhual *et al.*, 2014).

5.4.1.6 Telecouplings

Achieving global sustainability goals will likely require a targeted focus on the distant effects of local actions (telecouplings, such as spillover effects). Many existing environmental policy frameworks enable jurisdictions to meet targets by externalizing impacts to other jurisdictions (e.g., national greenhouse gas emissions and water use can and have been reduced in part by importing GHG and water-intensive agricultural commodities rather than producing them). While these allowances may have benefits, global sustainability will require assessing, addressing, and closing these loopholes.

Background

Systems in distant places across the world are increasingly interconnected, both environmentally and socioeconomically. The term telecoupling was created to describe socioeconomic and environmental interactions between multiple coupled systems over distances (Liu *et al.*, 2013). The concept of telecoupling is a logical extension of coupled human and natural systems because it connects distant systems instead of just studying individual systems separately or comparing different systems.

Telecoupling is an umbrella concept that encompasses many distant processes, such as migration, trade, tourism, species invasion, environmental flows, foreign direct investment, and disease spread. It expands beyond distant socioeconomic processes such as globalization by explicitly and systematically including environmental dimensions, and expands beyond distant environmental processes such as teleconnection by explicitly and systematically including socioeconomic dimensions simultaneously. As such, telecoupling emphasizes reciprocal cross-scale and cross-border interactions (e.g., feedbacks). It also helps to better understand interactions among multiple distant processes (Liu *et al.*, 2015a). Many telecouplings have existed since the beginning of human history, but their speed is much faster, their extents much broader, and their impacts much larger than in the past. Furthermore, current telecouplings occur in an entirely new context with many more people and more tightly constrained resources than ever before. Telecoupling can affect biodiversity and nature's contributions to people in distant locations and across local to global scales, with profound implications for the Aichi Biodiversity Targets, Sustainable Development Goals, and the Paris Agreement.

Spillover effects have been largely overlooked. For example, for international trade, the focus has been usually on impacts on trade partners. Several studies have reported spillover effects (also called offsite effects or spatial externalities) (e.g., Halpern *et al.*, 2008; van Noordwijk *et al.*, 2004). Placing spillover effects under the telecoupling framework can facilitate holistic understanding and management of the effects, as it helps to not only uncover the effects, but also connect them with causes and agents as well as flows across all relevant systems.

Evidence

As illustrated in Supplementary Table 5.4.4, many studies have demonstrated impacts of telecouplings on nature and nature's contributions to people. International trade has substantial impacts on ecosystem services and biodiversity in exporting countries (Lenzen *et al.*, 2012). Traditional trade research has focused on socioeconomic interactions between trade partners at the national scale, with some separate studies centered on environmental impacts (e.g., DeFries *et al.*, 2010; Lambin & Meyfroidt, 2011). More recently, studies have also showed that patterns of international investments through tax havens also have a direct impact on biodiversity loss in commodity-producing regions such as the Amazon (Galaz *et al.*, 2018). Such impacts result from land conversion from natural cover such as forests to crops (Brown *et al.*, 2014), or from pollution of water or air. It is clear that importing countries obtain environmental benefits (e.g., land allocation for biodiversity conservation and restoration rather than food production) at the expense of environmental degradation in exporting countries (Galloway *et al.*, 2007; Lenzen *et al.*, 2012; Moran & Kanemoto, 2016). For example, imports of food and other goods often have associated ecological footprints in producing regions (MacDonald *et al.*, 2015).

Spillover effects occur all over the world. These effects can be positive or negative, socioeconomic and/or environmental. They can be more profound than effects within the systems being actively managed. Evidence so far indicates that spillover effects are largely negative, such as degrading distant biodiversity, ecosystems and ecosystem services. In fact, much of the environmental impacts in many nations stem from activities driven by distant demand (e.g., through the production of goods for export; Halpern *et al.*, 2008; also see 5.4.1.2). Spillover effects are so prevalent that even policies intended to enhance regional or national sustainability can be perverse by shifting pressures to other

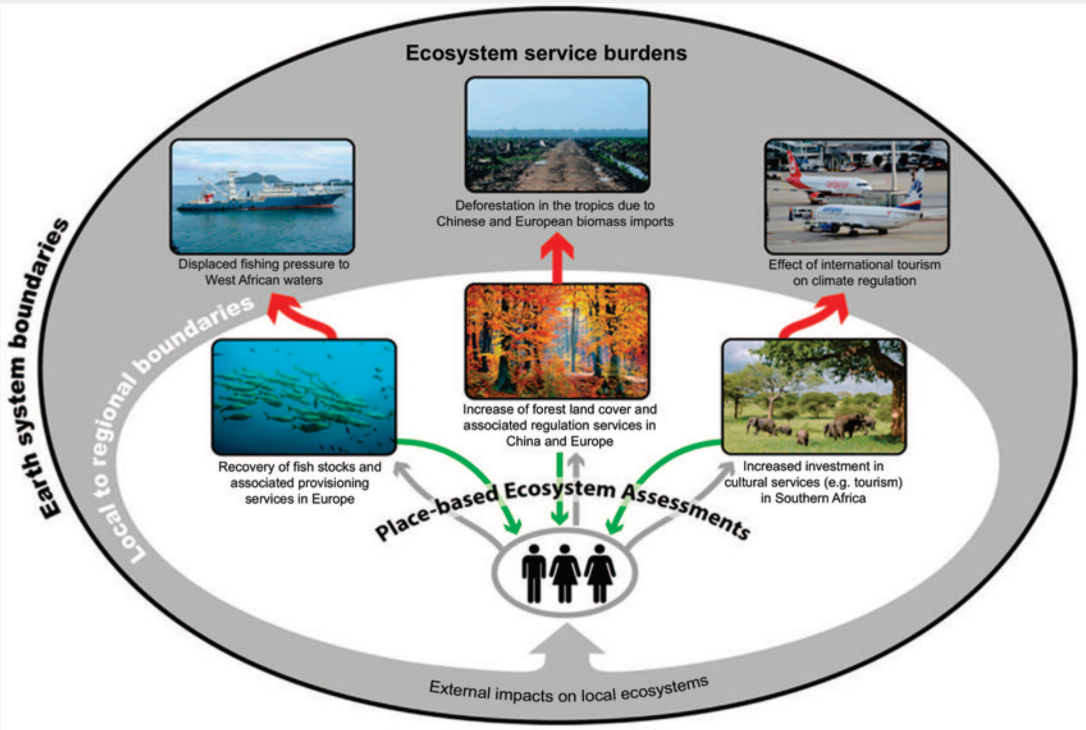

Figure 5 9 **Examples of telecoupling effects, in this case via unintended consequences associated with place-based ecosystem assessments.**

Current ecosystem services assessments focus on the benefits, trade-offs and synergies provided by ecosystem services within a delimited (often jurisdictional) boundary (green arrows) and the impacts that human activities have over such ecosystem services therein (grey arrows). Ecosystem assessments thus tend to overlook off-stage ecosystem service burdens (negative impacts on ecosystem services elsewhere; red arrows) of place-based management decisions and their feedbacks (e.g., due to climate change, bottom arrow re-entering the smaller white ellipse). Figure from Pascual *et al.* (2017b).

places (Pascual *et al.*, 2017b). Those other places may have lower environmental standards (Liu & Diamond, 2005) but richer biodiversity. For example, Sweden reduced rates of logging in Swedish forests, which increased imports from countries with greater forest biodiversity. Sweden also reduced oil use by substituting biofuels derived primarily from Brazilian sugar cane ethanol (Bolwig & Gibbon, 2009).

Even conservation efforts can generate negative spillover effects **(Figure 5.8)**. To conserve Amazonian forests, two supply-chain agreements (i.e., the Soy Moratorium and zero-deforestation beef agreements) have been implemented in the Amazon. Their implementation has substantially reduced deforestation in the Amazon but increased deforestation in the Cerrado (e.g., a 6.6-fold increase in Tocantins State of the Cerrado) (Dou *et al.*, 2018). The US and European Union countries implemented biofuel mandates to reduce their domestic carbon footprints, but these significantly changed land use and increased carbon footprints elsewhere (e.g., Africa, Asia) (Liu *et al.*, 2013).

Possible points of action

International agreements such as the Convention on International Trade in Endangered Species Flora and Fauna (CITES) and Reducing Emissions from Deforestation and Forest Degradation (REDD+) deal with distant interactions (e.g. trade), but could do so more effectively (Liu *et al.*, 2013). For example, telecoupling effects could be systematically integrated into processes of evaluating and revising the Convention and REDD+. Parties who are responsible for telecoupling effects can be identified and held accountable for negative effects (e.g., providing payment or compensation). New agreements may be needed to incorporate telecoupling effects.

Trade policies could be refined to disincentivize trade that entails negative spillover effects. Policies might restrict imports of products whose production entails large environmental damages (perhaps in part because the exporting country has very low environmental protection standards; Liu *et al.*, 2016). For example, the EU's Forest Law Enforcement, Governance and Trade (FLEGT, http://www.euflegt.efi.int/) bans the import of illegally harvested timber as a step to reduce spillover effects, which could be applied to other sectors. Such policies could be designed to raise standards by providing some assistance for nations lacking sufficient environmental governance regimes without punishing nations already suffering from extreme poverty.

Conservation scientists, policymakers and practitioners can also aid global sustainability by considering telecoupling effects in the design and evaluation of conservation policies, paying attention to negative effects outside focal conservation areas. Analyses of outcomes of conservation policies could include spillover effects in addition to the effects on the system in question.

5.4.1.7 Sustainable technology via social innovation and investment

Pathways to a desirable societal future entail a regime change first towards technologies that reduce environmental impacts and then towards those with net-positive impacts. These technological and social innovations must be proactive (not only reactive) and go well beyond the scope of traditional environmental protection policies. A sustainable economy fosters socio-technological systems that maintain, support and apply ecosystem services and biodiversity through different forms of nature-based solutions, including by galvanizing private, but public welfare oriented, investment in nature.

