CBD

UNEP

Distr.
GENERAL

UNEP/CBD/SBSTTA/16/INF/26
11 April 2012

ORIGINAL: ENGLISH

Convention on Biological Diversity

SUBSIDIARY BODY ON SCIENTIFIC,
TECHNICAL AND TECHNOLOGICAL ADVICE
Sixteenth meeting
Montreal, 30 April - 5 May, 2012
Item 7.2 of the provisional agenda*

BIODIVERSITY AND CLIMATE CHANGE: EXAMPLES OF BIOCLIMATIC MODELS

Note by the Executive Secretary

INTRODUCTION

1. The Second Ad hoc Technical Expert Group (AHTEG) on biodiversity and climate change considered the impacts of climate change on biodiversity. In doing so, the AHTEG recognized a number of gaps in knowledge linked to a lack of complete and comprehensive models linking biodiversity and climate change and gaps in associated, biological, ecological and climatic data.

2. In addition to the AHTEG findings, the need for improved models linking climate and biological processes has been recognized by a number of other bodies and processes. For example, the Nairobi work programme on impacts, vulnerability and adaptation to climate change under the United Nations Framework Convention on Climate Change, in its seventh call for action noted the need for improving "the accuracy of climate projections by strengthening research on biophysical and physical climate systems..."[1]. In addition, the meeting on Future Climate Change Research and Observations convened by the World Meteorological Organization, the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP), and the International Geosphere-Biosphere Programme (IGBP) called for, the development and enhancement of, "national and regional observational networks and data rescue activities that provide data on the same scale as the required downscaling activity, including collection, archiving and access. The data requirements encompass physical, chemical and biological datasets."[2]

3. Although significant gaps remain, a number of projects and programmes have already been supported or are underway to improve models assessing the impacts of climate change on biodiversity including through improving the data available as inputs to such models. In order to assist Parties, other governments and relevant organizations in addressing the remaining gaps, the following note has been prepared by the Executive Secretary. The note contains an introduction to models and modelling concepts and examples of projects and programmes modelling biodiversity – climate change interactions.

KEY ISSUES IN MODELING BIODIVERSITY – CLIMATE CHANGE INTERACTIONS

Types of Models

4. Various types of modelling tools exist for predicting impacts of climate change on biodiversity and/or ecosystem services. Scale, data and resource needs, and knowledge gaps may affect the type of model most appropriate.

5. When considering the climate portion of models, for example, Coupled Atmosphere-Ocean General Circulation Models (AOGCMs), used for global and continental predictions, typically operate on coarse resolutions (150-300 km) whereas broad categories of downscaling include: High-resolution "time-slice" Atmosphere General Circulation Models (AGCMs); Variable resolution AOGCMs (VarGCMs); Nested Regional Climate Models (RCMs); and statistical downscaling (SD) methods. Each regionalization method is being used in an increasingly wider range of applications however major source of uncertainty are cloud feedbacks, cryospheric processes, extreme and tropical precipitation patterns and southern ocean dynamics.

* UNEP/CBD/SBSTTA/16/1.

[1] http://unfccc.int/files/adaptation/sbsta_agenda_item_adaptation/application/pdf/cfa_modelling.pdf

[2] http://wcrp.wmo.int/documents/SydneyWorkshopRep_FINAL.pdf

/…

6. Such climate models can be combined with biological or ecological information as bioclimatic models. The Intergovernmental Panel on Climate Change, in its Third Assessment Report, defines bioclimatic models as, models "…used to determine the strength of association between suites of biotic and abiotic variables and species distributions. These associations can then be used to predict responses to environmental change, including climatic change."[3].

7. Integrative models have emerged in recent years and predict global climate change and social and environmental consequences, integrating climate science, technological change, economics, and policy. Some of these models are scalable and appropriate for regional use, but the resolution of the output depends on the quality of data being used for the input. Furthermore, integrative models are at a relatively nascent stage and need to be validated and verified against observed data. Currently, ecosystem service data are scarce and on coarse scale.

