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## Multiscale Scenarios for Nature Futures

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63

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

79

### 80 **A strategy for IPBES-tailored scenarios**

81 Changes in nature, including biodiversity loss, emerge from interactions between drivers  
82 operating across a wide range of spatial scales, from local to global. Consequences of these  
83 changes, such as loss of ecosystem services supply, also play out across multiple scales.  
84 However, the recent IPBES Methodological Assessment of Scenarios and Models of  
85 Biodiversity and Ecosystem Services showed that scenarios used in global assessments rarely

86 integrate values and processes from sub-regional scales, while scenarios used at local-scale are  
87 usually developed for specific contexts, hampering their comparison across regions<sup>1</sup>.  
88 Furthermore, existing global socioeconomic and climate change scenarios, being used by the  
89 Intergovernmental Panel on Climate Change<sup>4</sup>, do not adequately consider nature and its  
90 contributions to people. Scenarios generated by past initiatives informing global environmental  
91 assessments, such as the Millennium Ecosystem Assessment<sup>5</sup>, placed a stronger emphasis on  
92 nature, yet the socioeconomic pathways explored were similar to those in climate scenarios, and  
93 hence included no consideration of social-ecological feedbacks, and limited consideration of  
94 multi-scale processes.

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

103

#### 104         **Global biodiversity scenarios driven by socio-economic pathways**

105         Potential global trajectories for drivers of ecosystem change have been recently explored  
106 by the climate-science community<sup>6</sup>. The Shared Socio-economic Pathways (SSPs) focus on  
107 exploring a wide range of plausible human development pathways, from slow to fast dynamics

108 for population growth, economic growth, technological development, trade development and  
109 implementation of environmental policies. The SSPs can be used in combination with  
110 Representative Concentration Pathways (RCP), which describe pathways of greenhouse gas  
111 emissions resulting in different climate change scenarios.

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

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

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

132

### 133 **Visioning Nature Futures**

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

142 We propose an iterative, participatory and creative process, to identify these nature  
143 futures (Box 1b). This process will bring together key stakeholders from different sectors, at  
144 multiple spatial scales. Stakeholders will include public administration agencies,  
145 intergovernmental organizations, non-governmental organizations, businesses, civil society,  
146 indigenous peoples and local communities, as well as the scientific community. The articulation  
147 of nature futures between stakeholders, and spatial scales, will use visualization techniques and  
148 other facilitation tools to enrich existing statements of such futures<sup>7</sup>. These visioning exercises  
149 will build on emerging efforts at global, regional, and local scales (e.g. Nature Outlook  
150 Netherlands<sup>8</sup>, Box 1a). Tools such as scenario archetypes, *i.e.* grouping scenarios together as

151 classes based on similarities in underlying assumptions, storylines, and characteristics, can then  
152 be used to integrate visions, thus highlight conflicts and convergences, across scales<sup>6,9</sup>.

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

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

172

173           **Linking biodiversity with ecosystem services**

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

187           Recent work has started to explore how to map at continental scales the spatial  
188 distribution of these benefits based on the presence of species with particular traits<sup>14</sup>, opening the  
189 door to assessments of how regional and global scenarios of indirect and direct drivers of  
190 biodiversity change would affect ecosystem services, mediated by changes in species  
191 distributions and abundances. Such scenarios are likely to demonstrate that nature's contributions  
192 to people depend both on natural and human capital<sup>16</sup>, although their relative importance may  
193 vary across ecosystem services. Furthermore, scenarios could highlight that the perceived  
194 relationship between nature and nature's contributions to people may differ among stakeholder  
195 groups, *i.e.* landscape management preferences of farmers, hunters, and tourists differ because

196 they expect different combinations of services<sup>17</sup>. Inclusion of indigenous and local knowledge  
197 and practices is critical to guarantee that diverse values of nature are captured and integrated.

198

### 199 **Social-ecological feedbacks**

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

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

214 Global and regional policies set the boundaries for national policies, which affect  
215 decision-making in local communities. In turn, the decisions of local stakeholders and how they  
216 respond and manage different nature trajectories can scale up to determine the dynamics of  
217 ecosystem change at regional scales. The development of multi-scale scenarios provides a unique

218 environment to address these cross-scale social-ecological feedbacks, and their impact on human  
219 well-being, thereby stimulating further research in this field.

