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Fourth session
Kuala Lumpur, 22–28 February 2016
Agenda Item 5 (b)

Work programme of the Platform: scenarios and models of biodiversity and ecosystem services: methodological assessment and proposal on the further development of tools and methodologies

Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services (deliverable 3 (c))

High-level messages

High-level message 1: Scenarios and models can contribute significantly to policy support, even though several barriers have impeded their widespread use to date.

High-level message 2: Many relevant methods and tools are available, but they should be matched carefully with the needs of any given assessment or decision-support activity, and applied with care, taking into account uncertainties and unpredictability associated with model-based projections.

High-level message 3: Appropriate planning, investment and capacity-building, among other efforts, could overcome significant remaining challenges in developing and applying scenarios and models.

Introduction

The methodological assessment of scenarios and models of biodiversity and ecosystem services was initiated in order to provide expert advice on the use of such methodologies in all work under the Platform to ensure the policy relevance of its deliverables, as stated in the scoping report approved by the Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services at its second session (IPBES/2/17, annex VI). It is one of the first assessment activities of IPBES because it provides guidance for the use of scenarios and models in the regional, global and thematic assessments, as well as by the other task forces and expert groups of IPBES.

"Models" are qualitative or quantitative descriptions of key components of a system and of relationships between those components. This assessment focuses mainly on models describing relationships between: (i) indirect and direct drivers; (ii) direct drivers and nature; and (iii) nature and nature's benefits to people.

"Scenarios" are representations of possible futures for one or more components of a system, particularly, in this assessment, for drivers of change in nature and nature's benefits. including alternative policy or management options.

Because the assessment focuses on methods, the summary for policymakers and the full assessment report are more technical in nature than other thematic, regional and global assessments of IPBES. In particular, the assessment focuses on the following:

- Critical analyses of the state-of-the-art and best practices for using scenarios and models in assessments, policy design and policy implementation relevant to biodiversity and ecosystem services;
- Proposed means for addressing gaps in data, knowledge, methods and tools relating to scenarios and models;
- Recommendations for action by IPBES member States, stakeholders and the scientific community to implement and encourage those best practices in regard to the use of scenarios and models, engage in capacity-building and mobilize indigenous and local knowledge.

Unlike the thematic, regional or global assessments of IPBES, the methodological assessment does not analyse the status of, trends in or future projections of biodiversity and ecosystem services.

There are several audiences for the methodological assessment. The summary for policymakers and chapter 1 have been written to be accessible to a broad audience, including audiences within IPBES, as well as stakeholders and policymakers not directly involved with IPBES. The critical analyses and perspectives in chapters 2–8 are more technical in nature and address the broader scientific community in addition to the expert groups and task forces of IPBES.

Target audiences outside of IPBES include the following:

- Policy support practitioners and policymakers wishing to make use of scenarios and models to inform decision-making on the local to global scales. the assessment provides guidance on appropriate and effective use of scenarios and models across a broad range of decision contexts and scales.
- Scientific community and funding agencies: the assessment provides analyses of key knowledge gaps and suggests ways of filling those gaps that would increase the utility of scenarios and models for IPBES, and for use in policymaking and decision-making more broadly.

The intended target audiences within IPBES include the following:

- Plenary, Bureau and Multidisciplinary Expert Panel: the summary for policymakers and chapter 1 provide a broad overview of the benefits of and limits to using scenarios and models, of their applications to IPBES deliverables and of priorities for future development that could be facilitated by IPBES.
- Task forces and expert groups: the full assessment report provides guidance for catalysing, facilitating and supporting the use of scenarios and models within IPBES and beyond.
- Regional, global and thematic assessments: the summary for policymakers and chapter 1 give all experts an overview of the benefits and caveats in making use of scenarios and models, and chapters 2–8 provide experts who are working specifically on scenarios and models with guidance on more technical issues related to the application of scenarios and models in assessments of biodiversity and ecosystem services.

The messages in the summary for policymakers are divided into “key findings”, “guidance for science and policy” and “guidance for IPBES and its task forces and expert groups”.

Key findings are messages that arise from the critical analyses in the assessment and are aimed at a broad audience, both within and beyond IPBES. They are grouped under the three “high-level messages” emerging from the assessment.

Guidance for science and policy is based on the key findings and broadly addresses target audiences outside of IPBES, as called for in the scoping report approved by the Plenary at its second session.

Guidance for IPBES and its task forces and expert groups is based on the key findings and specifically addresses the Platform’s Plenary, Multidisciplinary Expert Panel and Bureau, and experts involved in its deliverables, as called for in the scoping report approved by the Plenary at its second session. The guidance proposes actions that could be undertaken or stimulated by IPBES.

Key findings

High-level message 1: Scenarios and models can contribute significantly to policy support, even though several barriers have impeded their widespread use to date.

Key finding 1.1: Scenarios and models can provide an effective means of addressing relationships between nature, nature's benefits to people and good quality of life, and can thereby add considerable value to the use of best-available scientific, indigenous and local knowledge in assessments and decision support (chapter 1, figure SPM.1). Scenarios and models play complementary roles, with scenarios describing possible futures for drivers of change or policy interventions, and models translating those scenarios into projected consequences for nature and nature's benefits to people. The contributions of scenarios and models to policymaking and decision-making are usually mediated by some form of assessment or decision-support process, and are typically used in conjunction with knowledge from a broader, and often highly complex, social, economic and institutional context.

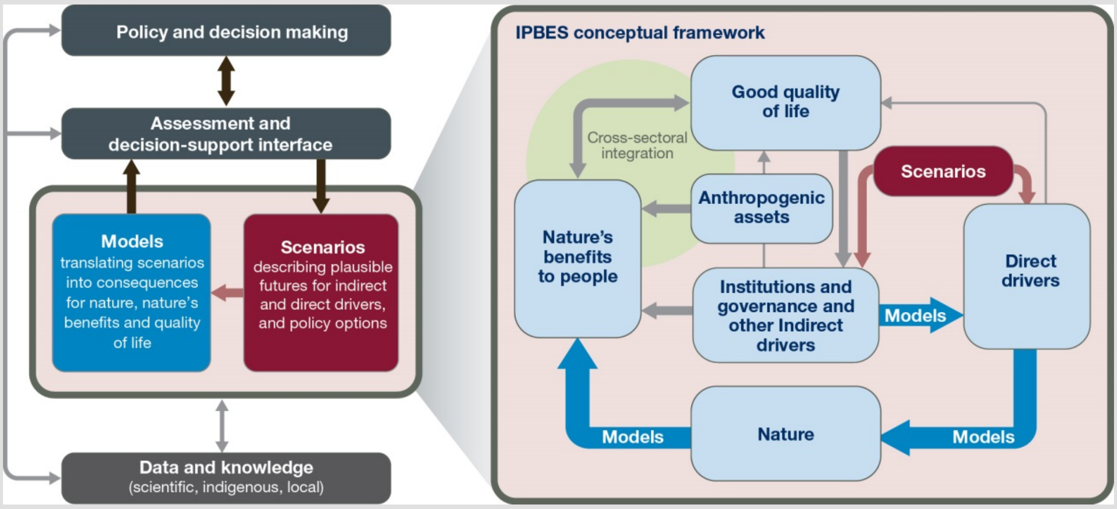

Figure SPM.1 – An overview of the roles that scenarios and models play in informing policy and decision-making. The left-hand panel illustrates how scenarios and models contribute to policy and decision-making through assessments, formal decision-support tools and informal processes (boxes and black arrows at top, chapter 2). Scenarios capture different policy options being considered by decision makers, which are then translated by models into consequences for nature, nature's benefits to people and quality of life. The left-hand panel also emphasizes that scenarios and models are directly dependent on data and knowledge for their construction and testing and provide added value by synthesizing and organizing knowledge (box and arrow on bottom). The right-hand panel provides a detailed view of the relationships between scenarios (burgundy arrows), models (blue arrows) and the key elements of the IPBES conceptual framework (light blue boxes, chapter 1; Diaz et al. 2015[1]). Grey arrows indicate relationships that are not the main focus of the assessment. The "cross-sectoral integration" element signifies that comprehensive assessment of human well-being and good quality of life will often involve integration of modelling from across multiple sectors (e.g. health, education and energy) addressing a broader range of values and objectives than those associated directly with nature and nature's benefits.

Key finding 1.2: Different types of scenarios can play important roles in relation to the major phases of the policy cycle: (i) agenda setting, (ii) policy design, (iii) policy implementation and (iv) policy review (chapters 1–3; figures SPM.2, 3 and 4; table SPM.1). "Exploratory scenarios" that examine a range of plausible futures, based on potential trajectories of drivers – either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion and climate change) – can contribute significantly to high-level problem identification and agenda setting. Exploratory scenarios provide an important means of dealing with high levels of unpredictability, and therefore uncertainty, inherently associated with the future trajectory of many drivers. "Intervention scenarios" that evaluate alternative policy or management options – through either "target-seeking" or "policy-screening" analysis – can contribute significantly to policy design and implementation. To date, exploratory scenarios have been used most widely in assessments on the global, regional and national scales (figure SPM.3, table SPM.1), while intervention scenarios have been applied to decision-making mostly on the national and local scales (figure SPM.4, table SPM.1).