Background

"Technology" is a container term for various approaches to enhance human performance. Scientific assessments of technology neither idealize nor demonize it from an environmental perspective, but consider it as an ambivalent means of achieving particular goals (see, e.g., Davies, 2014; Walker & Shove, 2007).

Whereas technological development and innovation-friendly economies were long combined with a belief in the superiority of technological civilization over nature, insights about the indispensability of ecosystem services and their cost-effectiveness (e.g., Chichilnisky & Heal, 1998) have produced new expectations of technological innovations (see Geels *et al.*, 2015). Even though technological progress cannot be considered a panacea for global sustainability problems, it can contribute to overcoming sustainability challenges under particular circumstances. First, precaution can contribute to minimize or prevent negative or ambivalent outcomes of technologies (see 5.4.2.3; Renn, 2007). Second, shedding past dependencies on unsustainable or less-sustainable technologies contributes to promote innovations and spur new economic opportunities while avoiding pathways that collectively pose non-negligible risks of irreversible effects in ecological systems (Foxon, 2007). Third, ensuring that technological enhancements and resulting efficiency do not stimulate increases in new types of consumption of unsustainable goods or services (Allan *et al.*, 2006; Dimitropoulos, 2007; Herring & Roy, 2007; Lambin & Meyfroidt, 2011).

Industry and businesses are major drivers of ecosystem change. Such positioning highlights the potential for their role in reducing these impacts, which must go beyond marginal improvements (Scheyvens *et al.*, 2016). Earlier sections of this chapter (5.4.1.1, 5.4.1.2) address the needed decoupling of consumption from well-being. Innovations in technology and its usage can play a key role here. Beyond technology, innovation in business models and accounting procedures are central to incorporating environmental externalities into economic decisions. Furthermore, cross-sectoral partnerships and collaborative efforts (e.g., public-private impact investments for public benefit, and multi-stakeholder platforms for commodities that exist for palm oil, sugar, cotton, soy and rubber) facilitate implementation and mainstreaming in business and practice (Dyllick & Hockerts, 2002). Healthy skepticism about the execution of these is merited to guard against greenwashing (see Dauvergne & Lister, 2013), and effective design incorporating monitoring, adaptation and commitment to continued improvement can ensure real on-the-ground impact—but such efforts take time.

The particular role of the private investment sector in supporting sustainable development innovations is subject for debate, both in terms of the needed capital for technological development, and realization of alternative financial mechanisms. Historically, governments fund initiatives that generate public welfare goods, or devise policy and regulation to promote investment or facilitate growth in certain sectors, as has been seen with subsidies (e.g., 5.4.2.1). The scale of transformation and investment required to achieve the Sustainable Development Goals is not possible through government action alone (see SDG 17 on partnerships). Impact investing is a rapidly growing financial mechanism where private and public-private arrangements seek to generate both economic and social returns (Oleksiak *et al.*, 2015). Such investments may come in the form of direct support of a business or project, indirectly through funds managed by an intermediary, or green or social impact bonds. Governments and foundations are often key partners whose participation helps leverage capital from private sources, creating a multiplier effect, though questions remain as to how such arrangements can be implemented in the conservation sector when an existing commodity (such as agriculture or fisheries) is not present (Olmsted, 2016).

Evidence

Socio-technological innovations play a key role for transformations towards sustainability. From the scenario reviews and nexus analyses we know that technological advances in the food system and agriculture are central to feeding the world's future population and enhancing the conservation and sustainable use of nature (5.3.2.1) and to improving water quality and water use efficiency and increase storage (5.3.2.4). Energy production from various bioenergy systems as well as climate change adaptations depend on further socio-technological developments (5.3.2.2). Resourcing growing cities while maintaining underpinning ecosystems and their biodiversity is a complex socio-technological challenge across spatial and social scales (5.3.2.6).

Responsible investment in industries that directly influence natural resources and assessment metrics that go beyond short-term economic profitability will be critical to achieving the nature-related SDGs in particular. Given the broad scope of socio-technological systems, such responsible investment strategies can contribute to the emergence of a new techno-economic paradigm of sustainability (Perez, 2002), if incentives and regulations are reconfigured according to the socioecological underpinnings of the global economy (5.4.2.1-5). First steps have already been achieved by acknowledging that unsustainable technology poses large and potentially unforeseeable risks to the ecological embeddings of societies (Altenburg & Assmann, 2017). Though not expanded upon here, these processes need to address cultural diversity, social justice and public interests (see 5.4.1.5; Beumer *et al.*, 2018).

Transformations of various sectors (including energy technology, transportation, and built infrastructure generally) are beginning to attend to climate change considerations but have yet to address as mainstream a comprehensive suite of biodiversity and ecosystem service considerations (CBD, 2010; Cowling *et al.*, 2008); if they are not addressed directly, such nature-related considerations are likely to be further undermined by technological and sectoral evolution (Gopalakrishnan *et al.*, 2017). Increasing returns from investments in socio-technological niche innovations entail increasing risks of promoting less sustainable technologies and/or institutions, since already funded projects are treated preferentially at the expense of potentially superior alternatives (Foxon, 2007).

The 'rebound' of efficiency gains can be tackled in the transition phase of an incremental innovation by taxation, regulation or other impulses for consumption change (see, for example, Herring & Roy, 2007). Here, sociocultural framings, norms, worldviews and relational values influence the outcomes of socio-technological innovations enormously. Nevertheless, these factors remain largely overlooked in studies on sustainable socio-technological transformations (see Beumer & Martens, 2010).

Socially responsible and impact investing sectors are growing rapidly (GIIN, 2017), though environmental and conservation projects represent a fraction of impact investments; and impact investments currently represent a tiny share of global private capital markets. The limited application to date in the conservation sector is due to a lack of investable projects at scale, as well as challenges assessing and attributing impact in complex ecological systems (Olmsted, 2016). While there are a few large and headline grabbing arrangements, such as the Seychelles debt swap that will result in 400,000 km^2 of marine protected areas in the coming 5 years, such outcomes take years of negotiation and involve an array of public and private partners (NatureVest, 2018). Impact investments need not be so complex, but such examples highlight the potential scale of impact.

Possible points of action

Socio-technological sustainability innovations can be stimulated by incentives (e.g., Costello *et al.*, 2008; Mulder *et al.*, 1999; see also 5.4.2.1), but can also be initiated in real world experiments (Liedtke *et al.*, 2015; Nevens & Roorda, 2014; see also 5.2). Technological enhancements in companies can be supported by new innovation methods (Gaziulusoy *et al.*, 2013). Furthermore, implementation of a precautionary approach encourages proactive orientations towards sustainability in socio-technological innovation processes (Leach *et al.*, 2010).

Since affordability is a key to diffusion of new technologies (e.g., Mazumdar-Shaw, 2017), diverse financial instruments, including public financing and sharing technologies, contribute to overcoming unsustainable socio-technological systems rapidly (Foxon & Pearson, 2008; Stirling, 2008; Technology Executive, 2017). Public deliberation and transparent decision-making which involve experts, stakeholders and interested citizens generates social robustness of envisioned changes (Bäckstrand, 2003) and helps to avoid technological and institutional dependencies (van den Daele, 2000).

Every transformation process in which new technologies are established generates winners and losers. This is not only true for species (Egli *et al.*, 2018), but also for groups and individuals (e.g., O'Brien & Leichenko, 2010). Blockades to sustainable socio-technological solutions and lock-ins might be considered as strategies for avoiding losses of socioeconomic status. Innovative changes in technological policy and regulation and in incentive structures could deepen and accelerate steps towards sustainable socio-technological systems by simultaneously addressing both the demand for and supply of innovation (Jaffe *et al.*, 2005).

While there has been increased emphasis on sustainability reporting, and efforts such as the Global Reporting Initiative aim to streamline and facilitate reporting, climate metrics receive significant attention and the lack of emphasis on ecological systems is of particular concern (Milne & Gray, 2013). A study of corporate commitments to reduce deforestation highlight the challenges to meeting targets due to obstacles including leakage, lack of transparency, traceability, and selective adoption (Lambin *et al.*, 2018). These authors and others recommend increasing partnerships and arrangements between NGOs, businesses, and governments to co-create solutions and work to reduce impacts. The emergence of legal arrangements to loosen profit-maximizing constraints of corporations have promoted social business and investments in long-term sustainability that may not have been viable previously. As consumers and investors demand transparency, communication of impact and information-sharing can hold organizations accountable. Coordinating efforts across the public and private sector can help develop relevant policy, regulation, and incentives that provides stability and confidence for business and investors in new technology and innovation (e.g., Dauvergne & Lister, 2012). Corporate targets can incentivize innovation in supply and value chains (e.g., improving transparency with new technologies). Effective transformation on the ground may require national level intervention, for example, policies to support small producers who may not otherwise be able to transition as quickly or effectively. Voluntary public commitments permit early movers to demonstrate a business case for sustainable transitions, which can be bolstered by public sector support (e.g., Tayleur *et al.*, 2017). Full-cost accounting and policy shifts including changing accounting rules to include natural capital as an asset class have been shown to facilitate long-term investment in ecosystem services (Municipal Natural Assets Initiative, 2017).

5.4.1.8 Education and transmission of indigenous and local knowledge

Education and knowledge transmission are often heralded as a route to sustainability through maintenance or change in behaviours and attitudes, but their role in sustainability is even more fundamental, as a precursor to well-functioning societies. Further, education will only serve either role if conceived much more broadly than as imparting information. Rather, education that leads to sustainable development and enduring change in knowledge, skills, attitudes, and/or values builds from existing understandings, fosters social learning, and embraces a "whole person" approach. Environmental education can enhance values such as connectedness, care, and kinship. Transmission of indigenous and local knowledge can serve all the roles above, including maintaining invaluable knowledge and experiences about ecological processes, but it is also a keystone to cultural integrity and the maintenance of collective identity.