8. Multi-model combinations are also emerging as more accurate predictors of climate change impacts on biodiversity. Specifically, by considering the weighted outputs of a number of models assessing the same process, multi-model combinations are able to minimize errors from both input data and the individual forecast models. This is particularly relevant when modelling interactions with high levels of uncertainty and high margins of error, for example, changes in hydrology and associated impacts on biodiversity.

9. Additional information and examples of biophysical models, integrated assessment tools, Bioclimatic Envelope/Ecological Niche Models and biodiversity indicator models are presented in table 1 below.

10. In addition to selecting the appropriate type of model, the scale of models is also an important consideration. For example, while finer scale models are required for local decision-making, it has been shown that downscaling techniques require that we make assumptions that introduce uncertainty in the process[4]. Assumptions made with insufficient caution will result in erroneous models. Therefore, it is recommended that this reality be taken into account in order to maintain a balance between the resolution of climate models and the number of assumptions required to generate them.

Improving basic biodiversity and ecosystem services data

11. There are a number of ongoing efforts to support the collection and dissemination of basic biodiversity data under other programmes of work and cross-cutting issues within the CBD. These include national, regional and global efforts to develop biodiversity data in response to reporting needs under the Strategic Plan for Biodiversity 2011-2020 and the associated Aichi Targets. For example, GEO-BON conducted a global assessment of data sets that could be used to develop indicators to monitor progress towards the Strategic Plan (http://www.cbd.int/doc/meetings/ind/ahteg-sp-ind-01/information/ahteg-sp-ind-01-inf-01-en.pdf). Furthermore, an assessment on the use of indicators by national governments based on the fourth national reports contains additional information that may be of use to Parties (http://www.cbd.int/doc/meetings/ind/ahteg-sp-ind-01/information/ahteg-sp-ind-01-inf-02-en.pdf).

Improving Access to Climate Data

12. Significant international efforts are targeting the need to improve access to climate data. In September 2009, at the World Climate Conference-3 in Switzerland, a Global Framework for Climate Services was established to strengthen production, availability, delivery and application of science-based climate prediction and services[5]. Pursuant to this declaration, the World Meteorological Organization established a High-Level Taskforce on Global Framework for Climate Services, which prepared a report, including recommendations on proposed elements for this Framework and next steps, for consideration by the Sixteenth World Meteorological Congress. Additional resources within the World Meteorological Organization include:

- The National Meteorological and Hydrological Services which provides capacity-building, training, research and development to provide reliable climate observations and address gaps;
- The Global Observing System (GOS), which consists of a global network of observations over land, sea and in the atmosphere; and
- The Climate Information and Prediction Services (CLIPS) project and the Regional Climate Outlook Forums (RCOFs) to enhance climate applications and services, also provide an effective mechanism for capacity-building and user liaison at the regional and national levels, particularly in developing countries[6].

[3] IPCC Third Assessment Report - Climate Change 2001, Working Group II: Impacts, Adaptation and Vulnerability

[4] Estrada, F., B.Martínez-López, C.Conde, C.Gay-García 2012. The new national climate change documents of Mexico: what do the regional climate change scenarios represent? Climate Change 110:1029-1046

[5] http://www.wmo.int/wcc3/declaration_en.php

[6] http://www.wmo.int/pages/publications/showcase/documents/WMO_1025_web_E.pdf

13. Regionally, the Africa Adaptation Programme (AAP) under UNDP supports improved access to, understanding of and application for climate data and information[7]. Also at the regional level, the Incheon Declaration on Disaster Risk Reduction in Asia and the Pacific 2010 calls on various stakeholders to, *inter alia*, increase availability of user-friendly climate information at all scales for community action[8] through a regional roadmap called Incheon REMAP including strengthening disaster risk reduction and climate change adaptation education and training, monitoring vulnerability, risk, hazards and resilience regularly and sharing the subsequent information.