[1] Díaz, S., Demissew, S., Joly, C., Lonsdale, W.M. and Larigauderie, A., 2015: A Rosetta Stone for nature's benefits to people. *PLoS Biology* **13**(1): e1002040.

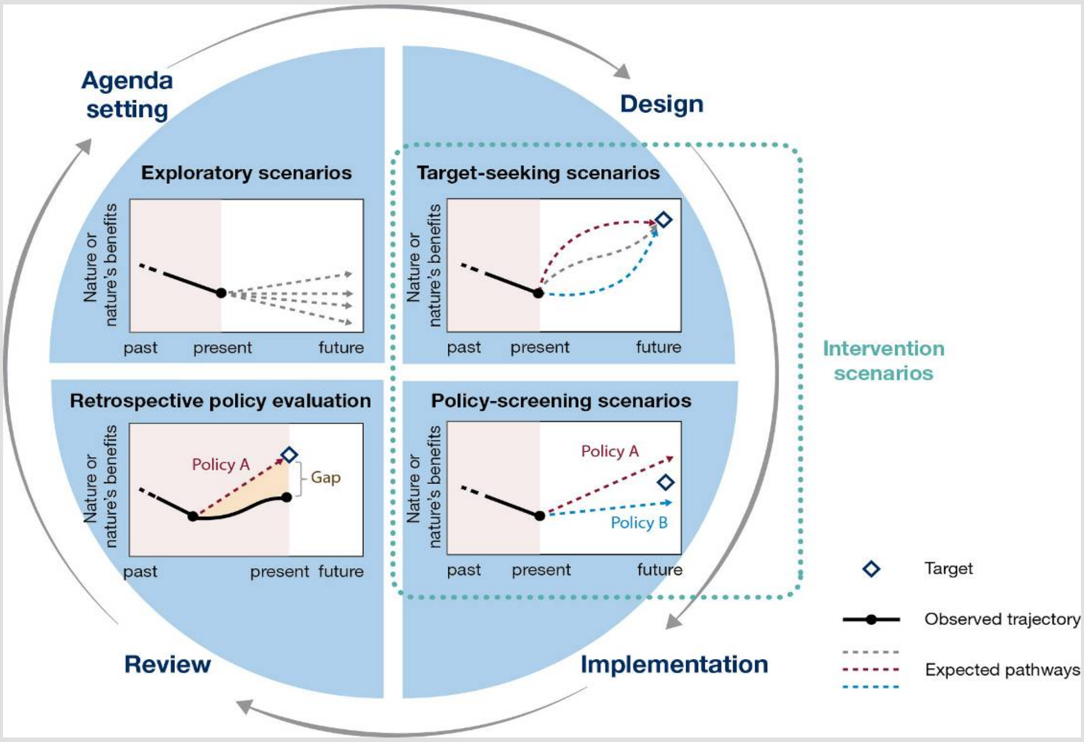

Figure SPM.2 – This figure shows the roles played by different types of scenarios corresponding to the major phases of the policy cycle. Types of scenarios are illustrated by graphs of changes in nature and nature's benefits over time. The four major phases of the policy cycle are indicated by the labels and grey arrows outside the blue-coloured quarters of the circle. In "exploratory scenarios", the dashed lines represent different plausible futures, often based on storylines. In "target-seeking scenarios" (also known as "normative scenarios"), the diamond represents an agreed-upon future target and the coloured dashed lines indicate scenarios that provide alternative pathways to reach this target. In "policy-screening scenarios" (also known as "ex-ante scenarios"), the dashed lines represent various policy options under consideration. In "retrospective policy evaluation" (also known as "ex-post evaluation") the observed trajectory of a policy implemented in the past (solid black line) is compared to scenarios that would have achieved the intended target (dashed line).

Key finding 1.3: Models can provide a useful means of translating alternative scenarios of drivers or policy interventions into projected consequences for nature and nature's benefits to people (chapters 1, 3–5; figures SPM.1, 3 and 4; table SPM.1). The assessment focuses on models addressing three main relationships: (i) models projecting effects of changes in indirect drivers, including policy interventions, on direct drivers; (ii) models projecting impacts of changes in direct drivers on nature (biodiversity and ecosystems); and (iii) models projecting consequences of changes in biodiversity and ecosystems for the benefits that people derive from nature (including ecosystem services). The contributions of these models will often be most effective if they are applied in combination. The above relationships can be modelled using three broad approaches: (a) correlative models, in which available empirical data are used to estimate values for parameters that do not necessarily have predefined ecological meaning, and for which processes are implicit rather than explicit; (b) process-based models, in which relationships are described in terms of explicitly stated processes or mechanisms based on established scientific understanding, and whose model parameters therefore have clear ecological interpretation defined beforehand; (c) expert-based models, in which the experience of experts and stakeholders, including local and indigenous knowledge holders, is used to describe relationships.

Key finding 1.4: Several barriers have impeded widespread and productive use of scenarios and models of biodiversity and ecosystem services in policymaking and decision-making (chapters 2 and 7). Those barriers include (i) a general lack of understanding among policymaking and decision-making practitioners about the benefits of and limits to using scenarios and models for assessment and decision support; (ii) a shortage of human and technical resources, as well as data, for developing and using scenarios and models in some regions; (iii) insufficient involvement of, and interactions between, scientists, stakeholders and policymakers in developing scenarios and models to assist policy design and implementation; (iv) lack of guidance in model choice and deficiencies in the transparency of development and documentation of scenarios and models; and (v) inadequate characterization of uncertainties derived from data constraints, problems in system understanding and representation or low system predictability. All of these barriers, and approaches to addressing them, are discussed in detail in subsequent key findings and guidance points.