Evidence

Education, as the broad transmission of knowledge and capabilities, is widely recognized as essential for stable, well-functioning societies (Nussbaum, 2000; Otto & Ziegler, 2010; Sen, 1999). Thus, education—*in and of itself*—is a crucial precursor of sustainability (Sachs, 2015). Though education systems have sometimes served to inculcate particular norms and attitudes (King & McGrath, 2004), some educators and scholars have for centuries recognized and taken steps to deal with the inherent ethical complexities of teaching to develop engaged citizens (e.g., Dewey, 1975; Hug, 1980).

A brief yet crucial point is the demonstrated importance of education for girls and women. Increased rates and quality of education for girls and women correlate with higher levels of gender equity and lower birth rates, both of which are components of pathways to sustainability (UNICEF, 2003; see also 5.4.1.2 and 5.4.1.4).

Beyond the crucial importance of indigenous and local knowledge for cultural integrity and identity, ensuring the transmission of this knowledge and practices is key to sustainable pathways. Over millennia, IPLCs have developed and integrated invaluable knowledge and experiences about ecological processes, environmental management, production systems, as well as institutions supporting the sustainable use of resources (Nadasdy, 2007; Taylor, 2009; Tuck *et al.*, 2014; Turner, 2005; Vickery & Hunter, 2016). Many landscapes around the world, and much global agrobiodiversity heritage, depend on the knowledge and cultural memory held by IPLCs and other farmers, hunters, fishers, foragers, herders, and pastoralists, etc. Continued transmission of these forms of knowledge in varied and culturally appropriate ways (Cajete, 1994) maintains alternatives for managing landscapes and seascapes sustainably (5.3.2.3; 5.4.1.5).

Emerging insights from western literatures on education appear to be converging with lessons from indigenous and local knowledge transmission. As a first example, research demonstrates that the "deficit model" of education and communication, which assumes that people would think and act differently if only they had the right information, is rarely effective at creating lasting attitudinal or behavioural change (Dietz & Stern, 2002; Kollmuss & Agyeman, 2002). More effective educational approaches—those that are more likely to foster fundamental and long-term change in knowledge, skills, attitudes, and/or values—encompass prior knowledge (e.g., existing understandings), social interaction (e.g., interpersonal relationships and collective learning), and affective as well as cognitive dimensions (e.g., emotional responses to what is learned; Heimlich & Ardoin, 2008; Wals, 2011). Based on these findings, fields related to environmental education, including nature conservation education and education for sustainable development, have moved away from an "information delivery" model to more integrated models that collaboratively explore the intricate links between environmental and social equity and empower learners as change agents.

Broad education and knowledge transmission literatures have identified that effective education, including that for sustainability, involves two interrelated components: process and content. The former is crucial, but often overlooked. Process involves the ways education is carried out, in other words, the approaches and how teaching and learning occur. Diverse theories of learning emphasize different aspects of the learning process (Merrian & Bierema, 2013). A few commonalities emerge, and three aspects of learning theory (detailed below) are particularly relevant to issues of sustainability.

The first commonality of learning theory is the importance of recognizing and responding to learners' context, experience, and existing understandings. A helpful metaphor here follows directly from constructivist learning theory, understanding is constructed from and upon "blocks" of what is already known and if existing understandings must be changed, that must be dealt with, not ignored. In sustainability-related education, this concept is paramount, it coincides with the importance of locally based solutions that account for diverse contexts.

A second commonality is the role that social interaction plays in learning. This focus on social dimensions of learning takes two primary forms: the idea that much learning occurs via observing others (Bandura & Walters, 1977; Rogoff *et al.*, 2003) and the idea that learning occurs collectively, in and by social groups (Rogoff, 1994; Wals, 2007). These social interactions may be particularly important for the transmission of indigenous and local knowledge (Berkes & Turner, 2006; Turner & Turner, 2008). The importance of social interaction for sustainability education manifests in many ways, including the strong role that social norms play in fostering sustainable behaviour (Miller & Prentice, 2016) and the substantial success of initiatives that engage social learning for sustainability (Wals, 2007).

A third commonality addresses the relevance of attending to the "whole person" in learning. The whole person approach emphasizes that education is about both cognitive and affective aspects of the learner, that education must think not only about cognitive development, but must also attend to the crucial role that emotion can play in learning (Podger *et al.*, 2010). This holistic approach has been central to education in IPLCs for millennia. These emotional aspects may be particularly important in sustainability-related education, which can involve strong emotions such as despair and hope (Hicks, 1998; Li & Monroe, 2017; Newman, 1996).

Content is the second pillar of sustainability education. Though content may seem more straightforward than process, decisions about content, what to include and exclude from educational initiatives, are crucial. Content encompasses knowledge, concepts, and skills that are relevant to sustainability. Content that is central to most recent frameworks of environmental and sustainability education includes the following: social justice and the centrality of equity to sustainability; participatory learning and engagement with local communities (both ecological and social); citizenship skills, such as knowledge and empowerment related to collaboration, dialogue, and democratic processes; interconnectedness and systems thinking; and attention to multiple scales (spatial, temporal, and organizational) (Tilbury, 2011).

Possible points of action

Given that a common challenge to sustainable behaviour is that people default to decision-making based only on technological or economic feasibility, sustainability-related education can develop understanding of the complexities of, and synergies between, the issues threatening planetary sustainability, and encourage consideration of complex options and trade-offs. The long timescales over which people's orientations and priorities become established, coupled with the many social and personal influences on these orientations and priorities, make study of the impact of sustainability-related education difficult. Even so, research suggests that time spent during childhood in outdoor or natural environments with respected adults can be an important motivator for learning about these complex issues and taking sustainability-related action in adulthood (Chawla & Cushing, 2007). Though results about the relations between connection to nature and behaviour are varied; connection to nature, which is often but not always established in childhood, in some cases correlates with increased pro-environmental behaviour (Geng *et al.*, 2015; Gosling & Williams, 2010; Mayer *et al.*, 2008).

For IPLCs, the educational system can be the basis for strengthening a political and cultural project that incorporates traditional and novel perspectives on management, use, and maintenance of existing resources in these communities. Some see an urgent need to recognize the importance and enhance the transmission of indigenous and local knowledge, both intergenerationally and among different societal groups, as a complement to mainstream education—including to maintain crucial relationships with nature and values of responsibility and stewardship associated with those (Chan *et al.*, 2016; Chan & Satterfield, 2016). Ideally, these two forms of knowledge can be integrated, but often formal education tends to be favoured and in some cases negates the value of local forms of knowledge. Education targeted at IPLCs can develop skills required to, for example, serve in government roles or innovate in fields such as production, trade, and management, *while maintaining traditions, values and culture*. At the same time, incorporating principles and content from indigenous and local knowledge would enrich and improve all education (McCarter *et al.*, 2014; World Bank, 2015).

Environmental education can lead to a variety of outcomes supportive of sustainability, including knowledge, attitudes, and skills (Stern *et al.*, 2014). It can also enhance values such as of connectedness, care, and kinship (Britto dos Santos & Gould, 2018). That said, the fields of environmental and sustainability education are home to many discussions of the extent to which education should explicitly encourage particular values or behaviours (Hug, 1980). Though opinions on the proper course of action differ, the most common approach is for environmental education to encourage active and informed citizenship. This citizenship inherently encompasses the ability to understand and assess one's own values (virtues and principles) and those of the society in which one lives (Tilbury, 2011). Increasing awareness of connectivity in the environmental crisis and new norms regarding interactions between humans and nature would support transformative change The goal of this work is to provide tools that allow people to engage in respectful, thoughtful, and informed negotiations toward decisions and actions that lead to a sustainable future (Huckle *et al.*, 1996; Tilbury & Wortman, 2004).

5.4.2 Levers for Sustainable Pathways

5.4.2.1 Strategic use of incentives and subsidies

Achieving SDGs and Aichi Biodiversity Targets will likely require a continued evolution of subsidies (including discontinuing harmful subsidies) and incentive programs to foster conservation and stewardship practices while cultivating appropriate norms and values. Such programs can be part of effective policy mixes, involving both positive and negative incentives through regulations and market-based instruments.

Background

While subsidies are a form of incentive, due to their prevalence as a policy tool and history of challenges, we see benefit in distinguishing them from other incentive types. Note also, that although incentive programs are often considered to trigger behaviour change by providing an incentive, a diverse body of literature strongly suggests that the incentive to conserve or restore may already exist and that 'incentive' programs may work best by removing financial and regulatory barriers (Kosoy *et al.*, 2007; Stoneham *et al.*, 2003; Wilcove & Lee, 2004).

Evidence

Many scenario and pathway analyses identified the importance of shifting incentive structures, either by removing perverse subsidies or adding new positive incentives, especially studies focused on climate action, energy systems, or water. For example, Schandl *et al.* (2016) explored the implications of imposing a global carbon price, which in their model created incentives for nations to invest in renewable energy generation. Carnicer & Peñuelas (2012) demonstrated the power of funds raised through small negative incentives, showing that a small global tax on financial transactions of 0.05% could provide funds required for widespread deployment of renewable energies. McCollum *et al.* (2012) concluded that incentive mechanisms are key to transforming the global energy system, including targeted subsidies to promote specific “no-regrets” options (e.g., microcredits and grants for low-income populations to buy low-emission biomass and low-emission biomass and Liquefied Petroleum Gas (LPG) stoves).