220

### 221 **From socio-economic driver trajectories to social-ecological pathways**

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

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

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

244

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276

## 277 **Acknowledgments**

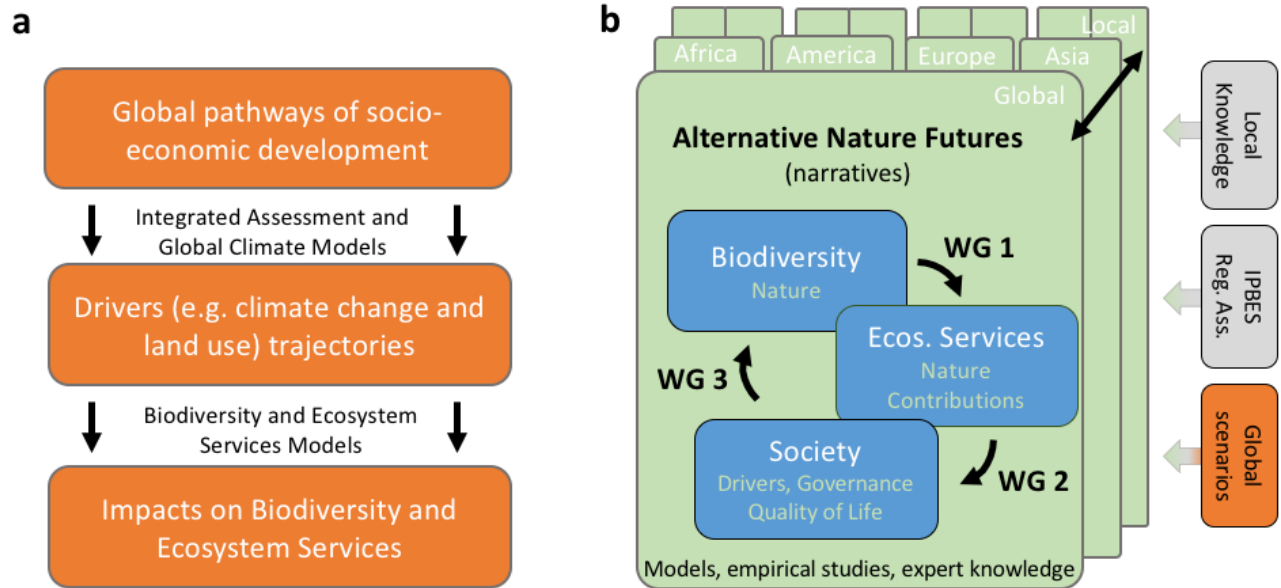
278 These recommendations emerged from a workshop held at the German Centre for  
279 Integrative Biodiversity Research (iDiv), in Leipzig, between the 3<sup>rd</sup> and 6<sup>th</sup> of October 2016,

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284

285

286 **Figures**



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

300

**Box 1a | Examples of nature futures from the Nature Outlook project (adapted from PBL<sup>8</sup>).**

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.

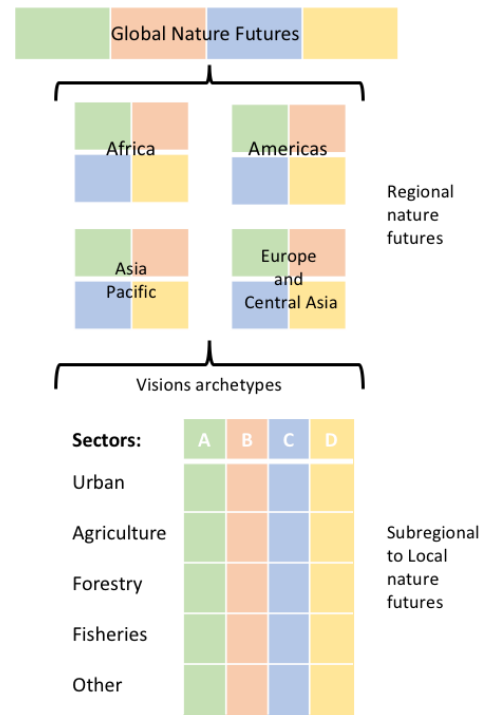


**Going with the Economic Flow**  
Nature serves lifestyles (production oriented), leaving management to businesses and citizens.



**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**



**Visions developed by stakeholders:** civil society, private sector, policy-makers, indigenous knowledge, ...

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