Integrating Observations from Indigenous Peoples and Local Communities

14. There are a number of past and ongoing processes that may help addressing obstacles to the enhanced integration of climate change observations from indigenous peoples and local communities in so far as they relate to biodiversity. For example, in 2008, the Secretariat of the CBD convened a workshop on opportunities and challenges of responses to climate change for Indigenous and Local Communities, their Traditional Knowledge and biological diversity, in Helsinki, Finland. Discussions touched on both scientific findings and on observations of impacts as noted by indigenous and local communities and how both types of information can be best integrated into future considerations of biodiversity and climate change.

15. Furthermore, under the thematic area on climate change, the United Nations University – Traditional Knowledge Initiative focuses its research on the impacts of climate change on indigenous peoples, contributions that traditional knowledge can make to addressing climate change, and ways to promote participation in international processes[9]. This has included an international workshop on Indigenous Peoples, Marginalized Populations and Climate Change: Vulnerability, Adaptation and Traditional Knowledge convened in Mexico City, Mexico (19-21 July 2011) by United Nations University (UNU), Intergovernmental Panel on Climate Change (IPCC), Secretariat of the Convention on Biological Diversity (SCBD), United Nations Development Programme (UNDP) and United Nations Educational, Scientific and Cultural Organization (UNESCO) in collaboration with the Mexican National Institute of Ecology (INE). The aim of the workshop was to identify, compile and analyze relevant indigenous and local observations, knowledge and practices related to understanding climate change impacts, adaptation and mitigation[10].

[7] Africa Adaptation Programme: Capacity Building Experiences, Improving Access, Understanding and Application of Climate Data and Information. UNDP Discussion Paper Series Vol. 2, June 2011
[8] http://www.unisdr.org/we/inform/publications/20382
[9] http://www.unutki.org/default.php?doc_id=13
[10] http://www.unutki.org/news.php?news_id=109&doc_id=6

Table 1. Overview of Models and Ecosystem Tools

Biophysical Models

The biophysical family of models includes hydrological and biogeochemistry (also known as global vegetation) models. They capture the impacts of climate change on biophysical processes that affect ecosystem services, such as changes in groundwater recharge, soil moisture, vegetation growth, element cycling, and energy exchanges between vegetation, soil and the atmosphere.

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
Universities of Kassel and Frankfurt	WaterGAP, Water Balance Model (WBM), SWAT	Hydrological model for determining global water availability, water use, water quality (industry, agriculture and domestic) http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/WaterGAP/index.html	Evapotranspiration Groundwater recharge Soil moisture Discharge Annual renewable water resources	Sub-national National Global [River basin (1162 basins included), grid cells 0.5° by 0.5°]	Calibrated and validated, has been used in several assessments; Not available for download
Colorado State University	CENTURY	Biogeochemistry model that assesses the impacts of regional climate change on a variety of important grassland ecosystems by imulateing C, N, P, and S dynamics through an annual cycle over time scales of centuries and millennia http://www.nrel.colostate.edu/projects/century/	Tree and crop production	Sub-national National [Aggegation on the basis of land management: cropland and grassland, forest, savanna]	Not spatially explicit; Widely used in global change research; Freely available for download; Can b e coupled to vegetation growth models
National Resource Ecology Laboratory, Colorado State University	SAVANNA	Biogeochemistry biome model, covers vegetation, animal population and management in grassland, shrublands, savanna and forested ecosystems http://www.nrel.colostate.edu/projects/savanna/	Plant and animal distribution (for functional groups) Livestock production Sustainability of systems Thresholds Habitat suitability	Sub-national [Resolution depending on input data and studied ecosystem (100-1000 grid cells)]	Has been calibrated and validated; Freely available for download; Highly integrated with plant and anima systems and hydrology
MIT Joint Programme on the Science and Policy of Global Change	Terrestrial Ecosystems Model (TEM)	Process-based ecosystem model that describes carbon and nitrogen dynamics of plants and soils for terrestrial ecosystems of the globe http://www.mbl.edu/eco42/#_wmh1_86613	Responses of terrestrial ecosystems to climate change Monthly estimates of important carbon and nitrogen fluxes and pool sizes of terrestrial ecosystems	Sub-national National Global [0.5 degrees Terrestrial	Requires specialized knowledge; Not available for download