Subsidies and other so-called incentive programs are implemented to shift institutional and individual practices, which is a key component of successful pathways, under two conditions. The first is that such incentive programs are implemented as components of policy mixes (Barton *et al.*, 2014; Bennear & Stavins, 2007; Porras *et al.*, 2011), in which regulations are also employed to set norms and provide negative incentives. In some contexts, the incentive program or subsidy is the positive element that makes a regulation politically feasible, where the regulation is the key factor in shifting practice—e.g., as apparently the case for the national payments for environmental services (PES, or ‘PSA’ in Spanish) program and deforestation ban in Costa Rica (Daniels *et al.*, 2010; Fagan *et al.*, 2013; Legrand *et al.*, 2013; Morse *et al.*, 2009; Pfaff *et al.*, 2009; Porras *et al.*, 2013; Robalino *et al.*, 2015).

Incentive programs play especially helpful roles in pathways when executed so as to avoid the historic pitfalls resulting in adverse environmental consequences. The evidence from natural and social sciences reveals two broad classes of failings with regard to the role of incentives and subsidies in resource management. First, a large number of incentives and subsidies are intended to encourage employment and production but have unintended large-scale impacts on biodiversity and ecosystem services (e.g., Milazzo, 1998; Sumaila & Pauly, 2007). In addition to direct negative effects on ecosystems, by distorting market signals to boost production, some subsidies promote overproduction that can fuel overconsumption and drive a vicious cycle (5.4.1.2, 5.4.2.1).

Subsidies are important features of major industries and their environmental impacts. Concerning marine fish biodiversity, for instance, an estimated $35 billion in subsidies (30–40% of estimated gross revenues from the sector) is provided to the global fishing sector annually. Nearly 60% of this is classified as harmful subsidies, i.e., those that ultimately stimulate over-capacity and overfishing (Heymans *et al.*, 2011; Sumaila *et al.*, 2016). Agricultural subsidies intended to stimulate growth in domestic markets and competitiveness in exports have likewise led to unintended ecological consequences. Corn subsidies for biofuel in the United States increased corn production and decreased soy, significantly increasing global soy prices, incentivizing Amazon deforestation as soy-related land conversion dramatically increased in Brazil (Laurance, 2007; Westcott, 2007).

In many cases, even incentives and subsidies that are intended to encourage conservation and stewardship behaviours can result in unintended negative effects at either individual or collective scales (Chan *et al.*, 2017b; Vatn, 2010). A good example here are so-called buyback or decommissioning subsidies. Millazzo (1998) considered these to be ‘green’ subsidies because the goal of governments who implement buyback subsidies is to reduce fishing capacity in overfished fisheries. But what often happens is that vessels supposedly retired quickly seep back into the fishery (Holland *et al.*, 1999). Furthermore, fishers may anticipate the implementation of a buyback subsidy, which can motivate them to accumulate additional fishing capacity so they can sell it later for profit in a buyback programme (Clark *et al.*, 2005).

Incentives and subsidies intended to encourage conservation and stewardship actions can also backfire by crowding out inherent motivations and by assigning or reinforcing notions of rights and responsibilities that may be counterproductive for long-term sustainability (Chan *et al.*, 2017b; Vatn, 2010). There is strong experimental evidence that when people have inherent motivations to undertake an action beneficial for biodiversity and ecosystem services, the introduction of a monetary incentive can sometimes undermine those inherent motivations (Rode *et al.*, 2015), with potentially damaging consequences for long-term outcomes. However, incentive programs can also sometimes strengthen pre-existing motivations (i.e., ‘crowd-in’ inherent motivations; Rode *et al.*, 2015), and can be designed to do so while articulating and reinforcing values and norms of stewardship and responsibility (Chan *et al.*, 2017b).

Possible points of action

Strategic incentive programs are pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs, IPLCs, and governments of all kinds. Programs like payments for ecosystem services (PES) can be initiated by a wide range of actors for private gain and also improved environmental outcomes (Chan *et al.*, 2017a).

Programs providing incentives to undertake positive actions may be less prone to perverse consequences than those incentivizing stakeholders to refrain from taking damaging actions. Programs designed as flexible grants and awards may be more successful at articulating socially desirable rights and responsibilities, and ‘crowding in’ inherent motivations, than those that provide set payments for particular metrics (e.g., trees planted or not harvested) (Chan *et al.*, 2017a).

On a general level, the rules and regulations governing day-to-day decision-making can be adapted to create the right incentive structure for transformative changes (PBL, 2012). This would include abolishing perverse incentives (e.g., capacity enhancing subsidies: Sumaila *et al.*, 2016; Sumaila & Pauly, 2007; WBCSD, 2010) and introducing environmental factors in current pricing systems, e.g., green taxation (e.g., Daugbjerg & Pedersen, 2004).

5.4.2.2 Integrated management and cross-sectoral cooperation

Integrated management is widely recognized as an important mechanism to realize co-benefits and avoid trade-offs among competing priorities involving food, biodiversity conservation, freshwater, oceans and coasts, cities and energy, as analysed above (5.3.2). Achieving multiple SDGs and Aichi Biodiversity Targets entails policy coherence and the mainstreaming of environmental objectives across institutions within and among jurisdictions (e.g., fishing, transportation, shipping, oil and gas, renewable energy). Not all action towards a given objective will simultaneously benefit all other objectives, so an integrated approach enables harmonization that achieves targets without undermining others. Additionally, achieving global objectives will take coordinated action among disparate governing bodies.

Evidence

Almost all reviewed scenario and pathway studies called for integration and harmonization of policies and programs across sectors, agencies or jurisdictions. As an example, Fricko *et al.* (2016) concluded that an integrated approach to developing water, energy and climate policy is needed, especially given anticipated rapid growth in demand for energy and water. Quite differently, McCollum *et al.* (2012) included one pathway with integrated implementation of energy efficiency measures across all major sectors, leading to substantial reduction in energy demand. Integrated management is also widely recognized as key for availability, distribution and access to water (Cosgrove & Rijsberman, 2000), including as implemented by national governments across a broad policy spectrum including agriculture, food security, energy, industry, financing, environmental protection, public health and public security (WWAP, 2015).

Environmental management typically follows a series of demarcations most often along geopolitical boundaries and human constructs of the environment. First, management agencies are often constrained by jurisdictional boundaries that do not correspond with meaningful ecological transitions (McLeod & Leslie, 2009; Tallis *et al.*, 2010). Because of telecoupling across boundaries (discussed in 5.4.1.6), integrated policy and governance is key to managing effectively. For example, the Rocky Mountains of North America are managed by different countries' natural resources, environment and parks agencies (Canada and the USA), and by different provinces and states within these countries, without overarching agencies to consider management across these divisions. Cross-jurisdictional efforts like the Yellowstone to Yukon Conservation Initiative are important for gathering a wide range of stakeholders across this large region; transboundary management would go further, reconciling multiple management goals from multiple agencies for the Rocky Mountains (Levesque, 2001).

Second, ecosystems are often managed, and studied, separately (O'Neill, 2001). Perhaps the most prominent example of this type of division is the separate management of oceans versus land (Álvarez-Romero *et al.*, 2011). Despite clearly important connections in the land-sea interface—terrestrial processes affect oceans and marine processes affect the land (Álvarez-Romero *et al.*, 2011; Hocking & Reynolds, 2011; Tallis, 2009)—these divisions persist.

Third, management is often conducted separately on different important human uses, such as government departments dedicated to parks, protected species, fisheries, agriculture, energy and development (Becklumb, 2013). In some cases, this means that environmental impacts of overlapping human activities are managed separately; in other cases (e.g., protected areas), multiple activities are managed simultaneously, but often only within tight boundaries whereas environmental impacts transcend these. Environmental impacts and risks often stem from a variety of different activities, but accumulate (Halpern *et al.*, 2008). By dividing environment management according to different uses and different goals, important interactions among ecosystem components may be ignored. For example, management plans targeting recovery of predators or higher trophic level fisheries will be more effective if management also targets recovery of prey species (Samhouri *et al.*, 2017).

Finally, paradigms of environmental management are marked by conceptual divisions, whose integration would also help achieve sustainability objectives. For decades, western environmental management has treated human interaction with the environment mainly as a source of negative impacts, when in fact humans are in many cases integral components beneficial to ecosystems functioning (Hendry *et al.*, 2017; Higgs, 2017). Human activities often can transform otherwise inhospitable ecosystems to productive food growing habitats (Higgs, 2017), and fishing activities, if regulated, can sustain fish populations for harvest (Dowie, 2009; Jacobsen *et al.*, 2017). Yet, the view that humans are exogenous to natural systems has led to a series of important negative effects. As discussed above (5.4.1.5), there are numerous examples of conservation and management agencies, with power and authority over local institutions, that have moved to displace local populations from the ecosystems that, in many cases, are conserved because of them (Dowie, 2009), discrediting local knowledge about ecosystems management (Fischer, 2000), and imposing top-down regulations over institutions that have co-evolved with local ecosystem dynamics (Ostrom, 1990). Management mechanisms to attend to local concerns and integrate local knowledge can both provide valuable information and increase legitimacy and effectiveness of management.

Siloed management explicitly excludes interactions that can affect management goals. One example is the independent management of shipping, energy production, and coastal development, and the cumulative impacts this has had on the southern resident orca ('killer whale') population (Ayres *et al.*, 2012; Murray *et al.*, 2016) in the Salish Sea (in southeastern British Columbia, Canada and northern Washington State, USA). Incorporating risks to species and systems that these whales depend on can greatly increase understanding of risk (e.g., Murray *et al.*, 2016). In most cases, however, knowledge of risks to ecosystem services deriving from different human activities and infrastructure is piecemeal and insufficient for ecosystem-based management (Mach *et al.*, 2015). For long-term sustainability of resources and environments, cross-sectoral management is key to addressing multiple goals (Harrison *et al.*, 2018).

