Multiscale Scenarios for Nature Futures

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Scenarios are powerful tools to envision how nature might respond to different pathways of future human development and policy choices[1]. Most scenarios developed for global environmental assessments have explored impacts of society on nature, such as biodiversity loss, but have not included nature as a component of socioeconomic development[2]. They ignore policy objectives related to nature protection and neglect nature's role in underpinning development and human well-being. This approach is becoming untenable because targets for human development are increasingly connected with targets for nature, such as in the United Nations Sustainable Development Goals. The next generation of scenarios should explore alternative pathways to reach these intertwined targets, including potential synergies and trade-offs between nature conservation and other development goals, as well as address feedbacks between nature, nature's contributions to people, and human well-being. The development of these scenarios would benefit from the use of participatory approaches, integrating stakeholders from multiple sectors (e.g., fisheries, agriculture, forestry) and should address decision-makers from the local to the global scale[3], thereby supporting assessments being undertaken by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES).

A strategy for IPBES-tailored scenarios

Changes in nature, including biodiversity loss, emerge from interactions between drivers operating across a wide range of spatial scales, from local to global. Consequences of these changes, such as loss of ecosystem services supply, also play out across multiple scales. However, the recent IPBES Methodological Assessment of Scenarios and Models of Biodiversity and Ecosystem Services showed that scenarios used in global assessments rarely integrate values and processes from sub-regional scales, while scenarios used at local-scale are usually developed for specific contexts, hampering their comparison across regions[1]. Furthermore, existing global socioeconomic and climate change scenarios, being used by the Intergovernmental Panel on Climate Change[4], do not adequately consider nature and its contributions to people. Scenarios generated by past initiatives informing global environmental assessments, such as the Millennium Ecosystem Assessment[5], placed a stronger emphasis on nature, yet the socioeconomic pathways explored were similar to those in climate scenarios, and hence included no consideration of social-ecological feedbacks, and limited consideration of multi-scale processes.

Here, we outline a strategy to develop a new generation of scenarios that overcome these limitations, in accordance with guidance provided by IPBES[1], which encouraged close collaboration with the wider scientific community "to develop a flexible and adaptable suite of multi-scaled scenarios specifically tailored to its [IPBES's] objectives"[1]. Our strategy has two components: i) the extension of existing global scenarios developed by the climate-science community, by modelling impacts on biodiversity and ecosystem services (Figure 1a); and ii) an ambitious effort to create a set of multi-scale scenarios of desirable 'nature futures' that take into account goals for both human development and nature stewardship (Figure 1b).

Global biodiversity scenarios driven by socio-economic pathways

Potential global trajectories for drivers of ecosystem change have been recently explored by the climate-science community[6]. The Shared Socio-economic Pathways (SSPs) focus on exploring a wide range of plausible human development pathways, from slow to fast dynamics for population growth, economic growth, technological development, trade development and implementation of environmental policies. The SSPs can be used in combination with Representative Concentration Pathways (RCP), which describe pathways of greenhouse gas emissions resulting in different climate change scenarios.

Integrated assessment models and global climate models can translate relevant combinations of SSPs/RCPs into land-use change and climate change projections. Existing biodiversity and ecosystem-service models[1] can then be used to translate these projections into potential impacts on nature, nature's contributions to people and good quality of life (Figure 1a). Although this approach does not account for drivers of change in biodiversity and ecosystem services operating at regional and sub-regional scales, it enables an assessment of impacts expected from projected changes in land use and climate at the global scale. In contrast with previous analyses, we propose the use of multiple models assessing impacts across diverse dimensions of biodiversity (*e.g.* species richness, abundance, composition) and ecosystem services (provisioning, regulating, and cultural services). Comparable metrics for biodiversity and ecosystem services (such as Essential Biodiversity Variables) will be needed to harmonize outputs from models addressing each of these dimensions[1,2].