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
		5027	The influence of soil thermal regime on terrestrial carbon and nitrogen		
Natural Resources Canada	EALCO (Ecological Assimilation of Land and Climate Observations)	Provides scientific support for ecosystem impact assessment at national scale; has the capability of assimilating large scale geospatial information including satellite observations, GIS datasets, and climate model outputs http://ess.nrcan.gc.ca/2002_2006/rcvcc/pdf/j28_ealcomodel.pdf	Responses of ecosystems to climate change - plant and ecosystem productivity, water conditions and hydrological cycles Carbon sequestration and greenhouse gas exchange Gross and net primary production Net ecosystem production	Sub-national [30 meter to 1 km] National [Canada] Continental [North America]	Specific to Canada; Not open source
Fisheries Centre, UBC	EwE (Ecopath with Ecosim)	EwE has three main components: Ecopath – a static, mass-balanced snapshot of the system Ecosim – a time dynamic simulation module for policy exploration Ecospace – a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas http://www.ecopath.org/	Projects impacts of fishing and climate change on ecosystems.	Global [Uses the 19 FAO statistical areas of the world as its finest geographical scale]	Open Source; Calibration and validation mechanisms available; Can be linked to other models; Requires expert knowledge
Other examples	LPJ, IBIS, ASSETS, GEEM, BIOME-BGC, E-SWAT	Ecosystem models integrating processes such as photosynthesis, respiration, competition, and biogeochemical cycles	Project shifts in distribution of terrestrial biomes with climate change scenarios; provides means to explore relationship between ecosystem services and shifts in distibutions	Sub-national National Global	

Integrated Assessment Tools

Integrated assessment tools are within the integrated model family, integrating both biophysical and socio-economic components to predict impacts of anthropogenic impacts such as land use change and climate change on ecosystem services. Because they integrate socio-economic considerations, they can be useful in guiding decision-making for natural resource planning.

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
International Food Policy Research Institute (IFPRI) of the CGIAR Network	IMPACT-Water (International Model for Policy Analysis of Agricultural Commodities and Trade)	Biogeochemical model that incorporates socio-economic information. http://www.ifpri.org/themes/impact.htm	Crop area, yield, production, demand for food, feed and other uses, prices, Livestock numbers, yield, production, demand, prices	Global [115 regions and countries, intersected with 126 river basins (281 spatial units), including EU-15 and eastern Europe] Aggregates data on national scale	Only biogeochemical model that incorporates feedback from ecosystem services to socio economic development, eg. Water availability; Used in many international assessments (e.g. MEA, GEO-4); Calibrated and validated; Full version difficult to access, limited freeware available
Netherlands Environmental Assessment Agency	IMAGE (Integrated model to assess the global environment)	Ecological-environmental framework that simulates the environmental consequences of human activities worldwide; represents interactions between society, the biosphere and the climate system to assess sustainability issues like climate change, biodiversity and human well-being http://www.pbl.nl/en/publications/2006/Integratedmodellingofglobalenvironmentalchange.AnoverviewofIMAGE2.4.html http://www.mnp.nl/en/themasites/image/index.html	Concentrations, emissions, energy, climate, effects of climate, land use, food production and demand	Global [0.5° x 0.5°]	Fine grid, good track record in assessments; Has been used for SRES, MA, and other global assessments
Gund Institute for Ecological Economics (U	MIMES (Multiscale Integrated	Multi-Ecosystem Service Assessment Tool MIMES builds on the GUMBO model to allow for spatial explicit modeling at	Value output in monetary terms, land area, and other parameters. global temperature, atmospheric carbon, sealevel, water, fossil	Sub-National National Global	Not spatially explicit; Open source, can be downloaded but requires simile software;

