# SCENARIOS AND MODELS FOR EXPLORING FUTURE TRENDS OF BIODIVERSITY AND ECOSYSTEM SERVICES CHANGES

FINAL APPROVED REPORT 18th September 2009

# 1 APPENDICES OF CHAPTER 2: Identification and Overview of Available Models

## 1.1 General description of all selected models

### *1.1.1 Integrated Assessment Models*

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| **Model name** | **AIM** |
| **Full model name** | Asian Pacific Integrated Model |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | effects of policies on climate change and resource supply |
| **Input (key drivers and pressures)** | socio-economic trends and governmental policies |
| **Output (key variables)** | energy consumption, land use change affecting water supply, vegetation changes (agriculture, forestry production), human health (malaria spread) |
| **Geographical coverage and resolution** | 9 regions : USA, Western Europe OECD and Canada, Pacific OECD, Eastern Europe and Former Soviet Union, China and Central Planned Asia, South and East Asia, Middle East, Africa, Middle and South America (focussed on Asian-Pacific region, but linked to a global model), resultion: 5º by 5º |
| **Temporal coverage and resolution** | from 1990 to 2100, 5 year time steps until 2030 (+2050, 2075, 2100) |
| **Analytical technique** | Dynamic systems model |
| **Model developers and/or owners** | National Institute for Environmental Studies, Japan |
| **Model development history** | 1st version in 1994, latest update website: feb 2008 |
| **Target Group/users** | AIM was selected as reference model in the Special Report on Emission Scenarios (SRES) and in Third Assessment Report (TAR) both of Intergovernmental Panel on Climate Change (IPCC) and also in the Global Environment Outlook (GEO) of United Nations Environmental Program (UNEP). AIM simulation results were used by many other international organizations including OECD, ESCAP, ADB, UNU, and WWF. AIM can also be applied to other issues, such as local air pollution issues, acid rain problems, forest management policies and other energy, agricultural and water resource management problems. AIM was also used in the GEO assessments. |
| **Calibration** | Not available |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Kainuma et al., (2004), Kainuma et al., (2002; http://www-iam.nies.go.jp/aim/book/clim_pol_assess.htm) |
| **Level of integration** | Submodels are: the greenhouse gas emission model (AIM/emission), the global climate change model (AIM/climate), and the climate change impact model (AIM/impact). Estimates greenhouse gas emissions and assesses policy options to reduce them, predicts changes in global temperatures and effects on natural environments and socio-economy; integrates bottom-up national modules with top-down global modules, feedbacks between the three modules; country level models are linked to 'rest of the world' |
| **Scenarios used** | SRES, GEO-scenarios |
| **Links to other models** | AIM has been used together with IMAGE, WaterGAP, Polestar and EwE/EcoOcean in the IPCC and GEO-4 assessment. |
| **Ease of use/accessibility** | Not available for download |
| **Website** | http://www-iam.nies.go.jp/aim/index.htm |

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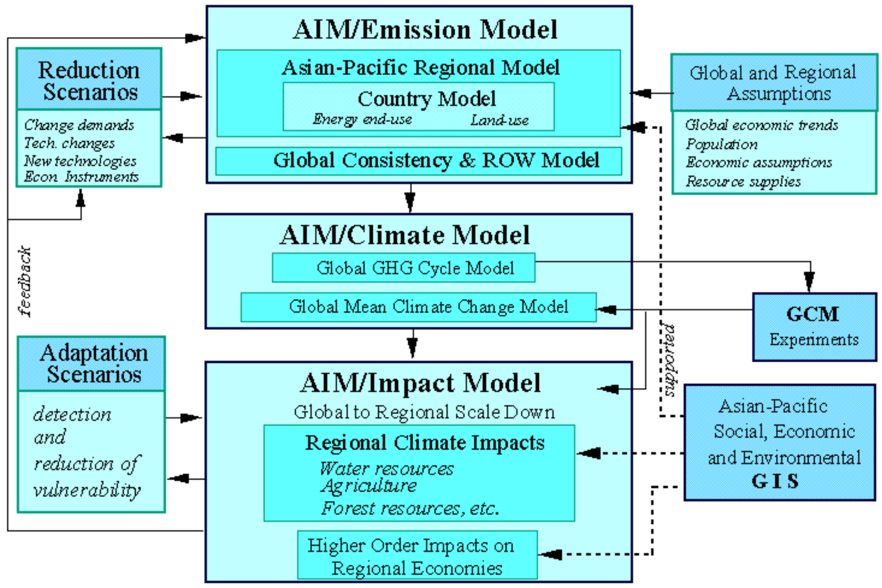
| **Model structure** |  |



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| **Model name** | **GUMBO** |
| **Full model name** | global unified metamodel of the biosphere |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | complex, dynamic interlinkages between social, economic and biophysical systems on a global scale, focusing on ecosystem goods and services and their contribution to sustaining human welfare |
| **Input (key drivers and pressues)** | Human population and GWP (economic goods and services) changes (economic investments, consumption) |
| **Output (key variables)** | 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 |
| **Geographical coverage and resolution** | global, 11 biomes globally aggregated, not spatially explicit |
| **Temporal coverage and resolution** | Base year: 2000, projections until 2100, annual time steps, historical data since 1900 |
| **Analytical technique** | dynamic systems model, meta-model (GUMBO relationships are base don outputs of more complex and computational intense models) |
| **Model developers and/or owners** | R. Costanza & R. Boumans, National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, CA |
| **Model development history** | first published: 2002, integrated into MIMES, modeling software: STELLA |
| **Target Group/users** | Main objective in creating the GUMBO model was not to accurately predict the future, but to provide simulation capabilities and a knowledge base to facilitate integrated participation in modeling. There are many (>100) internation collaborators. |
| **Calibration** | Historical callibration with time series from 1900/1950 to 2000 for 14 key variables (out of 930, of which: global temperatures and atmospheric carbon content) for which quantitative time-series data was available produced an average R2 of 0.922. |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Boumans et al., 2002, Werners et al., 2004, Costanza et al., 2007 |
| **Level of integration** | Both ecological and socioeconomic changes are endogenous to the model, with a pronounced emphasis on interactions and feedbacks between the two. Dyamic feedback between human technology, economic production, welfare and ecosystem services. |

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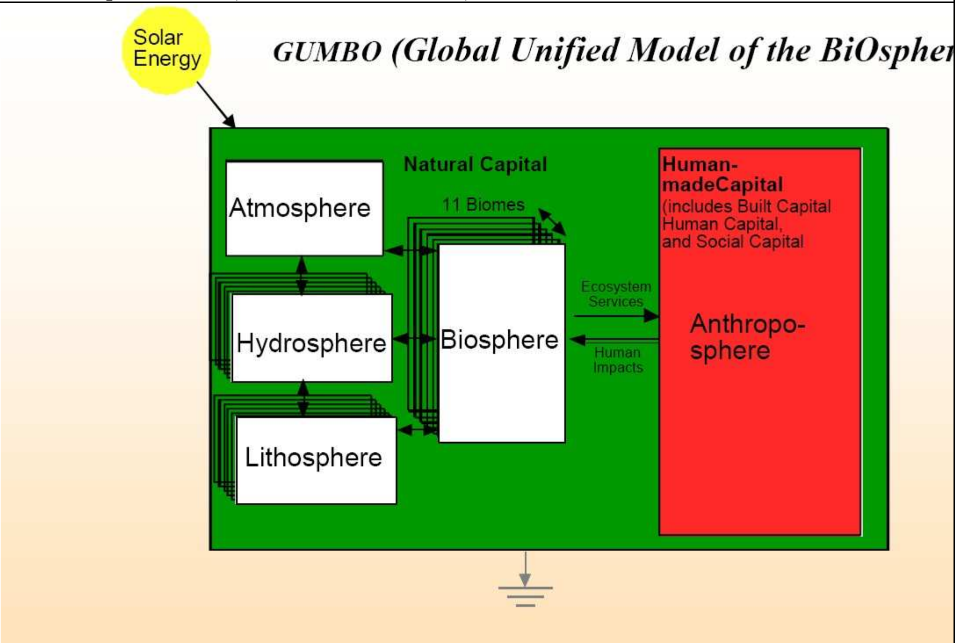
| | Modules to simulate carbon, water, and nutrient fluxes through the Atmosphere, Lithosphere, Hydrosphere, and Biosphere of the global system. Social and economic dynamics are simulated within the Anthroposphere. GUMBO links these five spheres across eleven biomes, which together encompass the entire surface of the planet. Limited degree of substitutablility between natural and social, human and built capital. |
| **Links to other models** | GUMBO is a metamodel which uses output from complex global models as input (which models are used, was not specified). |
| **Scenarios used** | MIMES/GUMBO, SRES |
| **Ease of use/accessibility** | The model can be downloaded and run on the average PC to allow users to explore for themselves the complex dynamics of the system and the full range of policy assumptions and scenarios. Commerical and consultancy uses have to be coordinated with developers/University of Vermont. |
| **Website** | http://ecoinformatics.uvm.edu/projects/the-gumbo-model.html |
| **Comments/remarks** | The current version of the model contains 234 state variables, 930 variables in total, and 1715 parameters (Boumans et al., 2002) |
| **Model structure** |   **From:** Boumans, R., R. Costanza, J. Farley, M. A. Wilson, R. Portela, J. Rotmans, F. Villa, and M Grasso. 2002. Modeling the Dynamics of the Integrated Earth System and the Value of Global Ecosystem Services Using the GUMBO Model. *Ecological Economics* 41: 529-560 |