Although this initial use of global scenarios based on SSPs/RCPs combinations will continue the tradition of viewing nature as the endpoint in a linear cascade of models (Figure 1a), there is little choice but to retain this approach for informing the IPBES Global Assessment, given its scheduled delivery in 2019. However, this approach will inform the more ambitious and longer term component of this two-step strategy. The second component places nature futures at the center of scenario development and addresses the full range of social-ecological feedbacks

(Figure 1b). Scenarios developed by this long-term endeavor will underpin future rounds of IPBES regional and global assessments.

Visioning Nature Futures

The process of developing nature futures will produce multiple, stakeholder-defined endpoints and then explore various pathways for reaching those (Figure 1b). These desirable nature futures should represent a wide range of human-nature interactions, and include a wide variety of different types of human-modified ecosystems encompassing different degrees of human intervention and activity. As in other visioning exercises (Box 1a), nature futures may range from seascapes and landscapes managed for multiple purposes (*i.e.* multi-functional landscapes) to intensely managed, highly productive regions co-existing with wilderness and minimally exploited marine and freshwater ecosystems.

We propose an iterative, participatory and creative process, to identify these nature futures (Box 1b). This process will bring together key stakeholders from different sectors, at multiple spatial scales. Stakeholders will include public administration agencies, intergovernmental organizations, non-governmental organizations, businesses, civil society, indigenous peoples and local communities, as well as the scientific community. The articulation of nature futures between stakeholders, and spatial scales, will use visualization techniques and other facilitation tools to enrich existing statements of such futures[7]. These visioning exercises will build on emerging efforts at global, regional, and local scales (e.g. Nature Outlook Netherlands[8], Box 1a). Tools such as scenario archetypes, *i.e.* grouping scenarios together as classes based on similarities in underlying assumptions, storylines, and characteristics, can then be used to integrate visions, thus highlight conflicts and convergences, across scales[6,9].

At the global scale, nature futures could, for example, explore multiple pathways to achieve the 2050 Strategic Vision of the Convention on Biological Diversity[10], and work in close collaboration with ongoing efforts across others sectors developing visions and pathways for the broader array of Sustainable Development Goals. At the regional scale, nature futures can be informed by the ongoing IPBES regional assessments, which are collecting information on trends of biodiversity and ecosystem services, as well as by national and regional biodiversity targets (*e.g.* National Biodiversity Strategies and Action Plans). Local studies, on the other hand, can provide knowledge on how to link nature futures to decision-making, while being inclusive of the diversity of nature values held by different local communities[11].

Once the alternative nature futures have been identified, a range of qualitative and quantitative approaches (*e.g.* modeling, empirical studies and expert knowledge) can be used to identify potential pathways for reaching these endpoints, including specific policy alternatives, and feedbacks between nature, nature's contributions to people, quality of life and decision-making (Figure 1b). These analyses could be carried out in working groups (WGs), focusing on three topics (Figure 1b): 1) models of interactions between biodiversity and ecosystem services; 2) social-ecological feedbacks, such as individual and institutional behavioral responses to nature changes and their impact on human well-being; and 3) trajectories of indirect (*e.g.* socioeconomic changes) and direct drivers (*e.g.* land-use change) of change and their impacts on nature.

Linking biodiversity with ecosystem services

Explicit consideration of links between biodiversity and ecosystem services is limited in most models, and therefore impacts of direct drivers on nature are usually modelled independently of their impacts on nature's contributions to people[2]. However, our knowledge about the relationships between biodiversity and ecosystem functioning, and therefore services, has improved greatly[12]. We know now that species composition, and particularly their functional identity, or the traits distribution, play a greater role than species richness in shaping ecosystem functioning[13]. Much of this ecological knowledge, acquired at very small scales (*e.g.* experimental plots) is still to be incorporated into models of ecosystem services at larger scales. Accounting for the role of biodiversity in the delivery of ecosystem services in each nature future can be accomplished by a combination of appropriate scale choice and application of the most recent empirical, experimental and modelling knowledge. When indicators that are robust across scales are available, methods that work at multiple spatiotemporal scales can be integrated (empirical studies, remote sensing and ecosystem modeling)[15].