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
Vermont)	Models of Ecosystem Services)	various scales, Open source integrated suite of models (metamodel) that assess the value of ecosystem services and their linkages to human welfare under a suite of management scenarios defined by stakeholder input; quantifies the effects of varying environmental conditions derived from land use change. Incorporates feedback links between environmental conditions and socio-economic development. http://www.uvm.edu/giee/mimes2/downloads.html	and alternative energy, consumption, area of different land covers, knowledge, human, built and social capital, physical and monetary values for 11 ecosystem services, per capita food and welfare	[Scalable in time and space]	Accessible/user-friendly
Natural Capital Project (Stanford University), NCEAS, Nature Conservancy	InVEST[11] (Integrated Valuation of Ecosystem Services and Tradeoffs)	Multi-ecosystem Service Assessment Tool Open source decision-support tool to assess how scenarios might lead to different ecosystem service and human well-being related outcomes in particular geographic areas;	Spatially explicit: estimates levels and economic values of ecosystem services, biodiversity conservation, and the market value of commodities provided by the landscape. Examples of ES include carbon sequestration, soil conservation, food and timber production. Other uses: evaluating trade-offs among different uses for natural resources Currently being used to map of priority areas for conservation in China and Indonesia, for watershed protection in Columbia and Ecuador, and to advise carbon sequestration investments in Hawaii	Sub-National National Global [Scalable]	Open source; User-friendly; Enables users to input their own site-specific data; Allows for expert opinion as data to address data gaps; Enables consideration of present and future tradeoffs; Requires basic to intermediate skills in ArcGIS; no feedback between ecosystem services and land use change incorporated yet; Has been applied in many regions; Training workshops have been

[11] Nelson et al (2009)

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
					provided
Gund Institute for Ecological Economics (U Vermont); Developed at NCEAS by Constanza et al.	GUMBO (Global Unified Metamodel of the Biosphere)	Multi-ecosystem Service Assessment Tool Open-source 'metamodel' representing a synthesis/simplification of existing dynamic global models in natural and social sciences - includes dynamic feedbacks among human technology, economic production and welfare, and ecosystem. Incorporates feedback links between environmental conditions and socio-economic development. http://ecoinformatics.uvm.edu/projects/the-gumbo-model.html	Graphical/Numerical; Simulates future scenarios representing different assumptions about future technological change, investment strategies and other factor; predicts the relative value of ecosystem services in terms of their contribution to supporting both conventional economic production and human well-being global temperature, atmospheric carbon, sealevel, water, fossil and alternative energy consumption, area of different land covers, knowledge, human, built and social capital, physical and monetary values for 11 ecosystem services, per capita food and welfare	Global [Data aggregated on a regional or ecosystem/biome scale]	Not spatially explicit; Open source, but requires experts/specialists
Potsdam Institute for Climate Impact Research (PIK), Wageningen University	ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling)[12]	Multi-ecosystem Service Assessment Tool Decision-support tool; assesses the vulnerability to global change of sectors relying on ecosystem services. Suite of ecosystem models, covering biodiversity, agriculture, forestry, hydrology, and carbon sequestration run with SRES-based scenarios http://www.pik-potsdam.de/ateam/	Spatially explicit; Projections of changing ecosystem service supply and changing adaptive capacity integrated into maps of vulnerability for different human sectors. Vulnerability maps aid in making comparisons between ecosystem services, sectors, scenarios and regions to tackle multidisciplinary questions such as identifying vulnerable areas, comparing vulnerabilities, identifying most vulnerable sectors, testing results of scenarios	Global [10' x 10' (16 km x 16 km in Europe] [But scalable]	Open source; Accessible/user-friendly