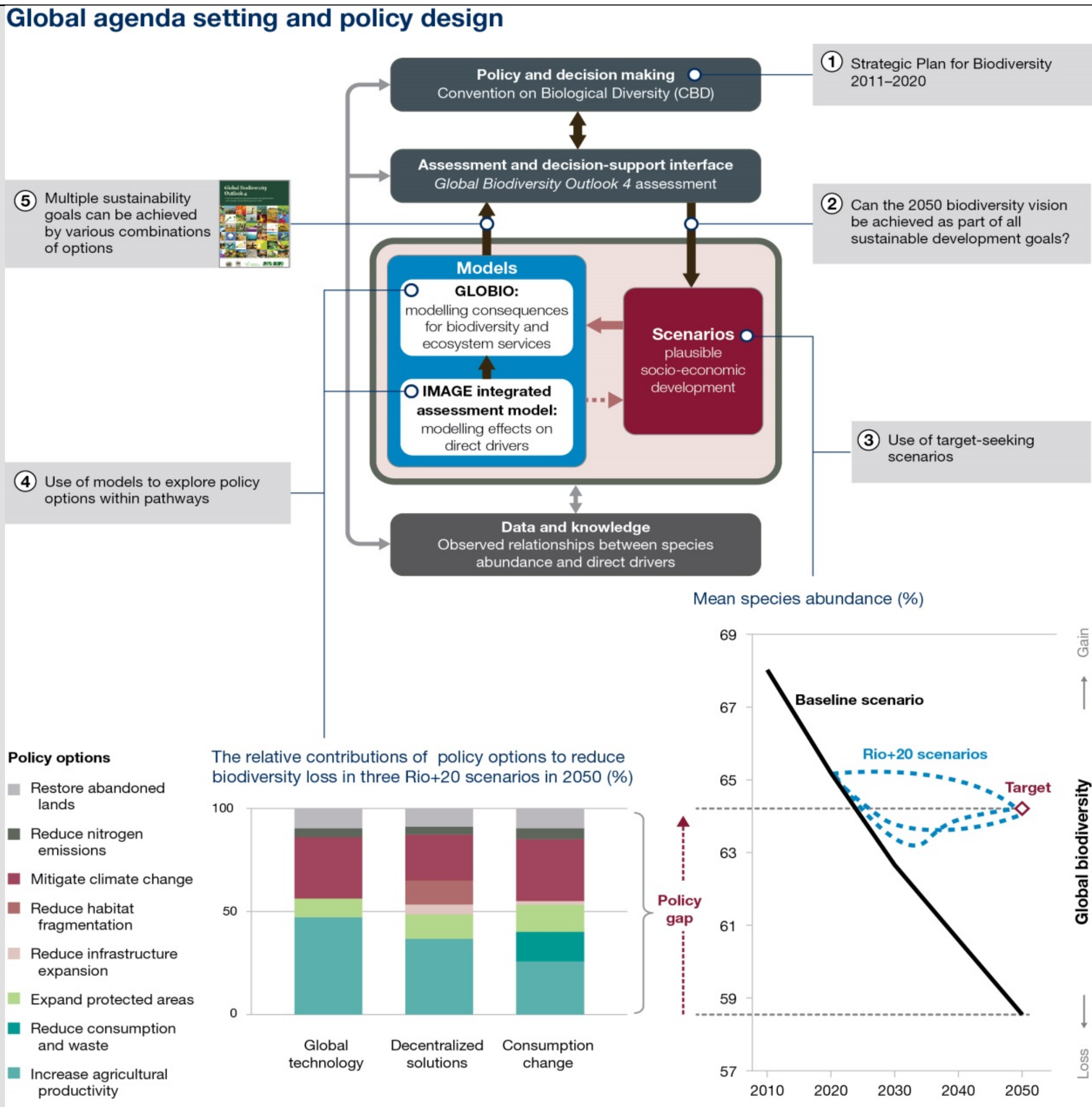

Figure SPM.3 – This figure shows an example of the use of scenarios and models for agenda setting and policy design in the Global Biodiversity Outlook 4 assessment of the Convention on Biological Diversity to evaluate the strategic plan for biodiversity 2011-2020 (step 1). The Global Biodiversity Outlook 4 used many types of scenarios and models and relied heavily on target-seeking scenarios to explore scenarios for attaining multiple international sustainability objectives by 2050. The targets in those scenarios included keeping global warming to below 2°C (United Nations Framework Convention on Climate Change), halting the loss of biodiversity by 2050 (Strategic Plan for Biodiversity 2011-2020) see bottom left-hand graph) and eradicating hunger (Millennium Development Goals) (step2). Three plausible scenarios for achieving these multiple sustainability objectives were explored. The bottom right-hand graph illustrates how these scenarios differ from a business-as-usual scenario in terms of impacts on global biodiversity (step 3). The IMAGE Integrated Assessment Model (http://themasites.pbl.nl/models/image) was used to evaluate scenarios of indirect drivers and to model the relationships between indirect and direct drivers. Impacts on terrestrial biodiversity were modelled using the GLOBIO3 biodiversity model (http://www.globio.info/). The bottom left-hand graph shows the relative contributions of indirect drivers to halting biodiversity loss by 2050 compared to the business-as-usual scenario (step 4). The Global Biodiversity Outlook 4 report indicates that multiple targets can be achieved and was an important factor in discussions at the twelfth meeting of the Conference of the Parties to the Convention on Biological Diversity, which ended with additional commitments for action and funding to achieve the Aichi Biodiversity Targets (step 5). See box 1.1 in chapter 1 for additional details and references.

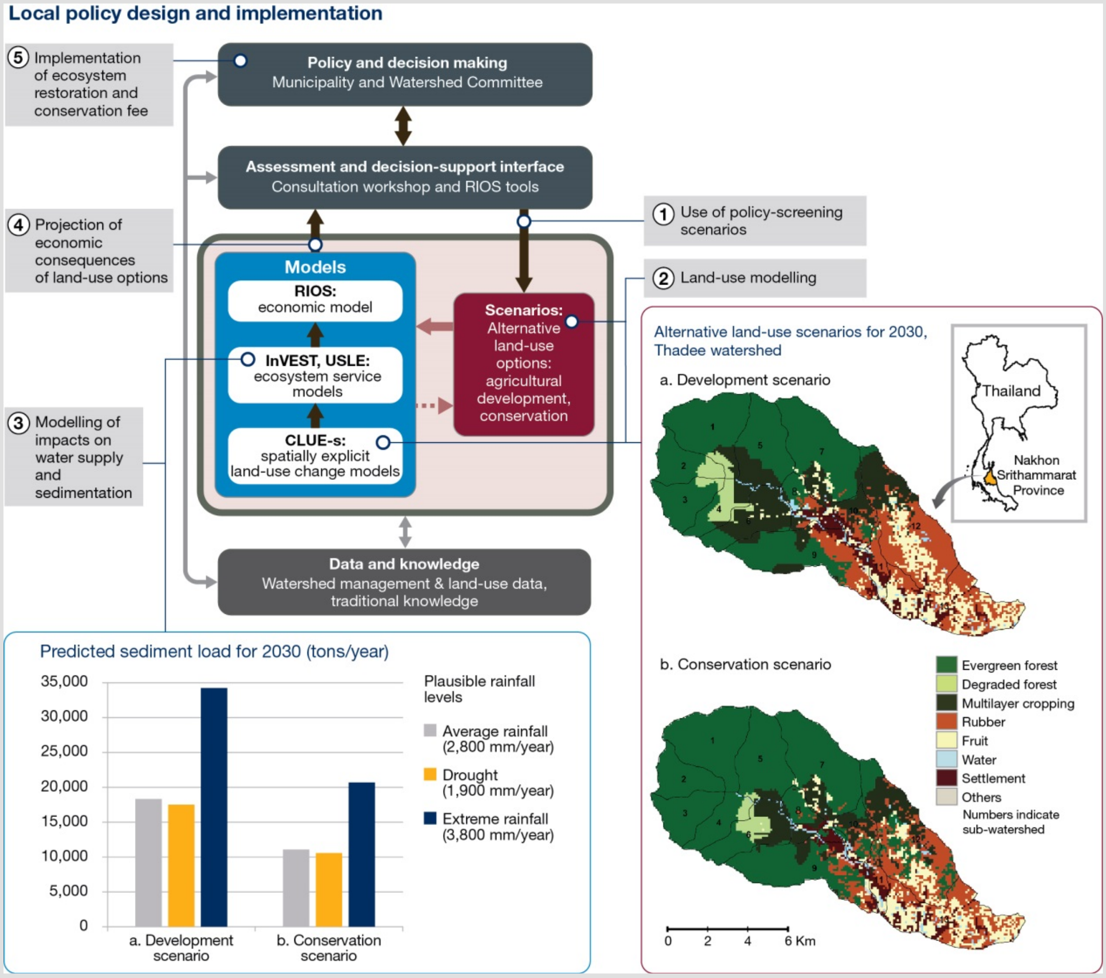

Figure SPM.4 – This figure shows an example of the use of scenarios and models in support of policy design and implementation. This case is in the Thadee watershed in southern Thailand, where the water supply for farmers and household consumption has been degraded by the conversion of natural forests to rubber plantations. Policy-screening scenarios (step 1) based on local datasets and knowledge were developed by stakeholders and scientists to explore plausible future land uses (step 2). Models were then used to evaluate the effects of three plausible rainfall levels on sediment load in rivers as a result of soil erosion and on other ecosystem services (step 3). The conservation scenario was foreseen to produce substantially less sedimentation than the development scenario with rapid expansion of rubber plantations and crops. The economics component of the Resource Investment Optimization System (RIOS) tool was then used to translate these effects into economic costs and benefits (step 4). A decision-support component of the RIOS tool was used by scientists and local decision makers to identify areas where forest protection, reforestation or mixed cropping could best be implemented. The municipality has agreed to find means of collecting a conservation fee based on payments for watershed services to fund these activities (step 5). See box 1.2 in chapter 1 for additional details and references. Source: Trisurat (2013).[2] For further information on modelling tools used in the study see

http://www.naturalcapitalproject.org/invest/
http://www.naturalcapitalproject.org/software/#rios
http://www.ivm.vu.nl/en/Organisation/departments/spatial-analysis-decision-support/Clue/index.aspx

[2] Trisurat, Y., 2013: *Ecological Assessment: Assessing Conditions and Trends of Ecosystem Services of Thadee watershed, Nakhon Si Thammarat Province (in Thai with English abstract). Final Report submitted to the ECO-BEST Project.* Bangkok, Faculty of Forestry, Kasetsart University.

Table SPM.1 – Illustrative and non-exhaustive set of applications of scenarios and models of biodiversity and ecosystem services to agenda setting, policy design and implementation at global to national scales
(For full reference list, see table 1.1, chapter 1)