Recent analysis of interrelationships between SDG targets provides insights into how to integrate policy towards achieving multiple goals. For instance, it suggests that achieving the ocean targets within SDG 14 has the potential to contribute to all other SDGs (Singh *et al.*, 2018). Moreover, ending overfishing and illegal fishing alone (SDG 14.4) can contribute to several other SDG targets. Increasing economic benefits to Small Island Developing States (SDG 14.7) could contribute to a suite of SDGs, depending on policy implementation and how benefits are distributed (e.g., whether marine development helps fund education (5.4.1.8)). In contrast, increasing the coverage of marine protected areas (SDG 14.5) can trigger trade-offs with other SDGs among the SDG 14 targets, because MPAs can limit access to needed local resources and decrease local peoples political power. However, these trade-offs can be avoided through proper consultation and implementation with local people (5.4.1.5), as in integrative policy planning.

Thus, integrated management is widely understood as a key mechanism to account for interactions, trade-offs and synergies between SDGs. Global scenarios underline this even though many challenges are beyond the capability of integrated assessment models (IAMs) and require additional consideration (e.g., globalization processes such as trade, migration or large-scale land acquisitions including land-grabbing).

Possible points of action

Integrating management across sectors is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. For example, diversified but integrated business models for forestry or farming operations may yield greater and more stable revenues as well as long-term environmental benefits (harvesting resources but also hosting tourists and other recreators, and participating in ecosystem service markets and incentive programs). However, integrated management approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Management efforts with cross-boundary provisions are often helpful (Levesque, 2001; McLeod & Leslie, 2009; Tallis *et al.*, 2010). Management across boundaries can also contribute to and benefit from Sustainable Development Goal target 17.16 (global partnerships for sustainable development, complemented by multi-stakeholder partnerships).

Laws requiring that management and policy (including protected areas and restoration efforts) state and reflect important spatial and temporal social-ecological dynamics may enable long-term cross-sectoral benefits (Kliot *et al.*, 2001; McLeod & Leslie, 2009).

Co-management arrangements and partnerships with informal environmental experts and users, may enable integration of important and time-sensitive information, enhancing legitimacy of and compliance for management plans (Dowie, 2009; Fischer, 2000).

Management plans may be more successful if they reflect multiple goals, potentially including the state of a resource/population as well as the uses of that resource (Lindenmayer *et al.*, 2000; McLeod & Leslie, 2009; Rice & Rochet, 2005).

5.4.2.3 Pre-emptive action and precaution in response to emerging threats

Sustainable pathways generally entail addressing risks well before system-specific proof of impact has been established.

Evidence

The scenario and pathway studies consulted involve a timely response to a variety of risks facing biodiversity and ecosystem services, either explicitly or implicitly. While scenarios do not generally detail the process of scientific study or the demonstration of proof, based on the long time lag between scientific focus on a phenomenon and consensus about causality, let alone proof (Oreskes, 2004), we can infer that most scenarios entail managing risky activities before establishment of proof that those activities cause particular harms. Furthermore, backcasting studies sometimes indicate that certain interventions require early implementation (Brunner *et al.*, 2016).

The need for early, precautionary action is also supported by arguments from theory, supported by a wide range of associated evidence. Many important challenges facing nature and its contributions to people involve several key complications of complex adaptive systems (numerous time-lags in social and ecological subsystems, multi-causality that impedes proof, and nonlinear responses that may appear slow until a threshold is passed, after which reversal may be impossible or impracticable; for more, see 5.4.2.4). These complications mean that empirical demonstration of system-specific cause-and-effect relationships is difficult (sometimes impossible), that it may take a long time, and that major and near-irreversible harms may have occurred before proof is established (e.g., Burgess *et al.*, 2013).

The various components of this argument from theory have considerable empirical backing. First, there is abundant evidence of time lags between ecological degradation and their societal consequences (e.g., Jackson *et al.*, 2001). This is exacerbated by interacting regime shifts at multiple scales (Leadley *et al.*, 2014). Second, ample evidence demonstrates that many changes in biodiversity and ecosystem services are the result of simultaneous action of diverse processes operating at multiple scales, which would impede the demonstration of any one factor as the cause of a given decline (e.g., Graham *et al.*, 2013; Levin, 1992; Marmorek *et al.*, 2011; Schindler *et al.*, 2003). Third, many systems exhibit thresholds (e.g., Folke *et al.*, 2004; Hastings & Wysham, 2010) combined with path-dependency (hysteresis, e.g., Graham *et al.*, 2015; Hughes *et al.*, 2010), which are difficult to reverse (Walker & Meyers, 2004) and the difficulty reducing stressors sufficiently to encourage reversal (Graham *et al.*, 2013).

This drawback of reactive management is particularly relevant for managing effects on “slow” system variables (variables that historically would generally have changed slowly, on evolutionary timescales), such as habitat availability. Such “slow” variables are often secondary concerns for stakeholders and managers more concerned with “fast” variables, such as annual fishery productivity, except where the habitat itself is widely appreciated (e.g., coral reefs; Pratchett *et al.*, 2014). However, should a slow variable pass a threshold, the system may shift rapidly to an alternate state, thus changing the dynamics of fast variables (Walker *et al.*, 2012). In such situations, even if the slow variable is restored to its previous level, the fast variables may be unable to return to their previous configurations due to the effects of path dependency.

The management of risks to slow variables is a key aspect of governing for resilience (Folke *et al.*, 2004; see also 5.4.2.4). However, as indicated above, it can be very costly if management waits for system change before acting to identify and manage risks. Due to their generally slower rates of change and susceptibility to threshold effects, slow variables in particular may often require precautionary approaches. This is the rationale for this specific lever as an issue that is separate but complementary to both integrated management (5.4.2.2) and management for resilience, adaptation, and transformation (5.4.2.4).

Possible points of action

Based on the above, it would appear that management, policies, and laws that place a strong burden of proof for the establishment of harm before requiring action are not conducive to long-term sustainability. Accordingly, a precautionary approach can be embedded in resource management and a diverse set of environmental policies and laws (e.g., Europe’s Registration, Evaluation, and Authorization of CHemicals (REACH) regulations). This point is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. However, precautionary approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Precautionary approaches have been subject of much debate (Stirling, 2007), but they have become accepted aspects of management in some respects. A precautionary approach is one of the principles of the UN’s voluntary Code of Conduct for Responsible Fisheries, for example, and thus has become established as a commonly invoked tenet of fisheries management. In the Alaska groundfish fisheries, for example, precaution has been integrated into the process by which allowable catches are determined, with estimates of maximum yield serving as a limit to be avoided rather than a target to be achieved; allowable catches are reduced from this limit following a series of steps that buffer against uncertainty, requiring greater reductions in catches in situations of less information (Witherell *et al.*, 2000).

A key precautionary mechanism is the maintenance of diversity. For instance, genetic diversity within and among species contributes substantially to ecosystem services, just as a diversity of species do. Genetic diversity within species maintains the potential for them to respond adaptively to environmental changes, thus facilitating and improving persistence in the face of environmental change. Diversity also maintains options for the future (NCP18).

The precautionary approach was not necessarily formulated to address issues of complex adaptive system management. However, it does provide a framework for the management of risks and uncertainty associated with complex social-ecological systems (Levin *et al.*, 2013), and thus represents an existing policy lever by which the challenges of complex adaptive system management may be addressed. Integrated Ecosystem Assessment may be useful for identifying appropriate early and pre-emptive actions (Levin & Möllmann, 2015), via a formal synthesis and quantitative analysis of relevant natural and socioeconomic factors in relation to specified ecosystem management objectives. Regardless, it is particularly important to avoid inaction (DeFries & Nagendra, 2017).

5.4.2.4 Management for resilience, uncertainty, adaptation, and transformation

Policies, programs and management agencies that seek optimal outcomes while assuming linear or equilibrium ecosystem dynamics are likely to result in undesirable surprises, as nature often operates in nonlinear ways. Policies and programs that are designed to be robust to uncertainty and to cultivate system resilience, including at the expense of program efficiency, may be more effective and efficient in the long term.

Evidence

Environmental management that seeks to maximize the extraction of a resource or population often backfires. System shocks and sudden changes can and generally will undermine effective management (Chapin III *et al.*, 2009). There are three ways in which the long term stability of an ecosystem can change that affect nature's contributions to people.

First, the consequences of ecological degradation may not be felt immediately but may manifest after a time lag. Historical overfishing has been linked to the collapse of coastal ecosystems, limiting their ability to provide resources for people (Jackson *et al.*, 2001). Similarly, the historic culling of wolves in North America has led to an abundance of coyotes and mesopredators, which has led to economic costs for ranching through predation on livestock (Prugh *et al.*, 2009).

Second, management to optimize a single goal can leave ecosystems vulnerable to disturbances. The literature on agriculture and forestry industry is replete with evidence of how management to maximize yield renders ecosystems vulnerable to pests and diseases (Meehan & Gratton, 2015; Taylor & Carroll, 2003). Future shocks to ecosystems in the form of invasive species and diseases can pose long term risks to managed ecosystems. The mountain pine beetle epidemic is a prime example, where management of forest landscapes for a single primary goal (timber extraction) resulted in monocultures of even-aged trees that facilitated a massive infestation that threatened both forest ecosystems and the forestry industry in western North America (Li *et al.*, 2005; Safranyik & Carroll, 2006). Often, this vulnerability to disturbance is due to managing ecosystems with little species and structural diversity (Meehan & Gratton, 2015). Conversely, there is ample evidence to show that incorporating ecological diversity in managed ecosystems can protect against diverse shocks and help maintain ecosystem services (Duffy, 2009; Oliver *et al.*, 2015; Tilman *et al.*, 2006a).