[12] Metzger et al (2006)

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
U. Vermont Ecoinformatics "Collaboratory" (Gund Institute for Ecological Economics), Conservation International, Earth Economics, Wageningen University.	ARIES[13] (Artificial Intelligence for Ecosystem Services)	Multi-Ecosystem Service Assessment Tool Open source modelling program to help with decision-making by quantifying environmental assets and factors influencing their values, in a geographical area and according to needs and priorities set by its users. http://www.ariesonline.org/	Spatially explicit: ad-hoc, probabilistic models of both provision and usage of ES in a region of interest, and maps of the actual physical flows of those benefits to their beneficiaries, model flows of sediment, nutrients, and freshwater from land to nearshore ecosystems; Generate scenarios to explore changes in ecosystem service provision and use based on changes in ecosystem service supply or demand; Predicts changes to provisioning of ecosystem services under various potential climate futures	Sub-National National Global [Scalable] Case study: New Jersey[14]	Open source; Several local case studies underway; Custom ARIES interfaces can be built to simplify use by specific groups of end users; Few case studies available

Bioclimatic Envelope/Ecological Niche Models

Bioclimatic envelope models (also known as ecological niche models) are used to investigate current distributions of species (or groups of species) and to project changes under climate scenarios. The bioclimatic envelope is determined using climatic tolerance limits/thresholds expressed in terms of climate variables.

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
Group on Earth Observations (GEO)	GEOSS – Global Earth Observation System of Systems[15]	Scenario-based framework that integrates earth observation efforts of the 140 GEO members Projects biodiversity impacts of climate change into the future by demonstrating recent impacts of anthropogenic changes in the 20th century ;	Predicted species' ranges or abundances	Global	

[13] Villa et al (2009)
[14] Costanza et al (2007)
[15] Nativi and Mazzatti (2004)

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
Fisheries Centre, UBC[16]	Dynamic bioclimate envelope model (Environmental Niche Model)	Forecasts global patterns of climate change impacts on fisheries by projecting the distributional ranges of a sample of 1066 exploited marine fish and invertebrates for 2050	Global patterns of local extinction, invasion and their combined effects on species turnover for the year 2050 relative to year 2003	Global [30' lat x 30' lon cell]	Model has not yet been run at a finer-scale; Methodology published
UC San Diego, Princeton	Land Cover Projection[17]	Land Cover Projection Modeling framework that integrates the interacting effects of future climate and land-use changes; uses Millennium Ecosystem Assessment (MA) global scenarios	Expected changes to the geographic occurrence of 18 natural and human-made land-cover types; Estimation of bird habitat change and loss	Global 2500 km^2 grid cells	Methodology published; Tool not available online
Netherlands Environmental Assessment Agency	EUROMOVE	Empirical bioclimatic envelope modelling based on realized niches, species based logistic regression model by which occurrence probabilities can be calculated for almost 1400 European vascular plant species	Changes in plant species number and distribution (stable, increase, decrease)	National [Europe, 2500km^2 grid cells]	Not available online for use
University of California, San Diego, Environmental Resources Information Network (ERIN	GARP (Genetic Algorithm for Rule-set Production)	GIS-based bioclimatic envelope/environmental niche models that predict species distributions; Uses raster-based environmental and biological information to predict suitable habitat for a given species	Number of species Species distribution	Sub-National National Global [Scalable]	Methodology available online; Data requirements vary depending on species modelled; Has been used to predict future ranges of invasive species (Herborg et al. 2007)
	SAR (Species/Are	Biodiversity indicator model that predicts biodiversity loss due to habitat loss from	Number of species	Global	Not spatially explicit; Used as biodiversity indicators in

[16] Cheung et al (2010)
[17] Jetz et al (2007)

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
	a Relationship)	climate change, based on species area relationship			Millennium Ecosystem Assessment 2005; Easily calculated

Biodiversity Indicator Models/Other Planning Tools

Biodiversity indicator models use indirect drivers such as population and economic growth to predict changes in environmental drivers such as land use, in turn providing estimates/indicators of biodiversity.