	Global Biodiversity Outlook 4 (2014)	**IPCC 5th Assessment Report, WG II and III (2014)**	**Millennium Ecosystem Assessment (2005)**	**United Kingdom National Ecosystem Assessment (2011)**	**Strategic environmental assessment of hydropower on the Mekong mainstream**	**South African fisheries management**
Maximum spatial extent	Global	Global	Global	National: United Kingdom	Regional: Analysis covers Cambodia, China, Laos, Thailand and Vietnam	National: Coastal fisheries of South Africa
Time horizons	Present–2020, 2050	2050, 2090 and beyond	2050	2060	2030	Present–2034 updated every 2–4 years
Position in policy cycle	Agenda setting, policy formulation	Agenda setting	Agenda setting	Agenda setting	Policy formulation and implementation	Policy implementation
Authorizing environment	Assessment requested by member countries of the Convention on Biological Diversity (CBD)	Assessment requested by member countries of the IPCC	Initiated by scientific community, then welcomed by the United Nations	Recommended by the United Kingdom House of Commons as a follow-up to the Millennium Ecosystem Assessment	Strategic environmental assessment (SEA) carried out for the Mekong River Commission	Evaluation carried out by the South African Department of Agriculture, Forestry and Fisheries
Issues addressed using scenarios and models	Are the Aichi Biodiversity Targets likely to be attained by 2020? What is needed to achieve the strategic vision for 2050 of the CBD?	How might future climate change impact biodiversity, ecosystems and society?	What are plausible futures of biodiversity and ecosystem services?	What changes might occur in ecosystems, ecosystem services and values of these services over the next 50 years in the United Kingdom?	Evaluate social and environmental impacts of dam construction, especially in the main stream of the Mekong river	Implementation of policy on sustainable management of fisheries
Scenarios and models of direct and indirect drivers	Statistical extrapolations of trends in drivers up to 2020* Goal-seeking scenarios and models for analyses up to 2050 ("Rio+20 scenarios", see figure SPM.3) Analysis of a wide range of published exploratory and policy-screening scenarios at local to global scales	Emphasis on exploratory scenarios for impact studies (IPCC Special Report on Emissions Scenarios)* Strong focus on models of climate change as direct drivers, some use of associated land use scenarios. Emphasis on target-seeking scenarios for climate modelling and climate change mitigation analysis	Exploratory scenarios using four storylines* Models of direct drivers from the IMAGE integrated assessment model*	Exploratory scenarios using six storylines* Emphasis on land use and climate change drivers	Policy screening scenarios using several dam development schemes Emphasis on economic growth and demand for electricity generation as main indirect drivers Climate change scenarios also assessed	Goal-seeking scenarios focus on identifying robust pathways for sustainable catch

	Global Biodiversity Outlook 4 (2014)	IPCC 5th Assessment Report, WG II and III (2014)	Millennium Ecosystem Assessment (2005)	United Kingdom National Ecosystem Assessment (2011)	Strategic environmental assessment of hydropower on the Mekong mainstream	South African fisheries management
		(Representative Concentration Pathways)*				
Models of impacts on nature	Statistical extrapolations of trends in biodiversity indicators up to 2020* Analysis of wide range of published correlative and process-based models Emphasis on impacts of a broad range of drivers on biodiversity	Analysis of a wide range of published correlative and process-based models Emphasis on impacts of climate change on biodiversity and ecosystem functions	Correlative models (e.g. species-area relationships) Emphasis on impacts of a broad range of drivers on biodiversity	Correlative model of species response (birds) to land use Qualitative evaluation of impacts of land use and climate change on ecosystem functions Emphasis on habitat change as an indicator of environmental impacts	Estimates of habitat conversion based on dam heights, habitat maps and elevation maps Estimates of species level impacts based on dam obstruction of fish migration and on species-habitat relationships	Population dynamics models of economically important fish Recently added models of indirectly impacted species (e.g. penguins) Use of ecosystem-based models under consideration
Models of impacts on nature's benefits	Analysis of published studies Focus on ecosystem services from forests, agricultural systems and marine fisheries Little evaluation of direct links to biodiversity	Analysis of wide range of published studies Little evaluation of direct links to biodiversity except in marine ecosystems	Estimates of some ecosystem services (e.g., crop production, fish production) from the IMAGE integrated assessment model	Qualitative and correlative models of ecosystem services Focus on correlative methods for estimating monetary value Emphasis on monetary valuation, except for biodiversity value	Empirical estimates of fisheries impacts based on reduced migration, and changes in habitat Diverse methods to estimate changes in water flow and quality, sediment capture, cultural services, etc.	Estimates of total allowable catch based on fish population models

	Global Biodiversity Outlook 4 (2014)	IPCC 5th Assessment Report, WG II and III (2014)	Millennium Ecosystem Assessment (2005)	United Kingdom National Ecosystem Assessment (2011)	Strategic environmental assessment of hydropower on the Mekong mainstream	South African fisheries management
Participation of stakeholders	• Debate and approval by member countries of the CBD • Dialogues between scientists and the secretariat and delegates of the CBD during assessment process	• Debate and approval by member countries of the IPCC • Little involvement of stakeholders in scenarios development	Dialogs with stakeholders during scenario development	• Consultation of stakeholders during scenario development • Adopted by "Living With Environmental Change" partnership of government and non-government stakeholders	Extensive dialog involving multiple governments, expert workshops, and public consultations	Consultation between government, scientists and stakeholders during development of management strategy and setting of total allowable catch
Decision support tools	None	None	None	None, but tools under development	Strategic Environmental Assessment methods (see chapter 2)	Management Strategy Evaluation (see chapter 2)
Outcomes	Extrapolations may have contributed to member countries of the CBD making non-binding commitments in 2014 to increase resources for biodiversity protection	Key documents underlying negotiations of UNFCCC, Commitments of countries to climate mitigation to be discussed Dec 2015	Increased awareness of the potential for substantial future degradation of biodiversity and ecosystem services	Contributed to Natural Environment White Paper and influenced the development of the biodiversity strategy for England	The Mekong River Commission recommended a ten-year moratorium on mainstream dam construction. However, 1 of 11 planned dams is under construction in Laos	Fisheries widely considered to be sustainably managed. Hake fishery is certified by the Marine Stewardship Council
Strengths	• Novel use of extrapolations for near-term projections • Clear decision context and authorizing environment	• Reliance on common scenarios and models of drivers provides coherence • Clear decision context and authorizing environment	One of the first global scale evaluations of future impacts of global change on biodiversity	Focus on synergies and trade-offs between ecosystem services and on monetary evaluation	• Clear decision context and authorizing environment • Strong involvement of stakeholders	• Clear decision context and authorizing environment • Policy and management advice clear and updated regularly
Weaknesses	• Focus on global scale limits applicability to many national and local decision contexts • Lack of common scenarios and models of drivers makes	Weak treatment of drivers other than climate change, large spatial scales and distant time horizons limits usefulness for policy and management concerning biodiversity and ecosystems	• Very limited set of scenarios and models explored • Decision context unclear and authorizing environment weak	• Heavy reliance on qualitative estimates of impacts of drivers • Biodiversity at species level weakly represented (only birds)	• Highly context-specific, especially the empirical models used, and therefore difficult to generalize or extrapolate to larger scales • Mekong River Commission recommendations non-	• Highly context-specific • Several key drivers (e.g., climate change) not considered

	Global Biodiversity Outlook 4 (2014)	**IPCC 5th Assessment Report, WG II and III (2014)**	**Millennium Ecosystem Assessment (2005)**	**United Kingdom National Ecosystem Assessment (2011)**	**Strategic environmental assessment of hydropower on the Mekong mainstream**	**South African fisheries management**
	analysis across targets difficult				binding	
References	Secretariat of the Convention on Biological Diversity (2014), Kok et al. (2014), Leadley et al. (2014), Tittensor et al. (2014)	Fifth Assessment Report of Working Group II (2014) and III (2014) of the IPCC	Millennium Ecosystem Assessment (2005)	United Kingdom National Ecosystem Assessment (2011), Watson (2012), Bateman et al. (2013).	International Centre for Environmental Management (2010), chapter 2, ngm.nationalgeographic.com/2015/05/ mekong-dams/nijhuis-text	Plaganyi et al. (2007), Rademeyer et al. (2007), chapter 2
Notes	** Methods developed for the Global Biodiversity Outlook 4*	** Developed in support of the IPCC assessment process*	** Developed for the Millennium Ecosystem Assessment*	** Developed for United Kingdom National Ecosystem Assessment*		

High-level message 2: Many relevant methods and tools are available, but they should be matched carefully with the needs of any given assessment or decision-support activity, and applied with care, taking into account uncertainties and unpredictability associated with model-based projections.

Key finding 2.1: Effective application and uptake of scenarios and models in policymaking and decision-making requires close involvement of policymakers, practitioners and other relevant stakeholders, including, where appropriate, holders of indigenous and local knowledge, throughout the entire process of scenario development and analysis (chapters 2-5, 7, 8; figure SPM.5). Previous applications of scenarios and models that have contributed successfully to real policy outcomes have typically involved stakeholders starting at the initial phase of problem definition, and have maintained frequent exchanges between scientists and stakeholders throughout the process. This level of involvement has often been achieved most effectively through the use of participatory approaches.

Figure SPM.5 – Major steps of interactions between policymakers, stakeholders and scientists, illustrating the need for frequent exchanges throughout the process of developing and applying scenarios and models. Each step involves interactive use of models and data (grey arrows) and requires information flow between models and data (green arrows). This is depicted as a cycle, but in many cases these steps will overlap and interact. See chapter 8 for details.

Key finding 2.2: Different policy and decision contexts often require the application of different types of scenarios, models and decision-support tools, so considerable care needs to be exercised in formulating an appropriate approach in any given context (chapters 1, 2-5; figure SPM.6; tables SPM.1 and SPM.2). No single combination of scenarios, models and decision-support tools can address all policy and decision contexts, so a variety of approaches are needed.