Recent work has started to explore how to map at continental scales the spatial distribution of these benefits based on the presence of species with particular traits[14], opening the door to assessments of how regional and global scenarios of indirect and direct drivers of biodiversity change would affect ecosystem services, mediated by changes in species distributions and abundances. Such scenarios are likely to demonstrate that nature's contributions to people depend both on natural and human capital[16], although their relative importance may vary across ecosystem services. Furthermore, scenarios could highlight that the perceived relationship between nature and nature's contributions to people may differ among stakeholder groups, *i.e.* landscape management preferences of farmers, hunters, and tourists differ because they expect different combinations of services[17]. Inclusion of indigenous and local knowledge and practices is critical to guarantee that diverse values of nature are captured and integrated.

Social-ecological feedbacks

In developing this new generation of scenarios, it is vital not only to include key stakeholders in identifying the futures, but also to describe and model how these stakeholders may respond to changes in drivers, biodiversity, ecosystem services and human well-being associated with each future. Models that couple social and ecological dynamics are now becoming available, demonstrating that insights from social-ecological feedbacks can be critical for anticipating regime shifts[18]. Agent-based and dynamic models can represent how the well-being of key agents, within each sector and realm, differ in each vision, and how individual responses and actions can impact the drivers' trajectories[19].

Many of these social-ecological feedbacks play out across multiple scales and locations through telecoupling between the production and consumption of ecosystem services[20], often mediated by trade, but also through institutional and governance linkages[16]. Being able to produce scenarios that show, for example, major relocation of crop production or fisheries as a result of environmental changes[21], is essential to help policy-makers prepare for potential socio-economic (transboundary) impacts.

Global and regional policies set the boundaries for national policies, which affect decision-making in local communities. In turn, the decisions of local stakeholders and how they respond and manage different nature trajectories can scale up to determine the dynamics of ecosystem change at regional scales. The development of multi-scale scenarios provides a unique environment to address these cross-scale social-ecological feedbacks, and their impact on human well-being, thereby stimulating further research in this field.

From socio-economic driver trajectories to social-ecological pathways

The Shared Socio-Economic Pathways do not adequately incorporate cross-scale dynamics and social-ecological feedbacks involving nature. These shortcomings lead to an underestimation of the effects of telecoupling and of tipping points in ecosystems (such as fisheries collapse or forest to savannah shifts)[22]. By producing multiscale scenarios for nature futures enriched with local to regional models of biodiversity and ecosystem services, we can assess how a similar scenario endpoint may produce distinct contributions to people in different areas of the world[23]. This is particularly relevant to broadening the range of drivers assessed in current global scenarios of biodiversity, as many drivers are not currently well modelled at the global-scale, but are well understood at local scales – e.g. the impacts of hunting on biodiversity or the impacts of forest loss on pollination. Such work on social-ecological feedbacks and the development of coupled analyses of society, nature and nature contributions to people, may ultimately lead to a revised set of Shared Socio-Economic Pathways, in which nature plays a central role alongside existing socioeconomic considerations.

To be successful, the scenario-development process proposed here will require scientific and technological advances to fill knowledge gaps[1] relating to the links between nature, nature's contributions to people and human well-being. It will thus rely on the activities of a broad and interdisciplinary community of scholars studying nature and social-ecological systems, and equally critically, on the engagement of policy makers, practitioners, and other stakeholders.

This engagement should occur throughout all stages of scenario development, from the identification of nature futures, to modelling and analysis, to decision-support and policy implementation[1]. Only through such continued engagement will scenarios be policy relevant and effectively used by decision-makers at all scales.