| **Model name** | **IFs** |
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| **Full model name** | International Futures simulator |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | climate change, energy, agriculture, demography, economy, political and others, possible to add: education, human well-being including poverty |
| **Input (key drivers and pressures)** | Current situation describing demography, economic, agricultural, energy, socio-political, international political, environmental situation. The relationship functions between and within modules can be altered, depending on scenario assumption |
| **Output (key variables)** | Future situation describing demography, economic, agricultural, energy, socio-political, international political, environmental situation. |
| **Geographical coverage and resolution** | Global (with details for 182 regions/countries), not spatially explicit |
| **Temporal coverage and resolution** | Base year: 2000, projections until 2100 with annual time steps |
| **Analytical technique** | dynamic systems model (partial equilibrium modelling and multiple agent approaches), economic model: CGE |

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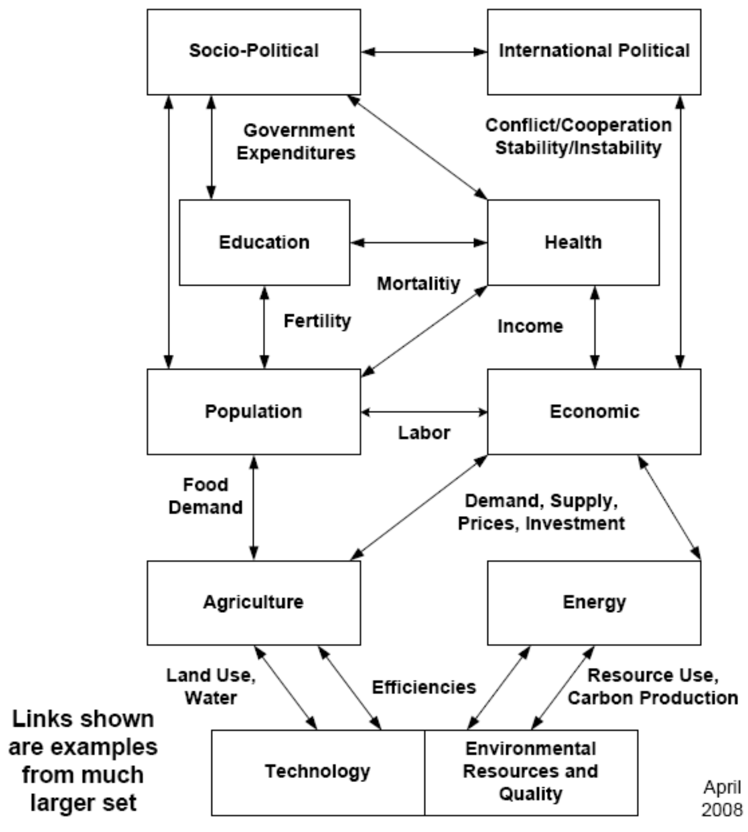
| **Model developers and/or owners** | Barry Hughes, Graduate school of international studies University of Denver. Model development is supported by a range of different foundations and funding sources. |
| **Model development history** | 1st version: 1980, current version: 2006 |
| **Target Group/users** | Ifs began as an educational tool and is mainly used for educational purposes. The model is increasingly being used in policy analysis and international assessments (e.g. UNEP). |
| **Calibration** | Initialized with data primarily from the 1995–2005 period and a very large data associated data base (nearly 1000 series) from a wide range of sources |
| **Validation** | runs of the model from 1960 through 2000 have been compared with data series from the same sources for key model variables |
| **Uncertainty analysis** | Not available |
| **Key reference** | Hughes & Hillebrand, 2006 |
| **Level of integration** | The overall model incorporates different sub-models, including the Population sub-model, the Economic sub-model, the Agricultural sub-model, the Educational sub-model, the Energy sub-model, the Socio-Political sub-model, the International Political sub-model, the Environmental sub-model, the Technology sub-model, and the Health sub-model. |
| **Links to other models** | unkown |
| **Scenarios used** | Includes own scenario-building tool |
| **Ease of use/accessibility** | Ease-of-use is high. No special permission is needed. Model is available online: www.ifs.du.edu |
| **Website** | http://www.ifs.du.edu/ |
| **Comments/remarks** | Description copied from EEA, 2008 |
| **Model structure** |  Figure 2 The modules of International Futures (IFs) |



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| **Model name** | **IGSM** |
| **Full model name** | integrated global system model |

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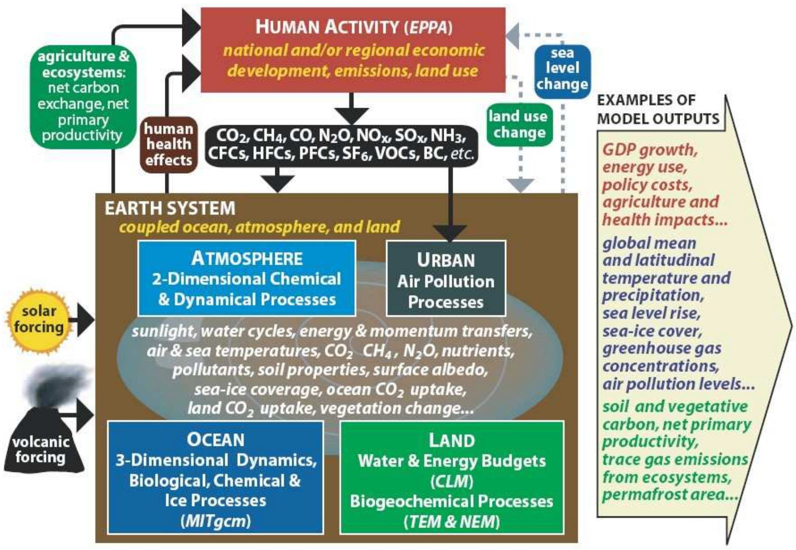
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | economics, climate change and ecosystems |
| **Input (key drivers pressures)** | capital, labour, land, fossil energy reserves |
| **Output (key variables)** | emission greenhouse gases, temperature, precipitation, sea level rise |
| **Geographical coverage and resolution** | global, 16 regions with special studies on European countries, 0.5º by 0.5º to 4º by 4º grid, depending on submodel used for the biogeochemical part |
| **Temporal coverage and resolution** | time steps: 10 minutes (atmosphere) to 5 years (policy analysis) |
| **Analytical technique** | dynamic system model (economy: general equilibrium) |
| **Model developers and/or owners** | Massachusetts Institute of Technology |
| **Model development history** | 1st version: 1999, current version: IGSM 2.3 (2005) |
| **Target Group/users** | IGSM is used to study causes of global climate change and potential social and environmental consequences, and the effects on different policies (carbon tax, biofuel programm; US, EU). |
| **Calibration** | Unknown |
| **Validation** | unknown |
| **Uncertainty analysis** | Prinn et al., 1999, Paltsev et al., 2005 |
| **Key reference** | Prinn et al, 1999, Sokolov et al., 2005<br>http://globalchange.mit.edu/pubs/abstract.php?publication_id=696,<br>http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt124.pdf |
| **Level of integration** | Different submodels, including TEM (carbon cycle), CLM (land use, energy), NEM (emissions), EPPA(economics, energy): emission model, a coupled atmosphere-ocean-land surface model with feedbacks of climate change on human activities |
| **Links to other models** | economic model built on GTAP dataset |
| **Scenarios used** | |
| **Ease of use/accessibility** | Model not available |
| **Website** | http://globalchange.mit.edu/igsm/ |
| **Model structure** |  Figure 1. Schematic of the MIT Integrated Global System Model Version 2 (IGSM2). |