Third, many systems exhibit thresholds of change, meaning that the build-up of human pressure may lead to sudden large changes in an ecosystem (Boettiger & Hastings, 2013). These 'tipping points' and ecosystem state changes have been documented on land and sea (Folke *et al.*, 2004; Hastings & Wysham, 2010), and may be accompanied by 'hysteresis effects', whereby a change in ecosystem state is difficult to reverse because of path-dependency (Graham *et al.*, 2015; Hughes *et al.*, 2010; Walker & Meyers, 2004; see also 5.4.2.3). Ecological state changes can occur at multiple scales and interact, which only increases their severity and difficulty in reversing (Leadley *et al.*, 2014), increasing the importance of managing more broadly for resilience, transformation and uncertainty.

Many case studies point to state changes being a result of multiple processes operating at multiple scales, impeding the identification of any single factor as the cause of a deleterious change (Graham *et al.*, 2013; Levin, 1992; Schindler *et al.*, 2003). Changes to Earth's climate, landscapes, and seascapes are the result of a growing human imprint, and the cumulative impacts of human actions can be more important as drivers of change than any single action (Halpern *et al.*, 2015). Research on the major drivers of tipping points for ecosystems and ecosystem services often points to interactions between emerging climate change and local human pressures, indicating that some risks posed by dramatic ecological changes may be more prevalent in the future (Halpern *et al.*, 2015; Rocha *et al.*, 2015). Thus, management that explicitly accounts for nonlinear dynamics will be more important than ever.

Possible points of action

Management that includes goals to reduce vulnerability to long term shocks and tipping points may be more effective at preventing or mitigating disasters, thus reducing the waste of resources associated with recovery efforts and accruing private benefits as well as more diffuse public ones (both social and ecological). In contrast, management focused principally on optimizing resources or populations may achieve short-term gains at the expense of long-term productivity and stability.

As with early action (5.4.2.3), managing for resilience, uncertainty, adaptation and transformation is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. Again, resilience-focused approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Management may be more effective if it explicitly considers how the underlying ecology and physical processes support specific management goals, and the major threats to these goals (Kelly *et al.*, 2015). The consideration of nonlinear ecosystem dynamics provides vital insights into appropriate timings, windows of opportunities and risks and the financial viability of investments in ecosystem management (Sietz *et al.*, 2017). For example, by linking nonlinear ecosystem behaviour to an economic evaluation of land management options, opportunities and challenges have been presented for cost-efficiently restoring or maintaining land ecosystems that are rich in biodiversity and help to mitigate climate change. Additionally, adapting to detrimental changes will require an understanding of how ecological change affects socioeconomic conditions, and effective ways that people in specific contexts can cope with changes, such as modifying growing seasons in response to climate change, or understanding how environmental change affects the ability of indigenous groups to harvest in traditional manners (Savo *et al.*, 2016).

Inherent and systemic uncertainties (time lags, tipping points, interacting mechanisms of change) imply that management can benefit from an adaptive process, whereby learning from ongoing management actions reduce uncertainty and refine management goals (Armitage *et al.*, 2009; Walters, 1986). The “learning by doing” approach of adaptive management is effective in many instances as a operational strategy to managing under uncertainty.

Biggs *et al.* (2012) offer a set of general recommendations for building resilience of ecosystem services, including maintaining diversity and redundancy in both ecological and governance aspects; understanding and managing connectivity, recognizing that there may also be negative effects like disease; managing feedback mechanisms and ‘slow’ variables important to nature’s contributions to people, including monitoring and adaptive management; accounting for complexity in scenarios and planning, including nonlinearity and critical thresholds; promoting learning, participation, and polycentric governance; and enabling the self-organization of agents of change.

5.4.2.5 Rule of law and implementation of environmental policies

Strengthening the rule of law is a vital prerequisite to reducing biodiversity loss and protecting human and ecosystem health (and thus the interests of the public and future generations from incursion by private interests). Stronger international laws, constitutions, and domestic environmental law and policy frameworks, as well as improved implementation and enforcement of existing ones, are necessary to protect nature and its contributions to people. Respecting differences in context, much can be learned from legislation, policies, and instruments with demonstrated successes, while still maintaining opportunities for regulatory experimentation and innovation.

Background

Over the past fifty years, every nation in the world has ratified international environmental laws, passed environmental laws, and developed environmental policies (see for instance chapters 3 and 6). In some countries, these rules have contributed to substantial progress on particular issues. In other countries, these rules have had little or no discernible effect. Despite a proliferation of both international and domestic environmental laws, global environmental problems, including biodiversity loss, climate change, and the breaching of planetary boundaries, continue to worsen.

Evidence

Good governance, respect for the rule of law, and reducing corruption are prerequisites to sustainable development (Morita & Zaelke, 2005). There is a strong correlation between a country’s performance on the Rule of Law Index (World Justice Project, 2016) and the Environmental Performance Index (Yale Center for Environmental Law and Policy *et al.*, 2016). For example, the top ten countries in the Rule of Law Index have an average ranking on the EPI of 14.6, while the bottom ten countries in the Rule of Law Index have an average EPI ranking of 126.5 (World Justice Project, 2016; Yale Center for Environmental Law and Policy *et al.*, 2016). From tackling illegal logging to implementing biodiversity laws, strengthening the rule of law is essential (Schmitz, 2016; Wang & McBeath, 2017).

It is widely acknowledged that international agreements intended to protect the planet’s ozone layer, beginning with the Vienna Convention for the Protection of the Ozone Layer in 1985, have succeeded in addressing this threat to biodiversity (Fabian & Dameris, 2014). However, international treaties on biodiversity and climate change, while contributing to progress in some areas, have fallen short of achieving their objectives (Kim & Mackey, 2014; Le Prestre, 2017; Rosen, 2015).

Constitutional protections for nature, biodiversity, and endangered species have contributed to conservation successes (Boyd, 2011; Daly & May, 2016; Jeffords & Minkler, 2016). Specific examples include Brazil's extensive constitutional environmental provisions (Mattei & Boratti, 2017), Bhutan's requirement that 60 per cent of forests be protected (Bruggeman *et al.*, 2016), and Ecuador's recognition of the rights of nature (Kauffman & Martin, 2017).

Strong laws intended to protect endangered species (e.g., US Endangered Species Act, Costa Rica's Biodiversity Act) have the potential to not only stem the decline of individual species but also achieve their recovery to healthy population levels (Suckling *et al.*, 2012). Weaker laws (e.g., Canada's Species at Risk Act, Australia's Environment Protection and Biodiversity Conservation Act), less rigorously implemented and enforced, are less likely to achieve recovery goals (Hutchings *et al.*, 2016; McDonald *et al.*, 2015; Mooers *et al.*, 2010; Waples *et al.*, 2013). Policies and programs also have an important complementary role in protecting biodiversity, from monitoring and evaluating wildlife populations to conservation agreements with landowners.

Effective management of human activities within protected areas is also vital to conserving biological diversity (Watson *et al.*, 2014). This applies to the regulation of both legal activities (e.g. ecotourism, recreation) and illegal activities (e.g. poaching, industrial resource exploitation).

Possible points of action

The many scenarios evaluated here recognize that, over the long-term, transformation involves legislations (and incentives) that nurture a shift from linear to circular economies (that is from pathways by which resources are extracted, manufactured into goods, then lost as waste to circular ones based on natural systems that recycle, re-use, and re-create with no waste). This is crucial for several leverage points (5.4.1.2, 5.4.1.6, 5.4.1.7). Innovative legislation and policies approaches to fostering circular economies are appearing in places as diverse as Ontario, the EU, Japan, and China (Ghisellini *et al.*, 2016). These regulatory tools would of course include laws and policies that support the shift from fossil fuels to renewable energy (Fischer & Fox, 2012; Jaffe *et al.*, 2005; Raymond, 2016).

Constitutions have particular force, and their possible amendments can help convey that governments, businesses, and individuals have a responsibility to protect and conserve biodiversity, and that individuals have the right to live in a healthy and ecologically balanced environment (Boyd, 2011). We are also increasingly learning from the experiences at various scales of governance (from municipal to international) that are recognizing the rights of nature, as in Bolivia and New Zealand, and many municipalities elsewhere (Boyd, 2018).

Equally important, however, is addressing corruption in all countries, especially that directly related to the unsustainable use of natural resources. In some regions, curbing corruption alone could have significant positive impact for biodiversity (Stacey, 2018), particularly in countries that are home to biodiversity hotspots, have weak government presence, or are experiencing expansion of commodity production.

5.4.3 Putting It Together: Joint Action of Levers on Leverage Points

Although these various actions and changes may seem insurmountable when approached separately, one action may remove barriers associated with another, potentially having mutually reinforcing positive effects. Accordingly, and perhaps counterintuitively, multiple actions may be successfully undertaken more easily than individual actions, as illustrated by a series of case studies.

5.4.3.1 The Whole Is Easier than the Sum of Its Parts: Six Case Studies

Namibia, Sweden, Costa Rica, the US, the Seychelles, and New Zealand are among the countries that have successfully integrated multiple approaches in protecting biodiversity and ecosystem services. To be clear, these are only specific examples of innovative leadership to illustrate the importance of addressing multiple components and drivers affecting nature and people. There are also important examples of regulatory interventions operating at other scales and in different manners. For example, regional initiatives can have important effects, including via market-based initiatives that affect investment and industrial production by putting a price on pollution, particularly when framed around positive values of collective benefit (Raymond, 2016). Similarly, there are countless examples of local initiatives that have proven effective, from bylaws restricting pesticide use for cosmetic purposes to bans on plastic bags and other single-use plastic items.

Namibia's success with community-based conservation illustrates many of the above levers and how they can work together. Following independence from South Africa in 1990, Namibia's new government passed progressive legislation in 1996 that devolved user rights regarding nature (in particular wildlife) to local communities (5.4.2.5, Law; 5.4.1.5, Involving local communities).