Table SPM.2 - Illustrative and non-exhaustive examples of major models of ecosystem services, highlighting differences in important model attributes and therefore the need for care in choosing an appropriate solution in any given context. "Dynamic" models are capable of projecting changes in ecosystem services over time, while "static" models provide a snapshot of the status of ecosystem services at one point in time. See chapter 5 for detailed descriptions of these models, discussion of additional models and references.[3]

Tool	Model Type	Spatial and temporal extent	Ease of use	Community of practice	Flexibility	Reference
IMAGE	Process	Global, dynamic	Difficult	Small	Low	Stehfest et al., 2014
EcoPath with EcoSim	Process	Regional, dynamic	Medium	Large	High	Christensen et al., 2005
ARIES	Expert	Regional, dynamic	Difficult	Small	High	Villa et al., 2014
InVEST	Process and correlative	Regional, static	Medium	Large	Medium	Sharp et al., 2014
TESSA	Expert	Local, static	Easy	Small	Low	Peh et al., 2014

[3] Christensen, V., Walters, C.J. and Pauly, D., 2005: *Ecopath with Ecosim: A User's Guide.* Vancouver, Canada, Fisheries Centre, University of British Columbia.

Peh, K.S.H., Balmford, A.P., Bradbury, R.B., Brown, C., Butchart, S.H.M., Hughes, F.M.R., Stattersfield, A.J., Thomas, D.H.L., Walpole, M. and Birch, J.C., 2014: Toolkit for Ecosystem Service Site-based Assessment (TESSA). Version 1.2. Cambridge, UK.

Sharp, R., Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Chaplin-Kramer, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C.K., Guannel, G., Papenfus, M., Toft, J., Marsik, M., Bernhardt, J., Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M., Mandle, L., Griffin, R. and Hamel, P., 2014: *InVEST tip User's Guide.* Stanford, The Natural Capital Project.

Stehfest, E., Van Vuuren, D., Kram, T., Bouwman, L., Alkemade, R., Bakkenes, M., Biemans, H., Bouwman, A., den Elzen, M., Janse, J., Lucas, P., van Minnen, J., Müller, M. and Prins, A., 2014: *Integrated Assessment of Global Environmental Change with IMAGE 3.0. Model description and policy applications.* The Hague, PBL Netherlands Environmental Assessment Agency.

Villa, F., Bagstad, K.J., Voigt, B., Johnson, G.W., Portela, R., Honzák, M. and Batker, D., 2014: A Methodology for Adaptable and Robust Ecosystem Services Assessment. *PLoS ONE*, **9**(3): e91001.

Key finding 2.3: The spatial and temporal scales at which scenarios and models need to be applied also vary markedly between different policy and decision contexts. No single set of scenarios and models can address all pertinent spatial and temporal scales, and many applications will require linking of multiple scenarios and models dealing with drivers or proposed policy interventions operating at different scales (chapters 1–6, 8; figure SPM.6; table SPM.2). Assessment and decision-support activities, including those undertaken or facilitated by IPBES, will require short-term (ca. 5–10 years), medium-term and long-term (2050 and beyond) projections. IPBES assessments will focus on regional and global scales, but should also build on knowledge from local-scale scenarios and models. The use of scenarios and models in assessments and decision support more broadly (beyond IPBES) requires applications at a wide range of spatial scales. Techniques for temporal and spatial scaling are available for linking across multiple scales, although substantial further improvement and testing of these is needed.

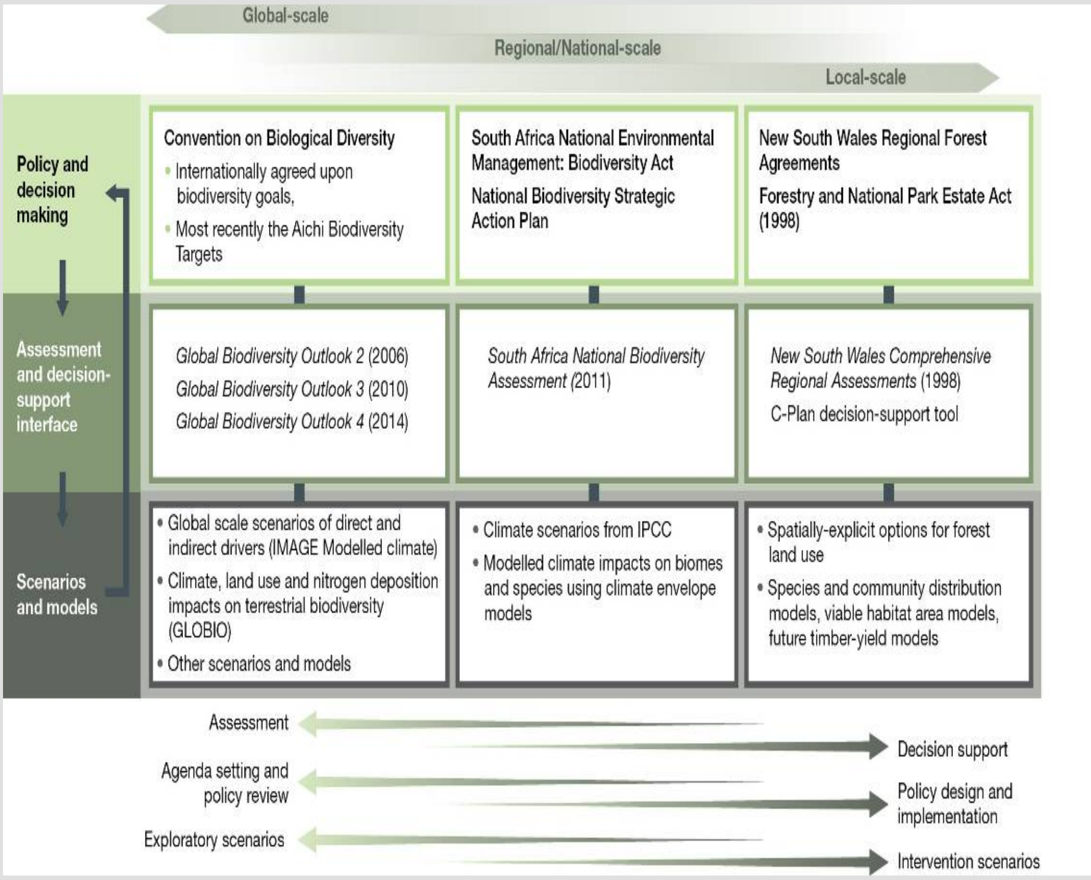

Figure SPM.6 – Examples of the use of scenarios and models in agenda setting, policy design and policy implementation relating to the achievement of biodiversity targets across a range of spatial scales. The diagram indicates the typical relationships between spatial scale (top arrows), type of science-policy interface (upper set of arrows at bottom), phase of the policy cycle (middle set of arrows at bottom) and type of scenarios used (lower set of arrows at bottom). See chapter 2 for further details and references.

Key finding 2.4: Scenarios and models can benefit from mobilization of indigenous and local knowledge because these can fill important information gaps at multiple scales, and contribute to the successful application of scenarios and models to policy design and implementation (chapter 7). There are numerous examples of successful mobilization of indigenous and local knowledge for scenario analysis and modelling, including scenarios and models based primarily on that knowledge source (Box SPM.1). However, substantial efforts are needed to broaden the involvement of such knowledge. Improving mobilization of indigenous and local knowledge will require efforts on several fronts including development of appropriate indicators, mechanisms for accompanying knowledge holders, collection of such knowledge and interpretation into forms that can be used in scenarios and models, and translation into accessible languages.

Box SPM.1. Incorporation of indigenous and local knowledge (ILK) into models informing decision-making. Bolivia's National Programme of Conservation and Sustainable Utilization (PNCASL) for the customary harvest and conservation of caiman (*Caiman yacare*) illustrates a case study of successful integration of ILK into biodiversity models to inform policy options. Previously, harvest quotas were estimated based on broad scale estimates of relative abundance from scientific surveys, with substantial variation between regions. Following increasing engagement of local communities in PNCASL, new biological, socio-economic and cultural indicators of species health and abundance were developed and trialled. One of the first trials took place in the Indigenous Territory and National Park Isiboro Sécure (TIPNIS), where traditional knowledge on the status of caiman was incorporated into the development of robust indicators to inform resource quotas for customary harvest within this protected area. Traditional resource users participated in workshops where they defined concepts, harmonized criteria and conceptualized traditional knowledge of caiman habitats and territories into spatial maps. Models for estimating population abundance were adapted to make use of indigenous techniques suggested by the communities and to incorporate qualitative indicators such as individuals' perceptions of changes in caiman abundance, e.g., accounting for information from statements such as "there are a lot more caiman than before". The process was repeated with communities across the TIPNIS territorial region and yielded a combined caiman population estimate for the protected area based on local knowledge. This estimate was used to develop a national-scale predictive model of abundance, which then informed national, regional and local policy options for improving the sustainable management of caiman harvest. Resulting management plans for indigenous territories and protected areas have been recognized as contributing to increases in caiman abundance in areas where they had been locally depleted and in reducing illegal hunting. See box 7.1 in chapter 7 for additional details and references.