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Figures

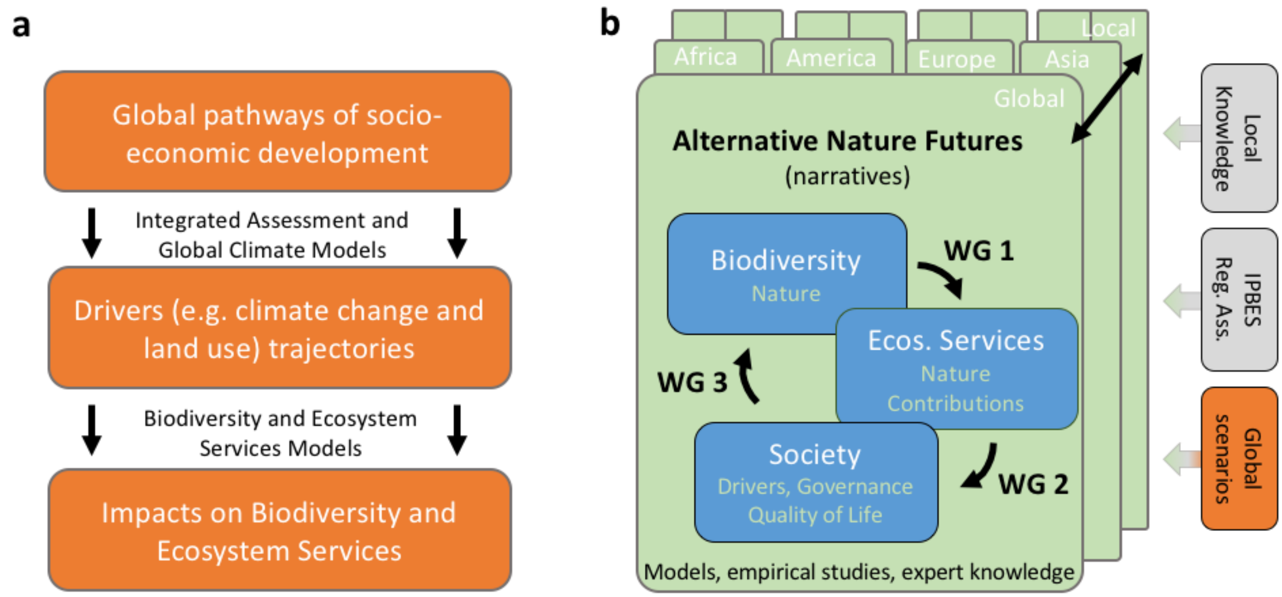

Figure 1. Two-step strategy to develop the next generation of biodiversity and ecosystem services scenarios to support the activities of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Based on **a)** Step 1: extend global scenarios developed by the climate modeling community, by carrying out a detailed analysis of impacts on biodiversity and ecosystem services; and **b)** Step 2: develop novel approach based on participatory nature futures, which can be transformed into scenarios using three working groups (WG): 1) models of interactions between biodiversity and ecosystem services; and 2) social-ecological feedbacks such as individual and institutional behavioral responses to nature changes and their impact on human well-being; 3) trajectories of indirect (*e.g.* socioeconomic changes) and direct drivers (*e.g.* land-use change) of change and their impacts on nature. *Note:* We use the terms biodiversity and nature, and ecosystem services and nature's contributions to people, interchangeably, throughout the text.

Box 1a| Examples of nature futures from the Nature Outlook project (adapted from PBL[8]).

The Nature Outlook project aimed to capture the values that nature has to people by engaging citizens and businesses of multiple sectors in the development of future visions for nature in the European Union. As a result of the participatory process that included stakeholders dialogues and a citizens' survey, four different nature futures were designed:

Strengthening Cultural Identity

People consider nature and the landscape part of their local and regional communities.

Allowing Nature to Find its Way

People feel strongly about the value of nature, providing it enough space and time to evolve.

Going with the Economic Flow

Nature serves lifestyles (production oriented), leaving management to businesses and citizens.

Working with Nature

Aiming for long term preservation of natural processes and delivery of services to people.

b| Expanding to a multiscale, multisector approach to produce alternative nature futures