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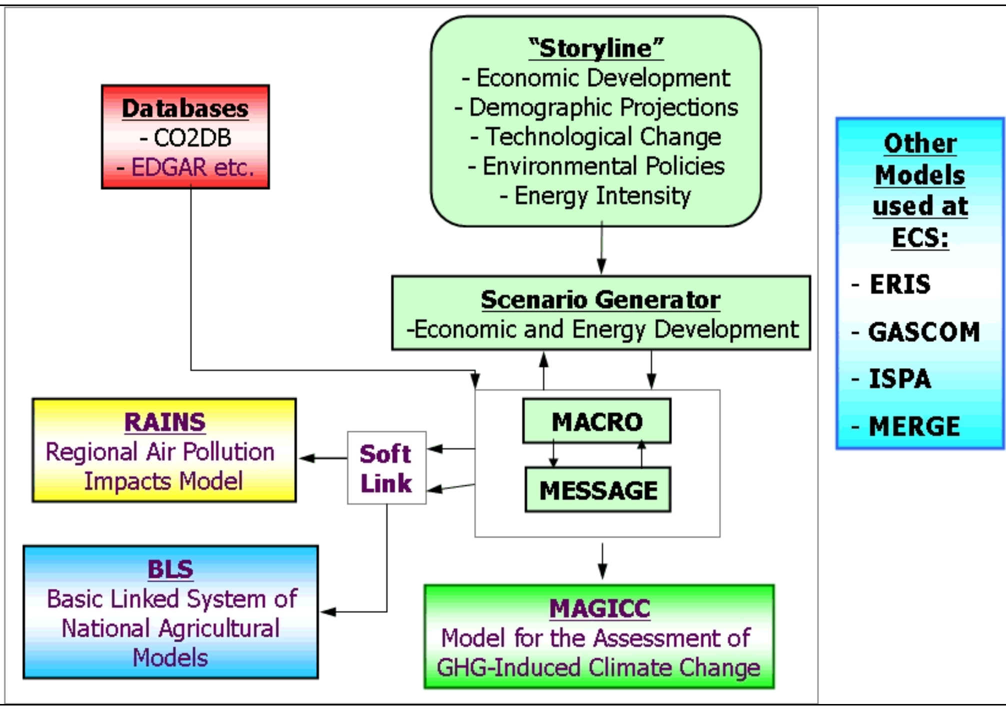
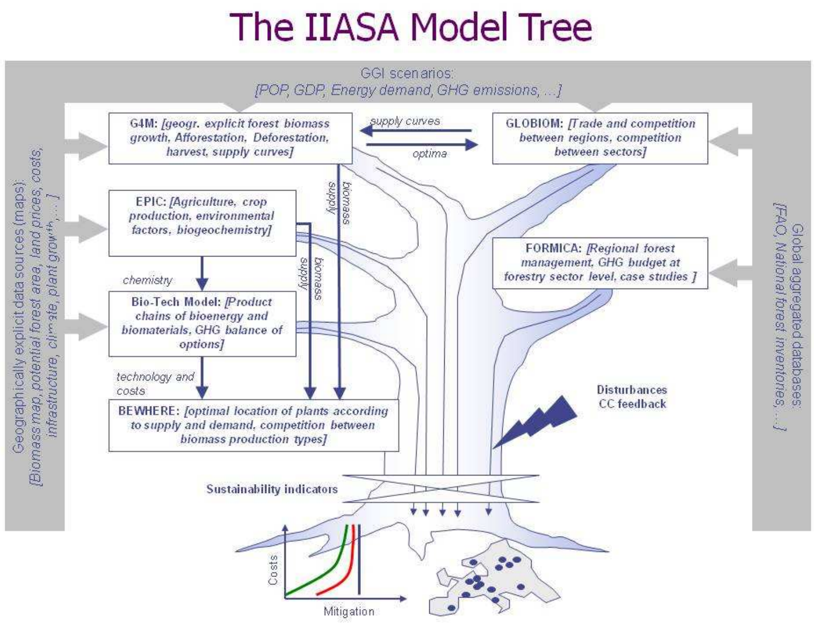
| **Model name** | **IIASA Integrated Assessment Modeling Framework<br>Including IIASA-ECS modelling and IIASA/FOR modelling cluster** |
| **Full model name** | |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | energy system planning, energy policy analysis, and scenario development, economics, climate change, agriculture |
| **Input (key drivers and pressures)** | population development, economic development, technological change, environmental policies, energy intensity |
| **Output (key variables)** | greenhouse gas emission, temperature change, development of least-cost mitigation scenarios, water supply and demand (water scarcity index), crop production |
| **Geographical coverage and resolution** | global, 0.5’ grid |
| **Temporal coverage and resolution** | 10 year time steps |
| **Analytical technique** | dynamic system modelling |
| **Model developers and/or owners** | IIASA (International Institute for Applied Systems Analysis) |
| **Model development history** | UNIX based system , new models and modules are constantly developed and integrated into the existing framework |
| **Target Group/users** | In 1998, IIASA-ECS completed a five-year joint study with the World Energy Council (WEC). The study analyzed six alternative global energy scenarios extending to 2100. The MESSAGE model is a systems engineering optimization model used for medium- to long-term energy system planning, energy policy analysis, and scenario development [24]. The model provides a framework to represent an energy system with all its interdependencies, from resource extraction, imports and exports, conversion, transport, and distribution to the provision of energy end-use services, such as light, space conditioning, industrial production processes, and transportation.<br>The IIASA/FOR modelling cluster focusses on forestry, carbon sequetration and biofuel production. |
| **Calibration** | Global statistics (FAO) were used for calibration of different model components. |
| **Validation** | Different (sub-) models have been validated and applied in many studies on national, regional and global scales. |
| **Uncertainty analysis** | Böttcher et al., 2008 |
| **Key reference** | Riahi & Röhrl, 2000, Keppo et al., 2007, Fischer er al., 2005, Fischer et al., 2007 |
| **Level of integration** | The IIASA integrated modeling approach consists of several models that represent two different model suites: First the ECS-model cluster with scenario-generator, MESSAGE-MACRO (macro-economy, energy supply and environmental impact), AEZ-BLS (agricultural-economic), DIMA (Dynamic Integrated Model of Forestry and Alternative Land Use) and MAGICC (climate change indusced by greenhouse gas emissions), those models are linked (including some feedback loops). The second group with CHARM (runoff), RAINS (air pollution), EPIC (agriculture), FORMICA (regional forest management), G4M (forestry), GLOBIOM (trade and competiton), BEWHERE (optimal land allocation) constitutes the FOR modelling cluster. |
| **Links to other models** | Different sub-models have links to other IIASA models. The agro-ecologic model AEZ (agro-ecological zone) is used by FAO to analyse present and future land resources. CAPRI is used for the estimation of agricultural demand. |
| **Scenarios used** | SRES, climate scenarios (HADCM3, ECHAM, CSIRO, CGCM2, NCAR-PCM) Fischer et al., 2005 |
| **Ease of use/accessibility** | Models not available online |
| **Website** | http://www.iiasa.ac.at/Research/ECS/docs/models.html |
| **Model structure** | The IIASA-ECS modelling cluster: |




The IIASA/FOR modelling cluster:



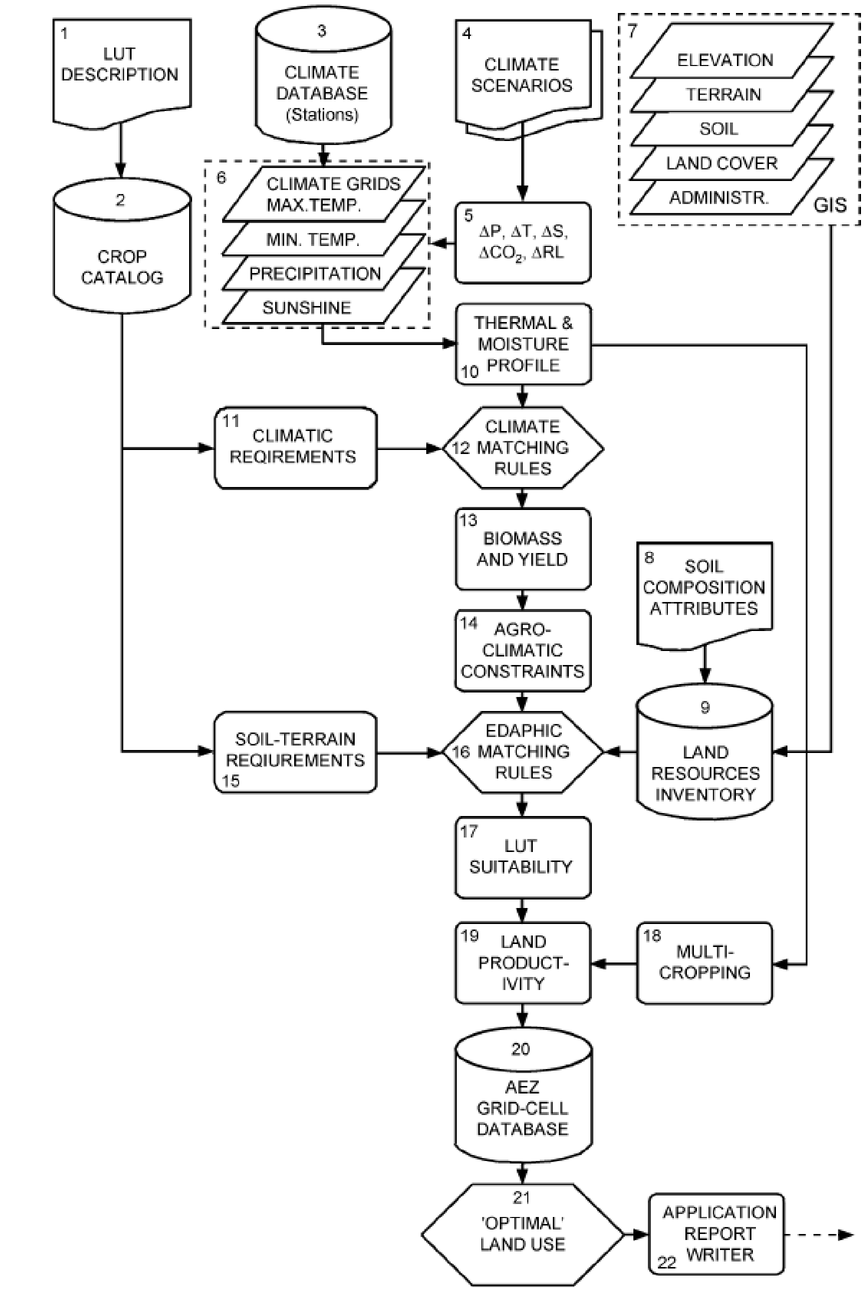



Fig. 1. Information flow and integration in the agro-ecological zone modeling.

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| **Model name** | **IMAGE** |
| **Full model name** | Integrated model to assess the global environment |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | Demography, world economy, agriculture, energy supply and demand, emissions, land allocation, carbon, nitrogen and water cycle, climate change, land degradation |
| **Input (key drivers and pressures)** | Population projections (from UN, IIASA, or from PHOENIX), economic drivers, technological development, policy options |
| **Output (key variables)** | concentrations, emissions, energy, climate, effects of climate, land use, food production and demand |
| **Geographical coverage and** | Global (with details for 24 world regions (energy, trade emissions)) or 0.5º x 0.5º grid (land cover, land use) |

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| **resolution** | |
| **Temporal coverage and resolution** | time period covered: 1970-2100 (historical data from 1900), time steps: from monthly to 5 years |
| **Analytical technique** | dynamic systems model with different sub-modules |
| **Model developers and/or owners** | Netherlands Environmental Assessment Agency |
| **Model development history** | 1st version: 1990, latest version: 2.4, software: FORTRAN/UNIX |
| **Target Group/users** | Designed to support science-policy dialoges, for scenario-development (for IPCC, OECD, MA). |
| **Calibration** | IMAGE is calibrated against historical data from 1765-2000 for carbon and climate, and data from 1970-2000 for energy and agriculture. These data were derived from large international databases (*e.g.* FAO). |
| **Validation** | Submodels have been validated. |
| **Uncertainty analysis** | To date, no comprehensive and systematic exploration has been performed of key uncertainties and how they are propagated throughout the entire IMAGE model to influence the final results. What has been done in many instances is to look at uncertainties in underlying data and model formulations in sub-systems of the overall framework, thus providing partial sensitivity analyses for IMAGE 2.4 framework. Sensitivity analysis: Rotmans 1990.<br>Furthemore IMAGE has been reviewed by an expert advisory board: http://www.rivm.nl/bibliotheek/rapporten/500110003.pdf |
| **Key reference** | http://www.pbl.nl/en/publications/2006/Integratedmodellingofglobalenvironmentalchange.AnoverviewofIMAGE2.4.html |
| **Level of integration** | Same drivers are used for energy, industry and land use, consistency between scenarios, feedback between different submodels |
| **Links to other models** | IMAGE uses input from Phoenix (demography) and has been linked to several other socio-economic models in global assessments, e.g. GTAP, Env-Linkages, WaterGAP, IMPACT. GLOBIO uses IMAGE output for the calculation of a biodiversity index. |
| **Scenarios used** | SRES, MA, GEO, OECD, IAASTD, EURuralis |
| **Ease of use/accessibility** | not available |
| **Website** | http://www.mnp.nl/en/themasites/image/index.html |

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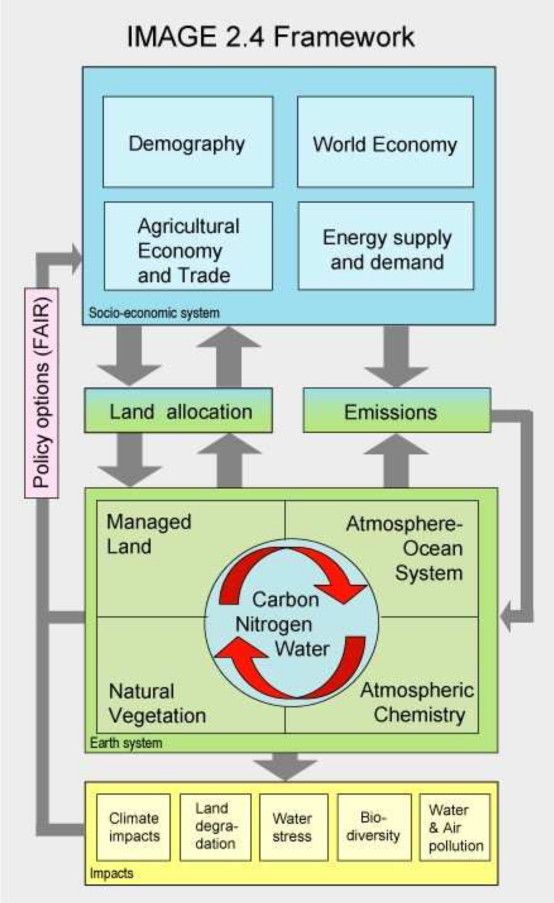
| **Model structure** |   |