Key finding 2.5: All scenarios and models have strengths and weaknesses, and it is therefore vital that these capacities and limitations be carefully evaluated and communicated in assessment and decision processes. Sources and levels of uncertainty should also be evaluated and communicated (Tables SPM.1 and SPM.2). Strengths and weaknesses may depend on the specific decision support context for which scenarios and models are being used and are related to aspects such as spatial and temporal extent, types of model inputs and outputs, flexibility and ease of use, among others. Uncertainty in scenarios and models arises from a variety of sources, including insufficient or erroneous data used to construct and test models; lack of understanding, or inadequate representation, of underlying processes; and low predictability of the system (e.g., random behaviour).

High-level message 3: Appropriate planning, investment and capacity-building, among other efforts, could overcome significant remaining challenges in developing and applying scenarios and models.

Key finding 3.1: Currently available scenarios, including those developed by previous global-scale assessments, do not fully address the needs of IPBES assessments due to incomplete consideration of relevant drivers, policy goals and intervention options at appropriate temporal and spatial scales (chapters 3 and 8). See box SPM.2 for further explanation of this finding, particularly in relation to the scenarios assessed by the Intergovernmental Panel on Climate Change (IPCC) and their derivatives.

Box SPM.2 – Scenarios in the context of IPCC and their relationship to IPBES

IPCC assessments, the Millennium Ecosystem Assessment, the Global Biodiversity Outlook 2, the Global Environmental Outlook and the Global Deserts Outlook have used related global storylines to generate scenarios. Regional assessments of the Millennium Ecosystem Assessment and the Global Environmental Outlook, as well as the national components of the Global Environmental Outlook such as those carried out for the United Kingdom, China and Brazil, have used globally consistent regional variants of existing storylines.

IPCC scenarios and pathways are developed in close collaboration with the scientific community. The scenarios of the Special Report on Emissions Scenarios (SRES) from 2000, which was long employed by IPCC, have given way to a new framework based on the representative concentration pathways (RCP) and shared socioeconomic pathways (SSP) developed by the scientific community. Representative concentration pathways are constructed from radiative forcing values of greenhouse gases and represent a range of plausible futures corresponding to a strong mitigation assumption , two intermediate stabilization assumptions and one high emissions assumption . Newly formulated shared socioeconomic pathways explore a wide range of socioeconomic factors that would make meeting mitigation and adaptation more or less difficult (O'Neill et al., 2014.)[4]

IPCC assesses relevant scenarios and pathways available from science and in their current form the resulting scenarios pose a number of challenges for use in IPBES assessments, including (i) an incomplete set of direct and indirect drivers needed to model impacts on biodiversity and ecosystem services (e.g., invasive species and exploitation of biodiversity); (ii) adaptation and mitigation strategies that focus on climate change (e.g., large-scale deployment of bioenergy), sometimes to the detriment of biodiversity and key aspects of human well-being; and (iii) a focus on long-term (decades to centuries) global-scale dynamics, which means that the scenarios are often inconsistent with short-term and sub-global scale scenarios. Therefore biodiversity and ecosystem services require specific efforts in the development of scenarios, including further collaboration efforts.

Close collaboration between IPBES, IPCC and the scientific community would provide the opportunity to build on the strengths of the new shared socioeconomic pathways scenarios and at the same time match the needs of IPBES (See IPBES Guidance Point 1 for further discussion of the benefits of this potential collaboration.)

For more information see chapters 3 and 8.

Key finding 3.2: There is a wide range of models available to assess impacts of scenarios of drivers and policy interventions on biodiversity and ecosystem services, but important gaps remain (chapters 4, 5, 8). Those include gaps in (i) models explicitly linking biodiversity to nature's benefits to people (including ecosystem services) and good quality of life; (ii) models addressing ecological processes on temporal and spatial scales relevant to the needs of assessment and decision-support activities, including IPBES assessments; and (iii) models anticipating, and thereby providing early warning of, ecological and socio-ecological breakpoints and regime shifts.

Key finding 3.3: Scenarios and models of indirect drivers, direct drivers, nature, nature's benefits to people and good quality of life need to be better linked in order to improve understanding and explanations of important relationships and feedbacks between components of coupled social-ecological systems (chapter 6). Links between biodiversity, ecosystem functioning and ecosystem services are only weakly accounted for in most assessments or in policy design and implementation (chapters 4 and 5). The same applies for links between ecosystem services and quality of life (chapter 5) and integration across sectors (chapters 1 and 7). As such, it is currently challenging to evaluate the full set of relationships and feedbacks set out in the conceptual framework of IPBES.

[4] O'Neill, B.C., Kriegler, E., Riahi, K., Ebi, K.L., Hallegatte, S., Carter, T.R., Mathur, R. and van Vuuren, D.P., 2014: A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change*, **122**(3): 387-400.

Key finding 3.4: Uncertainty associated with models is often poorly evaluated and reported in published studies, which may lead to serious misconceptions – both overly-optimistic and overly-pessimistic – regarding the level of confidence with which results can be employed in assessment and decision-making activities (all chapters). While many studies provide a discussion of the strengths and weakness of their modelling approach, most studies do not provide a critical evaluation of the robustness of their findings by comparing their projections to fully independent data sets (i.e., data not used in model construction or calibration) or to other types of models. This greatly reduces the confidence that decision makers can and should have in projections from models.

Key finding 3.5: There are large gaps in data availability for constructing and testing scenarios and models, and significant barriers remain to data sharing (chapters 7 and 8, figure SPM.7). The spatial and temporal coverage and taxonomic spread of data on changes in biodiversity, ecosystems and ecosystem services is uneven Similarly, there are large gaps in data for indirect and direct drivers, and there are often spatial and temporal mismatches between data on drivers and on biodiversity and ecosystem services. Much progress has been made in mobilizing existing data on biodiversity, ecosystem services and their drivers, but barriers to data sharing still need to be overcome, and major gaps in the coverage of existing data filled.

Key finding 3.6: Human and technical capacity to develop and use scenarios and models varies greatly between regions (chapter 7). Building capacity requires the training of scientists and policy practitioners in the use of scenarios and models, and improving access to data and user-friendly software for scenario analysis, modelling and decision-support tools. Rapidly growing online access to a wide range of data and modelling resources can support capacity-building.