This change in governance allowed communities to register their traditional lands as conservancies, providing them with both the legal right and the legal responsibility to manage their customary landholdings for the sustainable flow of benefits from wildlife and other natural resources. The proliferation of conservancies—from 4 in 1998 to 83 at present—has resulted in increased levels of financial benefits to the rural poor (Jones *et al.*, 2012; Naidoo *et al.*, 2016), recovering populations of wildlife (Naidoo *et al.*, 2011), a tremendous increase in the amount of land under conservation management (MET/NACSO, 2018), and the reconnection of a link between Indigenous Peoples and wildlife that spans thousands of years of joint history (5.4.1.2, Visions of a good quality of life). Governance decisions were the overall platform for the conservation successes that followed, with subsequent innovative linkages between local communities and international markets for tourism and plant products providing the tangible mechanisms by which local people have benefited from their natural resources (5.4.1.7, Technology and innovation; Barnes *et al.*, 2002). While community-based conservation has helped take a step towards improving the dramatic inequality between the marginalized rural poor and wealthier ranchers and urbanites in Namibia (5.4.1.4, Inequalities), considerable threats nevertheless remain that could hamper further gains. These include increased levels of human-wildlife conflict (Kahler & Gore, 2015), incentive structures (5.4.2.1) that are preventing the full sociocultural, economic, or biophysical values of wildlife from being unlocked (e.g., subsidies and political power dynamics related to livestock and mineral extraction; Muntifering *et al.*, 2017) and competing demands for land that are not evaluated in a synthetic way by governments at various levels of responsibility (5.4.2.2, Integrated management/ governance). Nevertheless, the successes seen in Namibia demonstrate that conservation by local communities on their lands can lead to gains both for people and for wildlife.

Sweden has been a global leader on issues ranging from climate change to toxic substances, ranked fifth on the Yale Environmental Performance Index in 2018 (Yale Center for Environmental Law and Policy (YCELP) *et al.*, 2018), and is proactively discussing what a future without economic growth would look like (Boyd, 2015). In 1999, the Swedish Environmental Code established a goal of solving all of the country's environmental problems over the course of a single generation (Government of Sweden, 2000). Sweden has recalibrated its economy by imposing taxes on pollution, pesticides, and waste to reduce levels of these undesired items (5.4.2.1, Incentives and subsidies; 5.4.1.3, Behaviour change) (Wossink & Feitshans, 2000). Sweden has reduced sulphur dioxide emissions by ninety per cent (in part due to a tax on emissions), cut greenhouse gas emissions by more than 20 per cent since 1990 (in part due to a high carbon tax), contributing to improved quality of life (cleaner air, safer streets, better public transit, healthier people, and more comfortable buildings). Sweden's long-term goal is to be fossil fuel free by 2050. They were the first country in the world to take strong regulatory action on polybrominated diphenyl esters (PBDEs) after researchers discovered rapidly rising levels of these flame retardant chemicals in women's breast milk (5.4.2.3, Early or precautionary action) (Darnerud *et al.*, 2015). Sweden has created timelines for eliminating the use of a broad range of toxic substances including mercury, lead, carcinogens, and chemicals that harm reproduction (5.4.2.3) (Swedish Environmental Protection Agency, 2005). They consistently rank as one of the most generous countries in the world, dedicating one per cent of their annual GDP as Official Development Assistance to help the world's poorest nations (5.4.1.4, Inequalities) (OECD, 2018). This is more than three times the level of foreign aid provided by Canadian and American governments.

Recently, Sweden recognized that some of their environmental solutions actually exported problems to other countries (i.e., leakage or spillover impacts) (Swedish Environmental Protection Agency, 2011). For example, reduced levels of logging in Swedish forests were offset by rising lumber and paper imports from countries with more biodiverse forests. Declining oil use was achieved, in part, through rising imports of biofuels from Brazil, with adverse effects on tropical forests. Sweden now recognizes that today's levels of consumption in wealthy countries need to be reduced to alleviate pressure on overexploited planetary ecosystems (5.4.1.2, Consumption) (Swedish Environmental Protection Agency, 2011). To their credit, Sweden revised its goal of achieving sustainability within one generation to state "the overall goal of environmental policy [is] to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, *and this should be done without increasing environmental and health problems outside Sweden's borders*" (5.4.1.6, Telecoupling; 5.4.2.5, Law) (Swedish Environmental Protection Agency, 2013). To achieve this goal, the Swedish government observed that "policy instruments and measures must be designed in such a way that Sweden does not export environmental problems" but rather solves them through changing patterns of production and consumption (5.4.1.2, Consumption; 5.4.1.6, Telecoupling) (Swedish Environmental Protection Agency, 2011).

Costa Rica is widely recognized as an environmental leader, as a result of decades of determined effort including the key turning point of constitutional recognition of the right to a healthy environment in 1994 (5.4.2.5, Law; 5.4.1.5, Human rights and Indigenous peoples' participation) (Boyd, 2011). This small Latin American nation has enacted and implemented strong laws (such as the award-winning Law on Biodiversity, which recognizes nature's intrinsic value), placed more than one quarter of its land in parks and protected areas, and reversed the trend of deforestation (5.4.2.5, Law) (Hanry-knop, 2017). Impressively, Costa

Rica produces 99% of its electricity from renewable energy sources including hydroelectricity, geothermal, wind, and solar (5.4.2.4, Managing for resilience; 5.4.1.7, Technology and innovation) (Hanry-knop, 2017). Costa Rican laws prohibit open pit mining and offshore oil and gas development (5.4.2.5, Law). The country has a national carbon tax whose revenues are dedicated to helping small-scale farmers in reforestation and habitat protection (5.4.2.1, Incentives and subsidies). This national payment for ecosystem services program that has been shown to leverage existing inherent motivations for conservation (5.4.1.3, Enlisting values) (Kosoy *et al.*, 2007).

In 1948, Costa Rica decided to disband its military and invest the money saved in education and health care (5.4.1.2, Visions of a good quality of life; 5.4.1.8, Education) (Abarca & Ramirez, 2018). The country now enjoys high levels of literacy (97.4 per cent) and long life expectancy (79.6 years) (UNDESA, 2017; UNESCO, 2018). Twenty years ago, Costa Rica's leading exports were coffee and bananas. Today Costa Rica's most valuable exports are computer chips and medical prosthetics, as corporations have located manufacturing facilities to take advantage of the country's educated workforce, clean air, and clean water. Costa Rica is the top-ranked country in the world on the Happy Planet Index, which integrates measures of life expectancy, self-rated happiness, and per capita ecological footprints (HPI, 2016). The national expression "pura vida" or the pure life, refers to achieving happiness in harmony with nature, a goal also established in the 2009 constitution of Ecuador (5.4.1.2, Visions of a good quality of life).

The effectiveness of strong legal protection for biodiversity is illustrated by the United States, which initially passed a law to protect endangered species in 1967, revised it in 1969, and introduced its most powerful elements, which remain in place today, in 1973 (5.4.2.5, Law) (Boyd, 2018). The law compelled the United States to host an international meeting intended to spark the development of a treaty to protect endangered species. The meeting led to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In a lawsuit involving the construction of a dam that threatened and endangered fish called the snail darter, the US Supreme Court ruled that "The plain intent of Congress in enacting the *Endangered Species Act* was to halt and reverse the trend toward species extinction, whatever the cost" (5.4.2.5; U.S. Supreme Court, 1978). The law's bold regulatory power was also alienating to some landowners, however, who resented the state imposition of restrictions on individuals and firms who happened to host species at risk. Arguably, the Act's survival in Congress and its ability to garner the willing participation of landowners depended upon regulatory innovation that removed disincentives for reporting species at risk and provided incentives for protection and restoration (5.4.1.3 Values, agency; 5.4.2.1 Incentives) through the Safe Harbour Agreement and mitigation banking (Bonnie, 1999; Fox *et al.*, 2006; Fox & Nino-Murcia, 2005). These programs enabled landowners to act in accordance with pre-existing stewardship values (5.4.1.3, Values) (Wilcove & Lee, 2004).

More than 30 species have been removed from the US endangered species list because their populations have recovered, including the bald eagle, peregrine falcon, gray whale, grizzly bear, gray wolf, brown pelican, Steller sea lion, American alligator, a snake, a flycatcher, a flying squirrel, a lizard, an orchid, and a daisy (U.S. Fish & Wildlife Service, 2018). Bald eagle populations in the lower 48 states rebounded from a low of roughly 400 nesting pairs in the early 1960s to more than 10,000 today. Keys to the bald eagle's recovery include prohibitions on hunting, banning the pesticide DDT, and protecting critical habitat, such as nesting sites (5.4.2.5, Law) (Doub, 2013). The US Center for Biological Diversity identified more than 20 species whose populations increased by more than 1,000 per cent in recent decades (Suckling *et al.*, 2012). There was a 2,206% increase in nesting Atlantic green sea turtle females on Florida beaches. The California least tern enjoyed a 2,819% increase in nesting pairs. The San Miguel island fox population increased 3,830%. Numbers of the El Segundo blue butterfly increased 22,312%. Studies indicate that roughly 90% of species listed under the US Endangered Species Act are on track to meet their recovery targets by the projected deadline (Suckling *et al.*, 2012).