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| **Model name** | **IMPACT -WATER** |
| **Full model name** | International Model for Policy Analysis of Agricultural Commodities and Trade |
| **Model type** | Integrated model (partical equilibrium + hydrological model) |
| **Subtype** | agriculture |
| **Thematic coverage** | agriculture, fishery, water (related to agriculture) |
| **Input (key drivers and pressures)** | Income, and population growth (to determine food and non-agricultural water demand), Crop productivity (depends on various drivers, incl. agricultural research), change in available agricultural area over time, climate parameters, plus irrigation and water supply information, trade policies |
| **Output (key variables)** | Crop area, yield, production, demand for food, feed and other uses, prices, Livestock numbers, yield, production, demand, prices, Net trade in 32 agricultural commodities (virtually all global food trade), Percentage and number of malnourished preschool children, Per-capita calorie availability from foods |
| **Geographical coverage and resolution** | global: 115 regions and countries, intersected with 126 river basins (281 spatial units), including EU-15 and eastern Europe |
| **Temporal coverage and resolution** | base: 2000 until 2020/2025/2050, annual time steps |
| **Analytical technique** | partial equilibrium model (sectoral agricultural model) |
| **Model developers and/or owners** | International Food Policy Research Institute (IFPRI) of the CGIAR Network |
| **Model development history** | 1st version of IMPACT (1990-2000), latest version: 2005<br>The partial equilibrium model IMPACT was coupled to the hydrological model WSM to create IMPACT-WATER to be able to include climate change effects on agriculture production. |
| **Target Group/users** | Aim was to help achieve long-term vision and consensus among policy makers and researchers about the actions that are necessary to feed the world in the future, reduce poverty, and protect the natural resource base. IMPACT has been used in |

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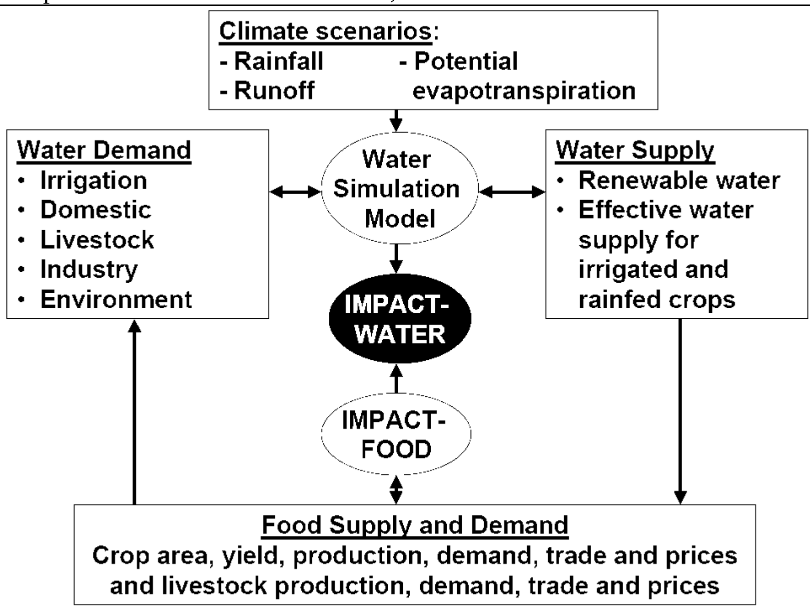
| | numerous international environmental assessments (such as World Water Vision, Millennium Ecosystem Assessment). Currently being used in UNEP's Global Environmental Outlook (GEO-4) and the International Assessment of Agricultural Science and Technology for Development (IAASTD). |
| **Calibration** | Model uses the UN Medium Variant Population growth projections, and follows the global hydrology patterns embodied from the climate data provided by the Climate Research Unit of the University of East Anglia. The streamflow and runoff data have been calibrated to WaterGAP of the University of Kassel. |
| **Validation** | IMPACT has been used in a historical counterfactual analysis that accurately produced the historical record of agricultural production and consumption from 1970 to 2000. |
| **Uncertainty analysis** | Climate uncertainty is explored with the use of alternative GCM scenarios, which are downscaled to the spatial units of IMPACT. |
| **Key reference** | Rosegrant et al. (2005) |
| **Level of integration** | Water is the key environmental component which is directly integrated into the model structure. Response to water availability is measured in terms of yield loss (relative to full potential). IMPACT-WATER is the only model that takes into account water availability for food production (other models assume that water for irrigation is available). |
| **Links to other models** | The IMPACT model has been linked to a range of models in international assessments, such as GTEM (AustraliaBARE), IMAGE (MNP, Netherlands), AIM (Nat'l Inst for Env Studies, Japan) and WaterGAP (Univ. of Kassel). |
| **Scenarios used** | MA, IAASD scenarios |
| **Ease of use/accessibility** | Ease-of-use is very limited (i.e. referring to the full version of IMPACT). IFPRI has developed a distributional version (IMPACT-D) that can be downloaded free of charge (www.IFPRI.org/themes/impact/impactd.asp). |
| **Website** | http://www.ifpri.org/themes/impact.htm |
| **Comments/remarks** | Description hase been taken from EEA, 2008 |
| **Model structure** |  |

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| **Model name** | **MIMES** |
| **Full name** | **Multiscale integrated model of ecosystem services** |
| **Model type** | integrated assessment model |
| **Subtype** | |
| **Thematic coverage** | dynamics and tradeoffs among natural, human, built and social capital, joint economic and social valuation of ecosystem services, based on physical ecosystem models |
| **Input (key drivers and pressures)** | climate, land use, socio-economic drivers |
| **Output (key** | global temperature, atmospheric carbon, sealevel, water, fossil and alternative energy |

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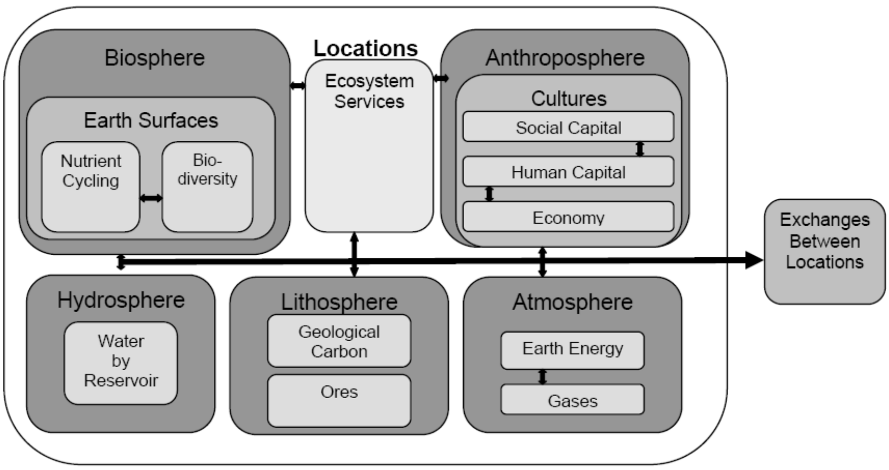
| **variables)** | consumption, area of different land covers, knowledge, human, built and social capital, physical and monetary values for 11 ecosystem services, per capita food and welfare |
| **Geographical coverage and resolution** | global, 1° by 1° resolution |
| **Temporal coverage and resolution** | unknown |
| **Analytical technique** | meta-model, dynamic system model |
| **Model developers and/or owners** | The Gund Institute for Ecological Economics, University of Vermont, USA, together with University of Sao Paulo, Helmholtz CER, Wageningen University, Palawan State University, Boston University, Florida Institute of Technology, Kansas University, Michigan State University, Stanford University, University of Denver, USDA Forest Service, National Center for Atmospheric Research |
| **Model development history** | 1st version: 2007, MIMES builds on the GUMBO model to allow for spatial explicit modeling at various scales, software: simile |
| **Target Group/users** | The MIMES project aims to integrate participatory model building, data collection and valuation, to advance the study of ecosystem services for use in integrated assessments. (http://www.uvm.edu/giee/mimes/media.htm) |
| **Calibration** | Not available |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | http://www.uvm.edu/giee/publications/Boumans_Costanza_GWSP%20Chapter_2007.pdf |
| **Level of integration** | Both ecological and socioeconomic changes are endogenous to the model, with a pronounced emphasis on interactions and feedbacks between the two. Dyamic feedback between human technology, economic production, welfare and ecosystem services. |
| **Links to other models** | MIMES is a metamodel that used output from several global models (IFs, IMAGE, CLUE, Phoenix, AIM, CLIMBER, EcoSim, IMPACT, WaterGAP, CENTURY, BIOME) to derive relationships between variables. |
| **Scenarios used** | MIMES/GUMBO scenarios. |
| **Ease of use/accessibility** | MIMES can be dowloaded at: http://www.uvm.edu/giee/mimes2/downloads.html requires simile software |
| **Website** | http://www.uvm.edu/giee/mimes2/ |
| **Comments/remarks** | Global maps of ecosystem services from the MIMES model can be found at: http://www.gulfofmaine.org/EBMWorkGroups/docs/Roelof-Boumans-presentation-at-Oct2007-WorkGroup1-2-meeting.pdf |
| **Model structure** | **Figure 1.** *General outline of the MIMES model: The multiscale integrated Earth Systems model*   |