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
NCEAS (National Center for Ecological Analysis and Synthesis), other partners[18]	Cumulative Impact Assessment	Biodiversity Indicator model; Analytical framework for calculating cumulative impact scores using expert opinion to quantify vulnerability of ecosystems to human drivers of ecological change; Used for implementing ecosystem-based management, marine protected areas, and ocean zoning http://www.nceas.ucsb.edu/GlobalMarine	Spatially explicit; Quantitative assessment of the spatial patterns of all human uses of the oceans and their cumulative effects	Sub-National National Global [Scalable] Case study: California, coral reef ecosystems, Canada's Pacific coast 1km^2 or 1 ha (0.01 km^2) resolution	Calibrated and ground-truthed; Widely used; Model considers a broad range of anthropogenic drivers including climate change, pollution, invasive species, and fisheries; Modeling process complex, but freely available
GLOBIO (UNEP World Conservation Monitoring Centre, UNEP GRID Arendal, Netherlands Environmental	GLOBIO3	Biodiversity Indicator model; framework to calculate the impact of five environmental drivers on land biodiversity for past, present and future. Uses spatial information on environmental drivers as input., derived from the Integrated Model to Assess the Global Environment (IMAGE).	Impacts of human induced environmental drivers on land biodiversity in past, present and future – estimates changes in mean species abundance and richness for all terrestrial locations (grid cells) on the planet; The relative importance of the environmental drivers;	Sub-national National Global (0.5 x 0.5 deg for climate data, 1 x 1 km for land use)	Not available for download, although methodology and key parameters are online; Has been used in major assessments; Terrestrial, aquatic version in development (GLOBIO-Aquatic)

[18] Halpern et al (2008, 2009)

Organization / Researcher	Model	Description	Outputs	Coverage/ Resolution	Benefits/Limitations
Assessment Agency)			Trends under future scenarios; Effects of policy response options, such as climate change mitigation, plantation forestry and protected areas		
Stockholm Environment Institute (SEI)	PoleStar	Scenario building and planning tool framework for building and assessing alternative development scenarios http://www.polestarproject.org/ http://www.seib.org/polestar	water and energy use, oil reserves left, CO2 emissions, agricultural requirements, pollution, poverty	Sub-National National Global [Scalable]	Easy to use, both a scenario-building tool and database of current indicators; Flexible and user-friendly ; Has been used for GEO-4 assessment; User manual available online
Forest Trends, Wildlife Conservation Society	BBOP (Business & Biodiversity Offset Programme)	Toolkit for corporate managers to assess whether biodiversity offsets are appropriate and providing guidance on design of these offsets	Biological and socioeconomic indicators to show net gain or loss of biodiversity	Sub-National National Global [Scalable]	Designed to sync with EIA; Flexible, due to emphasis on qualitative questions; Not spatially explicit
Fauna & Flora International, Brazilian business school FGV, and the United Nations Environment Program's Finance	NVI (Natural Value Initiative) Assessment Approach	Ecosystem Service assessment tool; An evaluation methodology for assessing biodiversity and ecosystem-services related risks and opportunities in the food, beverage and tobacco sectors. Not completely open source. http://www.naturalvalueinitiative.org/download/documents/Publications/LSNVExecSummary.pdf	Promotes greater awareness within the finance sector of (a) the business case for managing impacts on biodiversity and ecosystem services, and (b) the risks associated with mismanagement of resources Provides both guidance and case studies; tailored to the needs of the finance sector; Creates a risk profile based on publicly available information and direct corporate engagement	Sub-National	Methodology available online; Not spatially explicit; Qualitative assessments, does not incorporate ecosystem dynamics; Limited so far to food, beverage, tobacco, agriculture sectors

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