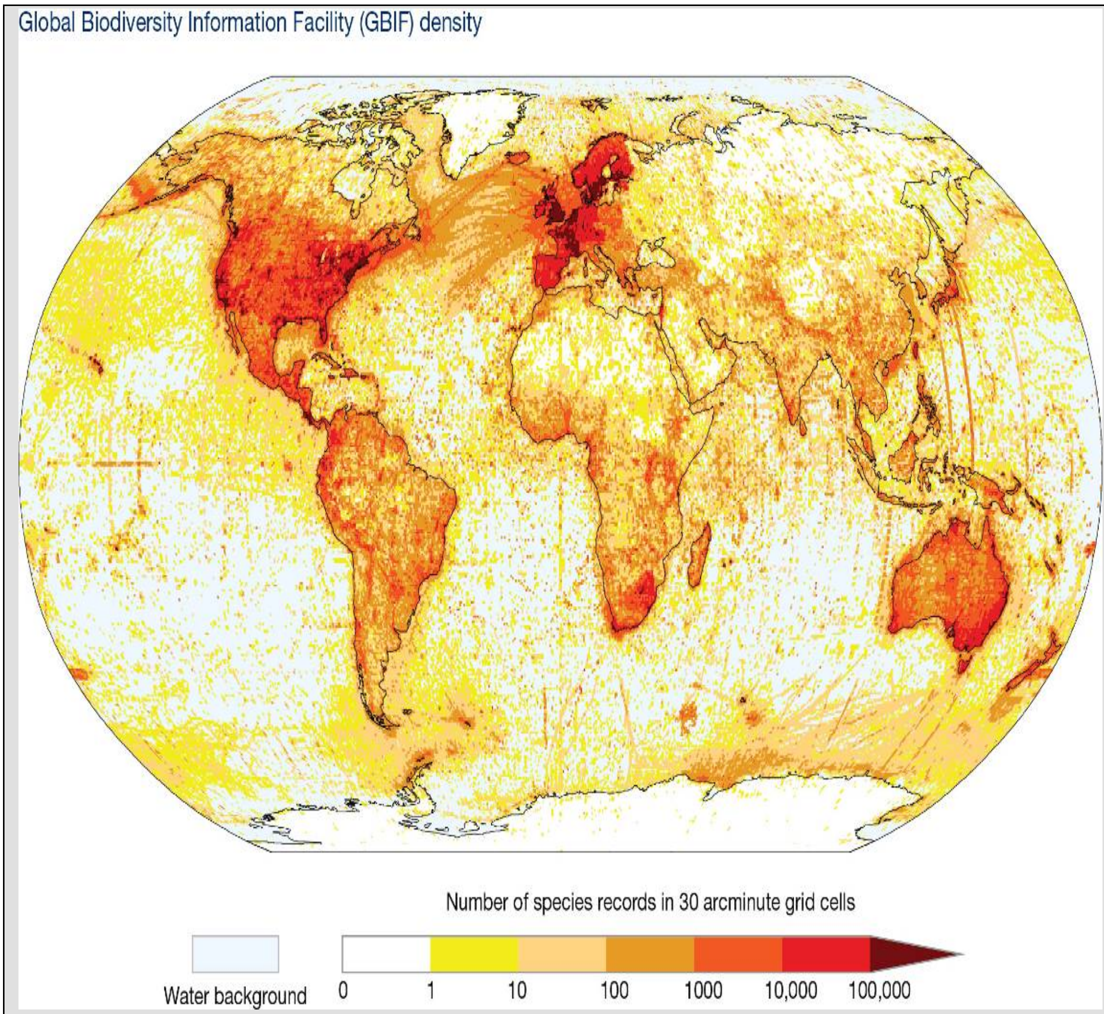

Figure SPM.7 – An example of spatial bias in the availability of biodiversity data. The map depicts the spatial distribution of species records currently accessible through the Global Biodiversity Information Facility. Colours indicate the number of species records per 30 arcminute (approximately 50 km) grid cell. These data are frequently used for model development and testing. Source: www.gbif.org. See chapters 7 and 8 for details and discussion.

Guidance for science and policy

The following lessons from best practices for building greater understanding of, strengthening approaches to, and making more effective use of scenarios and models, were identified:

Guidance point 1: Scientists and policy practitioners may want to ensure that the types of scenarios, models and decision-support tools employed are matched carefully to the needs of each particular policy or decision context (chapters 2–5). Particular attention should be paid to (i) the choice of drivers or policy options that determine the appropriate types of scenarios (e.g., exploratory, target-seeking or policy screening); (ii) the impacts on nature and nature's benefits that are of interest and that determine the types of models of impacts that should be mobilized; (iii) the diverse values that need to be addressed and that determine the appropriate methods for assessing these values; and (iv) the type of policy or decision-making process that is being supported and that determines the suitability of different assessment or decision-support tools (e.g., multi-criteria analysis and management strategy evaluation).

Guidance point 2: The scientific community, policymakers and stakeholders may want to consider improving, and more widely applying, participatory scenario methods in order to enhance the relevancy and acceptance of scenarios for biodiversity and ecosystem services. This would include broadening the predominantly local-scale focus of participatory approaches to regional and global scales (chapters 2, 3, 7 and 8). Such an effort would facilitate the dialogue between scientific experts and stakeholders throughout the development and application of scenarios and models. Broadening participatory methods to regional and global scales poses significant challenges that will require greatly increased coordination of efforts between all actors involved in developing and applying scenarios and models at different scales.

Guidance point 3: The scientific community may want to give priority to addressing gaps in methods for modelling impacts of drivers and policy interventions on biodiversity and ecosystem services. These gaps have been identified in Chapter 8 of the assessment, with additional specifics identified in chapters 3–6). Work could focus on methods for linking inputs and outputs between major components of the scenarios and modelling chain (chapter 8), and on linking scenarios and models across spatial and temporal scales. High priority should also be given to encouraging and catalysing the development of models, and underpinning knowledge, that more explicitly link ecosystem services – and other benefits that people derive from nature – to biodiversity, as well as to ecosystem properties and processes. One means of achieving this would be to advance the development of integrated system-level approaches to linking scenarios and models of indirect drivers, direct drivers, nature, nature's benefits to people and good quality of life, to better account for important relationships and feedback between those components (chapter 6; figure SPM.8). That could include encouraging and catalysing the extension of integrated assessment models, already being employed widely in other domains (e.g., climate, energy and agriculture), to better incorporate modelling of drivers and impacts of direct relevance to biodiversity and ecosystem services.

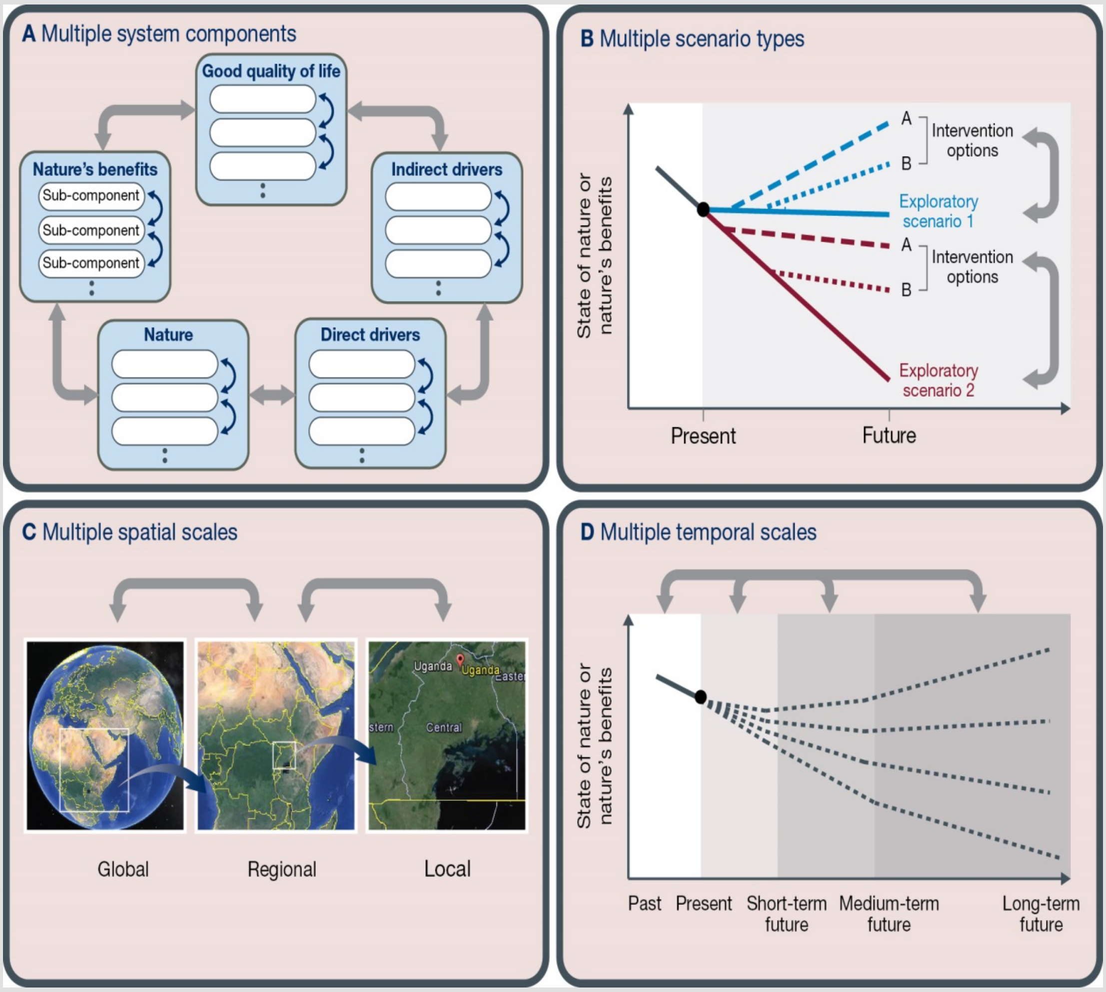

Figure SPM.8 – Linking scenarios and models in four key dimensions: system components, scenario types, spatial scales and temporal scales, with the thick grey arrows indicating linkages within each dimension. Panel A illustrates linkages between scenarios and models across the different components of the conceptual framework (thick grey arrows) as well as between their sub-components (thin blue arrows; for example linking biodiversity with ecosystem function
sub-components of nature). Panel B shows ways in which different types of scenarios, such as exploratory and intervention scenarios, can be linked. Panel C indicates linkages across spatial scales from local to global. Panel D illustrates linking the past, present, and several time horizons in the future (dashed lines indicate a range of exploratory scenarios). Two or more of these dimensions of linkages can be used in combination (e.g., linking different types of scenarios across spatial scales). See chapter 6 for details.

Guidance point 4: The scientific community may want to consider developing practical and effective approaches to evaluating and communicating levels of uncertainty associated with scenarios and models, as well as tools for applying those approaches to assessments and decision-making (overview in chapter 8; specifics in chapters 2–7). This would include setting standards for best practice, using model-data and model-model inter-comparisons to provide robust and transparent evaluations of uncertainty, and encouraging new research into methods of measuring and communicating uncertainty and its impacts on decision-making.

Guidance point 5: Data holders and institutions may want to consider improving the accessibility of well-documented data sources and working in close collaboration with research, and observation communities (including citizen science) and communities working on indicators to fill gaps in data collection and provision (overview in chapter 8; more specific recommendations in chapters 2–7). In many cases, this will coincide with efforts to improve collection of and access to data for quantifying status and trends. However, models and scenarios need additional types of data for development and testing that should be taken into account when developing or refining monitoring systems and data-sharing platforms.