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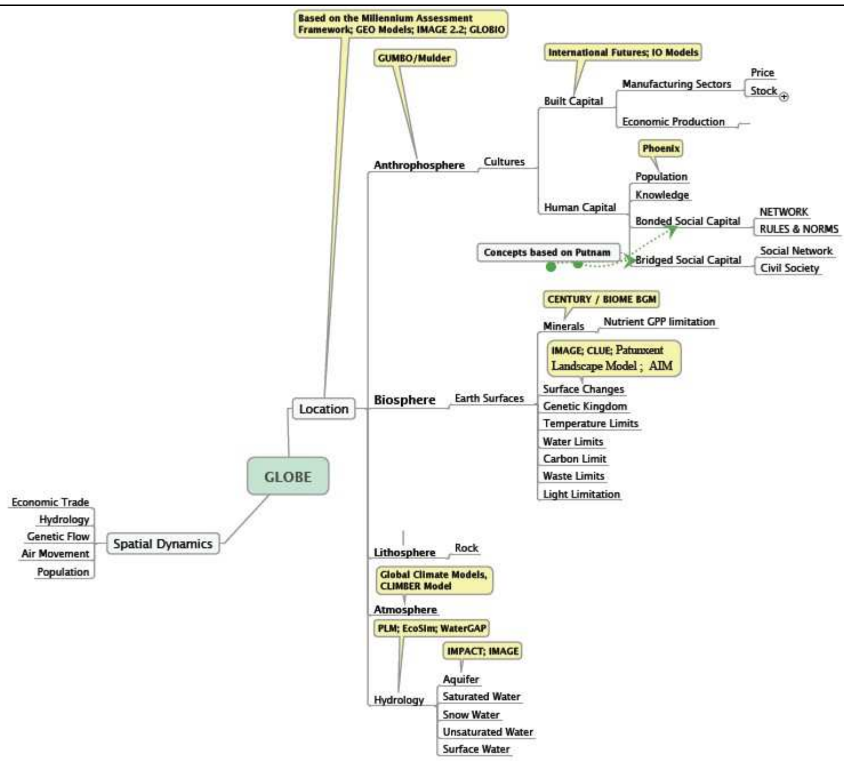
| |  |



### *1.1.2 Scenario-building tools*

| **Model name** | **PoleStar** |
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| **Full model name** | |
| **Model type** | scenario building and planing tools |
| **Subtype** | |
| **Thematic coverage** | Accounting model that combines exogenous economic, resource and environmental information on a global and regional level |
| **Input (key drivers and pressures)** | GDP and population development, more specified socio-economic drivers, environmental drivers (resources, pollution) |
| **Output (key variables)** | water and energy use, oil reserves left, $CO_2$ emissions, agricultural requirements, pollution, poverty |
| **Geographical coverage and resolution** | PoleStar is applied at community, national, regional and global level. |
| **Temporal coverage and resolution** | Base: 1996 |
| **Analytical technique** | Meta-model |
| **Model developers and/or owners** | PoleStar was conceived in 1991 by Gordon Goodman, Director of Stockholm Environment Institute (SEI) and Paul Raskin, President of Tellus Institute and Director of SEI's Boston Center. Dr. Raskin has supervised the design and development of the software and its national, regional and local applications. |
| **Model development history** | 1st version 1991 |
| **Target Group/users** | Scenarios were quantified using the PoleStar software and used in numerous global studies including UNEP's Global Environment Report series, the U.S. National Academy of Sciences' Board on Sustainable Development report Our Common Journey, the World Water Vision and the OECD Environmental Outlook. |
| **Calibration** | unknown |
| **Validation** | unknown |
| **Uncertainty** | unknown |

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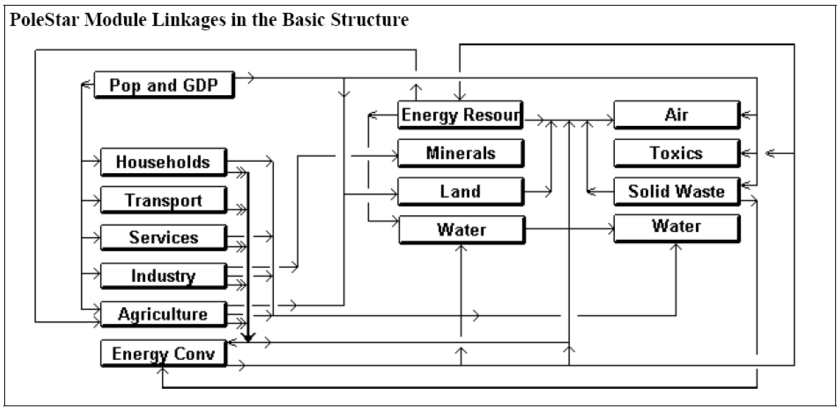
|---|---|
| **analysis** | |
| **Key reference** | http://www.sei.se/mediamanager/documents/Publications/Future/polestar_v2000.pdf |
| **Level of integration** | |
| **Links to other models** | PoleStar has been used in the GEO-4 assessment, linked with AIM, IMAGE, WaterGAP and EwE/EcoOcean. |
| **Scenarios used** | GSG scenarios were quantified using PoleStar. |
| **Ease of use/accessibility** | Easy to use software tool for sustainability studies, both scenario-building tool and database of current indicators, flexible and user-friendly framework for building and assessing alternative development scenarios, user manual (http://www.seib.org/polestar) |
| **Website** | http://www.polestarproject.org/, http://www.seib.org/polestar |
| **Model structure** |  |

| | |
|---|---|
| **Model name** | **Threshold 21** |
| **Full model name** | |
| **Model type** | Integrated scenario building and planing tools |
| **Subtype** | |
| **Thematic coverage** | national development, policies |
| **Input (key drivers)** | policy options, socio-economic factors, resources, technology |
| **Output (key variables)** | GDP |
| **Geographical coverage and resolution** | focussed on the national level, globally applicable, not spatially explicit |
| **Temporal coverage and resolution** | 50-100 years |
| **Analytical technique** | dynamic simulation tool (uses Montecarlo optimization techniques) |
| **Model developers and/or owners** | Millennium Institute |
| **Model development history** | 1st version 1994, programming software: Vensim |
| **Target Group/users** | First version was a country-level model for national decision makers focussed on national development. It is a user-friendly, systems thinking software program that permits users to organize, access and analyze necessary information for making prudent decisions on sustainable development strategy. It is the first computer analysis tool to integrate human, economic and environmental concerns into one model and is uniquely designed for national application. Threshold 21 (T21) is a dynamic simulation tool designed to support comprehensive, integrated long-term national development planning. T21 supports comparative analysis of different policy options, and helps users to identify the set of policies that tend to lead towards a desired goal. This insight into how different indicators of development interact with one another to produce an outcome deepens users understanding of development challenges. |
| **Calibration** | Country level data are used to calibrate the national models, if possible, otherwise international data sources (World Development Indicators, FAOSTAT, World Population |