The Seychelles is among the world's leaders in the percentage of its land that is designated as protected, at over 42 per cent (World Bank, 2018). The Seychelles Islands amended their constitution in 1993 to recognize that citizens have the right to live in a healthy environment, and that government has a responsibility to protect the environment (5.4.2.5, Law; 5.4.1.5, Human rights) (Boyd, 2011). In a case involving the prosecution of eight individuals for unlawful possession of meat from protected species, including sea turtles and boobies, the Supreme Court of Seychelles referred to the constitutional right in interpreting the *Wild Animals and Birds Protection Act*. The court wrote: "The right to a healthy environment has become a fundamental right. In Seychelles that right extends to the Management of Marine Resources as well as protected Land or Sea Birds" (5.4.2.5, Law) (Seychelles Legal Information Institute, 2004). Seychelles was recognized by the United Nations Environment Program as a Center for Excellence in its approach towards coastal development with reference to both efforts to protect coral reefs and a successful dolphin-free tuna industry (5.4.2.2, Integrated management; 5.4.2.4, Managing for resilience) (CountryWatch, 2018). Finally, air quality in the Seychelles is ranked number one according to the Yale Environmental Performance Index (Yale Center for Environmental Law and Policy *et al.*, 2016).

New Zealand is the highest rated non-European country on the EPI, ranked 17th in 2018 (Yale Center for Environmental Law and Policy (YCELP) *et al.*, 2018). More than 32 per cent of New Zealand's land enjoys legal protection (World Bank, 2018). New Zealand is the first country in the world to pass laws that transfer ownership of land from humans to nature (5.4.2.5, Law; 5.4.1.5, Human rights and conservation) (Boyd, 2018). Two recent laws, governing the Whanganui River and an area previously designated as Te Urewera National Park, designate these natural systems as legal persons with specific rights (New Zealand Government, 2017). For example, the Te Urewera ecosystem has the right to protection of its biological diversity, ecological integrity, and cultural heritage in perpetuity (Te Urewera Act, s. 4). These innovative laws that may eventually change the way New Zealanders relate to nature, from one in which we treat nature as a commodity that we own, towards nature as a community to which we belong (5.4.1.3, Behaviour change; 5.4.2.4, Managing for resilience). In each case, the laws establish a guardian, comprised of Indigenous Maori representatives and government representatives, to ensure that nature's rights are respected and protected (5.4.1.2, Visions of a good quality of life) (Te Urewera Act, ss. 16-17). All persons exercising powers under the Te Urewera Act "must act so that, as far as possible,

(a) Te Urewera is preserved in its natural state:
(b) the indigenous ecological systems and biodiversity of Te Urewera are preserved, and introduced plants and animals are exterminated" (Te Urewera Act, s. 5)

New Zealand is also noteworthy for having changed its electoral system in 1992 from first-past-the-post to mixed-member proportional representation (5.4.2.4, Managing for resilience) (New Zealand Electoral Commission, 2014). Advantages of proportional representation include parliaments that fairly reflect the popular vote, embody diverse populations, and require a genuine majority of the votes to form a majority government. The Green Party has played a significant role in New Zealand politics since the shift to proportional representation, serving in several coalition governments and contributing to stronger environmental laws and policies (Bale & Bergman, 2006).

5.4.3.2 Initiating Transformation, before Political Will

The examples provided throughout the chapter largely illustrate the multifaceted progress that is possible given sufficient political will, which begs the question of how to initiate transformative change towards sustainable pathways in the absence of such political will. Even in the six cases above (5.4.3.1), surely the political opportunity was created in part by various actors intervening in creative ways to enable broad and focused public support (such reconstructions of historic political processes are beyond the scope of this assessment). One of the most empowering findings that emerge from the analysis of societal responses to nature and biodiversity degradation is that individual and local efforts might be scaled up to transformative change for sustainability, including as initiated by the private sector, civil society, and governments at all scales.

There are countless worthy initiatives addressing the aforementioned leverage points and levers in various ways. These efforts deserve to be commended, and they can scale up. But they can also be better aligned with our findings above (5.4.1, 5.4.2). For example, there is a great deal of attention to reforming investment and technological innovation for a low-carbon economy, but few efforts broaden beyond climate pollution to include comprehensive impacts on biodiversity and ecosystem services, as suggested above (5.4.1.6, 5.4.1.7). Addressing the leverage points obliquely or partially (e.g., only carbon) can be counterproductive, e.g., potentially incentivizing other kinds of impacts on nature.

Existing efforts can also be better integrated, so that the various efforts can together leverage sustainability rather than undercut each other. For example, efforts to change behaviours among producers or urban populations (5.4.1.3) can be designed also to support the involvement of Indigenous Peoples and Local Communities (rather than detracting or distracting from this; 5.4.1.5).

There are also three apparent gaps in current efforts. First is laying the groundwork for a broad-scale reform of subsidies and incentives, which have structural effects (5.4.2.1). Although there is recent progress with carbon pricing (Kossoy *et al.*, 2015), there are benefits to extending these efforts in several ways. These would include advocating for and ensuring that carbon prices permeate supply chains and cross-border trade (Fischer & Fox, 2012); extending beyond carbon to include water (Molle & Berkoff, 2007), land use or conversion, and other metrics of damage or threat to biodiversity and ecosystem services; and ensuring that incentive programs are designed to foster relational values, not just 'buy' behaviour change (Chan *et al.*, 2017a) (5.4.2.1). Moreover, across many nations, there is disproportionately little effort to take stock of and address the perverse ecological impacts of subsidies on production and consumption (5.4.2.1). Because of the opposition that often arises in response to such policy reform, however, in many contexts policy progress may rely upon first laying the groundwork by enabling the widespread expression and reinforcement of supporting values (5.4.1.3; see also final point).

Second, compared with environmental laws and policies, there is a dearth of attention to the structure and approach of governing institutions to ensure that they are adaptive, precautionary, and addressing the resilience of social-ecological systems (5.4.2.2, 5.4.2.3, 5.4.2.4). Multi-stakeholder non-governmental organizations—often around certification systems—offer some promise to leverage change within commodity sectors (e.g., palm oil, soy, cotton, and rubber), when power inequities are addressed (e.g., so that small-holders have a substantial voice). Such structural changes can be fundamental (e.g., Olsson *et al.*, 2008), and yet sometimes they can elicit a broader base of support or less focused opposition. Accordingly, they may present especially promising targets for advocacy and intervention, recognizing it may take persistent and prolonged engagement.

Finally, although there are many behaviour-change programs, these efforts generally encounter one of two major obstacles to fostering system transformation. Many campaigns appeal only to a small minority of self-identified environmentalists (Moisander, 2007), which can impede behaviour change among the broader public due to negative stereotypes and the narrow reach of social norms (Chan *et al.*, 2017b). Alternatively, broad systems of taxation or incentives often lack a broad base of support or conflict with existing attitudes and values, which can backfire due to widespread resentment and/or non-participation (Chan *et al.*, 2017a). The values and concerns of voting publics are often key impediments to and enablers of top-down change. Accordingly, we see a crucial opportunity in programs and approaches that seek to leverage widely held but latent values of responsibility into new social norms in environmental (and social-ecological) contexts, perhaps by empowering all people to act in accordance with those values—easily, enjoyably and inexpensively (5.4.1.3).

Thus, a key message of this chapter is the transformative potential of identifying the diverse relational values that people already hold (principles, preferences, and virtues about relationships involving nature) that are conducive to sustainability and engineering the structural and social changes that will allow the full expression and growth of those values. These values include diverse ideals of sufficiency at the centre of *notions of a good life* that don't entail runaway *consumption* (5.4.1.1, 5.4.1.2); diverse values of responsibility are central to enabling new *social norms and action* for sustainability (5.4.1.3) including through *incentives* and regimes of *innovation, technology and investment* that align with those values (5.4.2.1, 5.4.1.7); recognition of local values consistent with conservation is an important reason to *involve Indigenous Peoples and Local Communities in conservation* (5.4.1.5); *education* is key for appreciating diverse values, which are embodied in the diverse *knowledge systems* that deserve to be maintained (5.4.1.8).

5.5 CONCLUDING REMARKS

Options for sustainable pathways abound, and our analysis suggests that they are within reach, if a diverse set of actors take action to enable them. These pathways entail addressing knotty nexuses of competing human needs, including food, biodiversity conservation, freshwater, oceans and coasts, cities, and energy. Both the actions and the pathways are clearly context-specific, with a need to tailor to regional and local circumstances via inclusive participation, but there are also key commonalities across regions and nexus points.

Across and beyond the six foci, one commonality is a diverse set of 'levers' and leverage points within which outcomes for nature, its contributions to people, and human drivers can be accomplished with strategic change. Many of these levers and leverage points have been identified elsewhere, but none have been employed widely and fully. This limited uptake is, of course, due to a variety of obstacles (chapter 6), but none of these are insurmountable with time, effort, resources, coordination, creativity, strategy, and persistence.

While all levers and leverage points are important, not all need be addressed by any one project, policy, or actor. But given strong interactions (e.g., synergies and trade-offs) between various levers and leverage points, we have described how engaging several together may be easier and more effective than addressing them piecemeal (5.4.3). For example, subsidy reform (5.4.2.1) and improved policies for innovation and technology (5.4.1.7) are excellent steps alone but often ineffectual in the presence of systemic corruption or weak rule of law (5.4.2.5). Similarly, enlisting values to encourage widespread conservation (5.4.1.3) and involving Indigenous Peoples and Local Communities in landscape management (5.4.1.5) are much needed, but they cannot yield long-term achievement of nature-based goals without also reining in overconsumption (5.4.1.2), likely by engaging appropriate visions of a good quality of life (5.4.1.1).

A key constituent and outcome of the transformational pathways suggested to achieve the SDGs is the emergence of a global sustainable economy, underpinned by a networked set of sustainable societies. The SDGs and many other agreements and collective efforts are inspiring societies and nations to envision a world in which innovation, new technology, and environmentally responsible consumption evolve towards eliminating environmental impacts, diminishing inequalities, and improving human well-being. Such a world would be enabled by diverse people and organizations engaging voluntarily in conservation and restoration, where all people are accorded inherent rights to nature and celebrated for their crucial roles in maintaining that nature for distant people, future generations, and nature itself.

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