Guidance point 6: Human and technical capacity for scenario development and modelling may need to be enhanced, including through the promotion of open, transparent access to scenario and modelling tools, as well as the data required for their development and testing (chapter 7; table SPM.3). This can be facilitated through a variety of mechanisms, including (i) supporting training courses for scientists and decision makers; (ii) encouraging rigorous documentation of scenarios and models; (iii) encouraging the development of networks that provide opportunities for scientists from all regions to share knowledge including through user forums, workshops, internships and collaborative projects; and (iv) using the catalogue of policy support tools developed by IPBES to promote open access to models and scenarios, where possible in multiple languages.

Table SPM.3 - Capacity-building requirements for development and use of scenarios and models of biodiversity and ecosystem services. See chapter 7 for details.

Activity	Capacity-building requirements
Stakeholder engagement	• Processes and human capacity to facilitate engagement with multiple stakeholders, including holders of traditional and local knowledge
Problem definition	• Capacity to translate policy or management needs into appropriate scenarios and models
Scenario analysis	• Capacity to participate in development and use of scenarios to explore possible futures, and policy or management interventions
Modelling	• Capacity to participate in development and use of models to translate scenarios into expected consequences for biodiversity and ecosystem services
Decision making for policy and management	• Capacity to integrate outputs from scenario analysis and modelling into decision making
Accessing data, information and knowledge	• Data accessibility • Infrastructure and database management • Tools for data synthesis and extrapolation • Standardisation of formats and software compatibility • Human resources and skill base to contribute to, access, manage and update databases • Tools and processes to incorporate local data and knowledge

Guidance for IPBES and its task forces and expert groups

IPBES guidance point 1: Experts planning to employ scenarios and models in IPBES thematic, regional and global assessments may want to consider maximizing the benefit derived from analysing and synthesizing results from existing applications of policy-relevant scenarios and models (chapters 3–5). Even where the timing of future IPBES assessments, including the global assessment, allows for the development of new scenarios (see IPBES guidance point 2) any such development needs to build on, and complement, the effective analysis and synthesis of existing scenarios and models. Experience from previous assessments on the global and regional scales suggests that the full cycle of new scenario development through to final analysis of impacts based on modelling requires several years of effort to generate results of sufficient rigour and credibility for the purposes of IPBES assessments. Experts involved in regional and thematic assessments already under way should therefore focus on working closely with other relevant IPBES deliverables and the wider scientific community to harness the power of new approaches to analysing and synthesizing best available exploratory, target-seeking and policy-screening scenarios on the global, regional, national and local scales. The approaches adopted for the four regional assessments should be coherent enough to enable the collective contribution of results to the global assessment while still allowing for significant regional differences.

IPBES guidance point 2: IPBES may want to consider encouraging and working closely with the wider scientific community to develop a flexible and adaptable suite of multi-scaled scenarios specifically tailored to its objectives. This would mean adopting a longer-term strategic view of catalysing the development of scenarios that meet its needs and would involve working closely with the scientific community to articulate criteria guiding the development of new scenarios by that community. Table SPM.4 summarizes several criteria that are important for the specific needs of IPBES (see also chapters 1, 3 and 8 and figure SPM.8), many of which go well beyond the criteria underlying the current development of other scenarios such as the Shared Socioeconomic Pathways (SSPs) being catalysed by IPCC (box SPM.2). IPBES would, however, benefit from close collaboration and coordination with regard to ongoing activities within the scientific community developing the SSPs. The advantage of using the SSPs as a common resource for IPBES and IPCC include saving of effort, increasing consistency and improving aspects of the SSPs that would be of mutual benefit for IPBES and IPCC. Developing a full suite of interlinked scenarios as outlined in table SPM.4 would require catalysing research on a variety of types of scenarios on multiple spatial and temporal scales. This should therefore be viewed as a long-term objective.

IPBES guidance point 3: In order to overcome barriers to the use of scenarios and models, it is important that IPBES [member States] continue to support and facilitate capacity-building within the scientific community and amongst policymaking and decision-making practitioners (chapters 2 and 7). The IPBES task force on capacity-building could play a vital role in achieving this by helping to build human and technical capacity, specifically targeting the skills needed for the development and use of scenarios and models. Such engagement should link, where appropriate, with relevant networks and forums that are already established within the scientific and practitioner communities. IPBES should also set high standards of transparency for all scenarios and models used in its assessments, or promoted through the deliverable on policy support tools and methodologies.

IPBES guidance point 4: Because of the highly technical nature of scenarios and models, it is preferable that all of the IPBES deliverables involve experts with knowledge of the utility and limitations of scenarios, models and decision-support tools (chapter 1 for overview; all other chapters for specific guidance). This point can be addressed by encouraging nomination and selection of experts familiar with scenarios and models, keeping in mind that expertise is needed across the various classes of models and scenarios. Owing to the diversity and often highly technical nature of scenarios and models, the IPBES task forces and expert groups should also seek advice and support from the full report of the methodological assessment, the associated evolving guide on scenarios and models, and from relevant specialists involved in the IPBES deliverables, including the task force on knowledge, information and data. Due to the importance of indigenous and local knowledge to the objectives of IPBES, particular consideration should be given to mobilizing experts with experience in formulating and using scenarios and models that mobilize indigenous and local knowledge, including participatory approaches (chapter 7). Experts involved in the IPBES deliverables should work closely with the indigenous and local knowledge task force in implementing those approaches. Broader use of participatory scenario methods in work undertaken or promoted by IPBES is one potentially important pathway for improving the contribution of indigenous and local knowledge.

IPBES guidance point 5: IPBES should consider putting in place mechanisms to help experts involved in the IPBES deliverables utilize scenarios and models and communicate results effectively. The experts involved in IPBES assessments will need to critically analyse and synthesize scenarios and models operating on different scales, so they are likely to require assistance (chapters 2–6, 8). Many experts involved in the IPBES deliverables will also need guidance in evaluating and communicating capacities and limitations of scenarios and models employed in those activities, along with types, sources and levels of uncertainty associated with resulting projections (all chapters). To that end, the task force on knowledge, information and data, ongoing work on the evolving guide for scenarios and models and other relevant deliverables should consider developing practical guidelines for evaluating and communicating capacities, limitations and uncertainties associated with scenarios and models.

IPBES guidance point 6: Scenarios and models can potentially be promoted through all of the IPBES deliverables, so the implementation plans of those deliverables should be reviewed to ensure they reflect such potential (chapter 1 for overview; all chapters for examples). Effective use of scenarios and models in policy formulation and implementation will require embedding of those approaches within decision-making processes across a wide range of institutional contexts and scales. IPBES can help to achieve this by complementing the use of scenarios and models in regional, global and thematic assessments with promotion and facilitation of their uptake by other processes beyond IPBES through its task forces on capacity-building, indigenous and local knowledge, and knowledge, information and data, as well as its deliverable on policy support tools and methodologies and the evolving guide on scenarios and models.

Table SPM.4 – Important characteristics of scenarios that could be catalysed by IPBES in support of its activities. The framework for these scenarios might consist of a family of inter-related components rather than a single set of scenarios. These components could rely heavily on existing scenarios and scenarios being developed in other contexts, with a strong emphasis on participatory methods and on developing tools for creating and analysing linkages between spatial scales, across temporal scales and between different types of scenarios (i.e., exploratory vs. intervention scenarios) as outlined in Figure SPM.8. See chapters 3 and 6 for further details.

Characteristics of an ideal suite of "IPBES scenarios"	Why important	Examples
Multiple spatial scales	Different drivers of change operate at different spatial scales. The relative importance of drivers also varies greatly across localities, countries and regions. Including regional, national and local scales improves opportunities for capacity building.	Southern Africa Ecosystem Assessment, European Union "OPERAS" and "OPENNESS" projects.
Multiple temporal scales	Decision-making often requires both short-term (c. 10 years or less) and long-term perspectives (multiple decades). Most international environmental assessments have focused only on longer time scales.	Global Biodiversity Outlook 4 (see Table SPM.1)
Multiple scenario types	Exploratory, target-seeking and policy-screening scenarios address different phases of the policy cycle.	Global Biodiversity Outlook 4 (primarily focused on exploratory and target-seeking scenarios)
Participatory	Engaging actors in the development of scenarios contributes significantly to capacity building in the science-policy interface and creates opportunities for engaging with indigenous and local knowledge.	Best examples are at local to national scales (see Table SPM.1, Figure SPM.4)
Strong interactions with scenarios development underway in other sectors	It is important to avoid duplication of efforts and over-mobilization of scientists and policy makers. Taking advantage of strong complementarities would be beneficial for all parties involved.	Ties with SSP activities for global scenarios (see Box SPM.2) in support of the IPCC. Links to other initiatives working with multi-scale scenarios.