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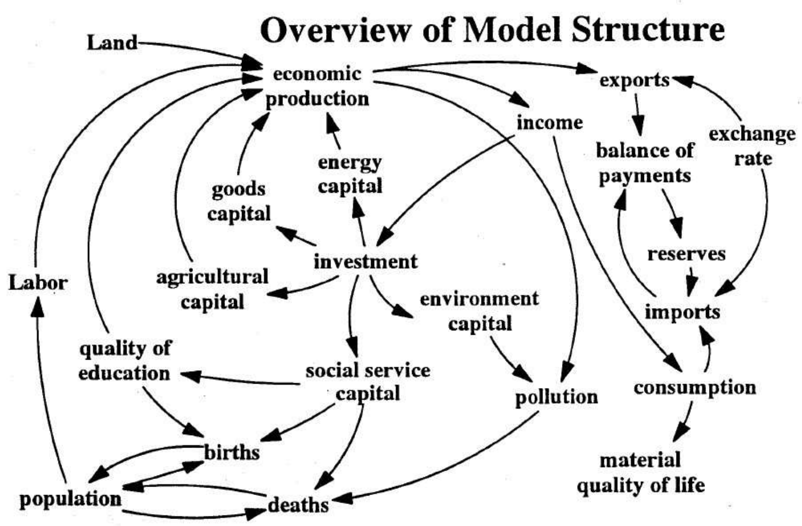
| | Prospects, Energy Statistics and International Financial Statistics) are used. |
| **Validation** | T21 has been validated through a variety of tests, including effective simulation of historical periods. (http://www.threshold21.com/integrated_planning/tools/T21/validationstudy.html) |
| **Uncertainty analysis** | Not available |
| **Key reference** | http://www.systemdynamics.org/conferences/1995/proceed/papersvol1/barne022.pdf |
| **Level of integration** | High level of integration: 800 variables in different sector modules (demographics, agricultural production, health care, food and nutrition, international trade, national accounts, social services, energy, energy efficiency, goods production, education and environment) are dynamically linked. Individual sectors can modelled in a more elaborate or simple version, several countr-specific versions have been developed (e.g. Bangladesh, USA, Italy, China, Ghana) |
| **Links to other models** | unknown |
| **Ease of use/accessibility** | PC-based, user-friendly tool, open source, library for download, requires active role of user in the definition of the model structure. |
| **Website** | http://www.millenniuminstitute.net/integrated_planning/tools/T21/ |
| **Model structure** |   Figure 1: Overview of Threshold 21 |

### *1.1.3 Economic models*

| **Model name** | **Env-Linkages** |
|---|---|
| **Full model name** | |
| **Model type** | general economic model |
| **Subtype** | |
| **Thematic coverage** | macro-economy and climate (carbon emissions) |
| **Input (key drivers)** | socio-economic factors, policy instruments (carbon taxes, tradable emission permits, regulatory policies), labour, capital, energy, technology |
| **Output (key variables)** | GDP/capita, production of food (crops, livestock), household consumption |
| **Geographical coverage and resolution** | global, aggregated in 34 countries/regions |
| **Temporal coverage and resolution** | Base year: 2001, annual time steps |
| **Analytical technique** | general equilibrium model |

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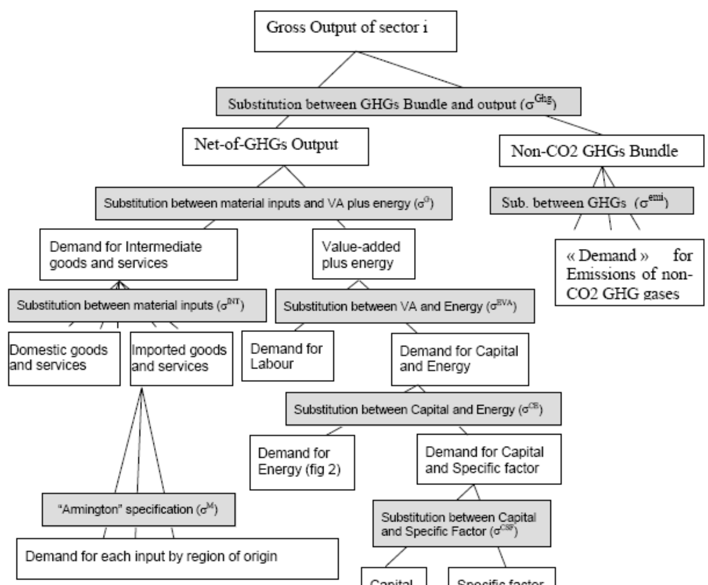
| **Model developers and/or owners** | Environment Directorate of the OECD Secretariat |
| **Model development history** | Env-Linkages is based on the GREEN model ans was further developed into JOBS. Software: GAMS |
| **Target Group/users** | This model has been developed to assess the economic impact of abating Greenhouse Gases using several different economic instruments. It is used by the World Bank for research on global economics. |
| **Calibration** | unknown |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | http://lysander.sourceoecd.org/vl=2821760/cl=15/nw=1/rpsv/workingpapers/18151973/wp_5kz7wcbr7l9n.htm, van Mensbrugghe (2005): LINKAGE technical reference document version 6.0 |
| **Level of integration** | The different modules are well-integrated. |
| **Links to other models** | Within the OECD environmental outlook, Env-Linkages has been linked to IMAGE, TIMER and LEITAP (version of GTAP). |
| **Ease of use/accessibility** | Model is not available |
| **Website** | http://www.olis.oecd.org/olis/2008doc.nsf/linkto/eco-wkp(2008)61 |
| **Model structure** | **Figure 1. Structure of production in ENV-Linkages**  Note: see Table 1 for parameter values |



| | |
|---|---|
| **Model name** | **GTAP** |
| **Full model name** | **Global Trade Analysis Project** |
| **Model type** | general economic model |
| **Subtype** | |
| **Thematic coverage** | Agro-economy |
| **Input (key drivers)** | production functions including capital, labour and land prices |
| **Output (key variables)** | calculates consumption and trade of agricultural products |
| **Geographical coverage and resolution** | Country-level, not spatially explicit |
| **Temporal coverage and resolution** | Base: 1995-2005 |
| **Analytical technique** | general equilibrium model |
| **Model developers and/or owners** | Purdue University, together with collaborators worldwide |
| **Model development** | current version: GTAP 7, a dynamic version of GTAP is also available |

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| **history** | (GDyn) |
| **Target Group/users** | The underlying GTAP database combined with the model is used by most individuals and agencies exploring the effects of different policies on aricultural trade. |
| **Calibration** | GTAP was calibrated against the GTAP-database. |
| **Validation** | Global Trade Analysis: Modeling and Applications, T.W. Hertel (ed.), Cambridge University Press, 1997, chapter 14; https://www.gtap.agecon.purdue.edu/resources/download/1813.pdf |
| **Uncertainty analysis** | https://www.gtap.agecon.purdue.edu/resources/download/39.pdf |
| **Key reference** | Global Trade Analysis: Modeling and Applications, T.W. Hertel (ed.), Cambridge University Press, 1997; https://www.gtap.agecon.purdue.edu/resources/download/1736.pdf |
| **Level of integration** | The different modules are well-integrated. |
| **Links to other models** | GTAP has been linked to IMAGE (van Meijl et al., 2006): IMAGE provides land-supply curves, yields and yield changes |
| **Ease of use/accessibility** | GTAP6.2a can be downloaded at: https://www.gtap.agecon.purdue.edu/models/current.asp |
| **Website** | https://www.gtap.agecon.purdue.edu/ |
| **Comments/remarks** | Like all models, general equilibrium models have their limitations. By their very size, they may lack the detail of sector-specific models. Many of the parameters have not been estimated specifically for the model, and such models are difficult to validate in the traditional sense. The static framework limits treatments of savings, capital accumulation and stockholding, and the dynamic gains from trade cannot be calculated. The macro side is also rather limited, precluding some of the effects of changes in interest rates and exchange rate that may follow liberalisation. Nonetheless, for the purpose of analysing world trade issues such as agricultural liberalisation and regional integration, the GTAP model and database remains one of the best tools available. (Frandsen et al., 2000) |
| **Model structure** | not available |

### *1.1.4 Land-use models*

| | |
|---|---|
| **Model name** | **CLUE** |
| **Full model name** | conversion of land use and its effects |
| **Model type** | land use model |
| **Subtype** | |
| **Thematic coverage** | land use, agriculture, urbanization |
| **Input (key drivers and pressures)** | land use maps, remote sensing of land cover or census data on land use, demographic change, land use requirements (based on trends, scenarios or macro-economic modelling), spatial policies, (assumed) location factors |
| **Output (key variables)** | land cover/ land use change |
| **Geographical coverage and resolution** | Europe (EU-27), also case studies in a.o. Costa Rica, Ecuador, Honduras, the Netherlands, China, Java, Phillippines, Malaysia, Vietnam, Kenya, USA, 1x1km, case studies between 30m and 32km |
| **Temporal coverage and resolution** | 20-40 years, time steps: monthly to annual |
| **Analytical technique** | hybrid model (systems dynamic and empirical statistical, alternatively: cellular automata mechanism) |
| **Model developers and/or owners** | Department of Environmental sciences Landscape Centre Wageningen University. |
| **Model development history** | 1st version: mid 1990s, ongoing |
| **Target Group/users** | The CLUE model has been used by a large number of both universities and governmental research institutes from all over the world. Case study versions for a variety of regions exists. |
| **Calibration** | Calibration is based on observed land use patterns and, if possible, based on |

| | |
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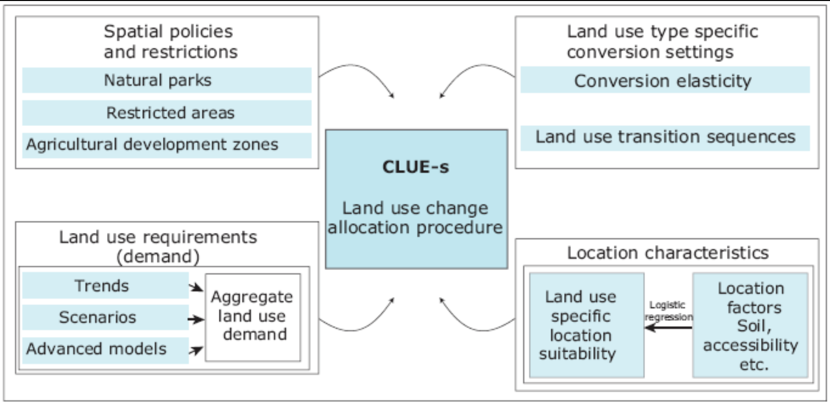
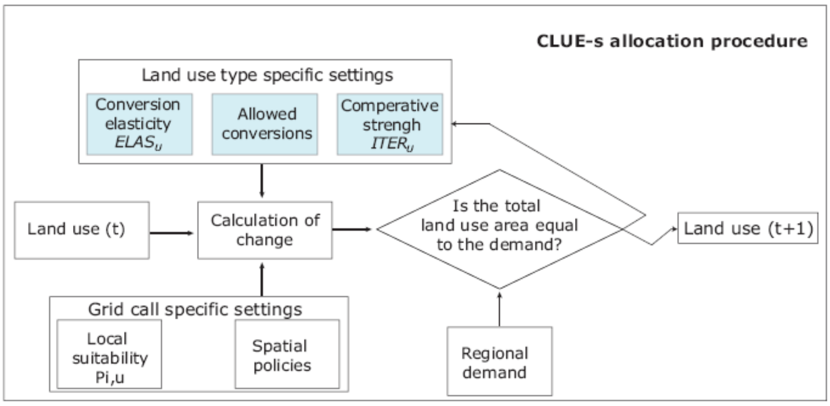
| | historic data. For some case studies calibration is helped by interviews with land managers. |
| **Validation** | Validation is based on historic land use changes for various case studies. Pontius, R.G. et al., 2007. Comparing the input, output, and validation maps for several models of land change. Annals of Regional Science. In press. |
| **Uncertainty analysis** | Has been performed for some parameters in a number of case studies including the use of monte-carlo techniques. |
| **Key reference** | A wide range of scientific publications (full list at www.cluemodel.nl): e.g. Verburg, P.H., Soepboer, W., Veldkamp, A. Limpiada, R. Espaldon, V., Sharifah Mastura S.A. 2002. Modeling the Spatial Dynamics of Regional Land Use: the CLUE-S Model. Environmental Management 30(3): 391–405. |
| **Level of integration** | High level of integration among land use sectors and spatial-temporal dynamics including path-dependence and spatial interactions. Feedbacks with environmental indicators can be addressed by tight coupling of the model with indicator models. Regional biophysical module, regional land use objectives module and local land use allocation module. Interactions between neighbouring grid-cells. |
| **Links to other models** | In many projects, including EURURALIS and SENSOR the land requirements are based on macro-economic modelling results from models such as GTAP, NEMESIS or IMAGE. |
| **Ease of use/accessibility** | Full version with technical support of the model is only available for collaborative projects. Others may use the model signing a memorandum of understanding excluding the commercial use of the model and requirement of proper referencing. |
| **Website** | www.cluemodel.nl |
| **Comments/remarks** | Description taken from EEA, 2008 |
| **Model structure** |   |

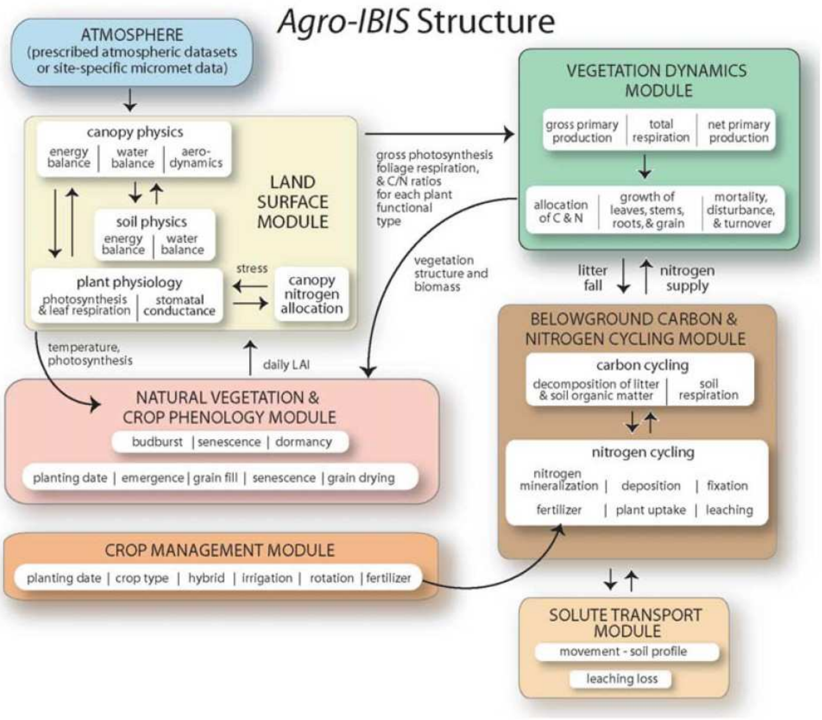




### *1.1.5 Biogeochemical models*

| | |
|---|---|
| **Model name** | **Agro-IBIS** |
| **Full model name** | |

| | |
|---|---|
| **Model type** | biogeochemistry model |
| **Subtype** | agriculture |
| **Thematic coverage** | Natural terrestrial vegetation plus agriculture |
| **Input (key drivers and pressures)** | climate, soil texture, farm management (fertilization, irrigation) |
| **Output (key variables)** | Vegetation cover, crop yield, LAI, N mimeralization, $CO_2$ flux, N leaching, water cycling, energy balance (crops: maize, soybean, winter and spring wheat) |
| **Geographical coverage and resolution** | currently only run for North America, global application planned, 0.5º grid, model implementation also desired on field and precision agriculture scale ($100m^2$ respectively $25m^2$). |
| **Temporal coverage and resolution** | time steps for calculations: hourly;<br>for output: annual |
| **Analytical technique** | Dynamic systems model (process-based model) |
| **Model developers and/or owners** | SAGE- Center for Sustainability and the Global Environment, University of Wisconsin-Madison |
| **Model development history** | IBIS is a dynamic global vegetation model (DGVM). The coupled crop-climate model also examines the impact that agricultural land use has directly on the climate system through changes in biogeochemical cycling and the associated changes to land surface properties. Codes are written in FORTRAN. |
| **Target Group/users** | Primarily a research model, Agro-IBIS has been used extensively in the North American Carbon Program (NACP). |
| **Calibration** | Agricultural module was calibrated to the maize yield of the Upper Mississippi basin during the late 1990s (Kucharik & Brye, 2003). |
| **Validation** | Kucharik & Brye, 2003: all processes were modelled with reasonable accurancy (within 20% error), except for soil N; Kucharik, 2003 (Earth Interactions 7): simulation of US maize yields and comparison with national yield databas for regional scale (1958-1994); slight overestimation of high yields and underestimation of low yields, Kucharik & Twine (2007): comparision with AmeriFlux site at the Mead, Nebraska, Twine & Kucharik (2008): comparison of LAI and absorped photosynthetically active ratiation with remote-sensing data; LAI of conifers was underestimated and LAI of grasslands overestimated. |
| **Uncertainty analysis** | not available |
| **Key reference** | Donner & Kucharik, 2003, Kucharik & Brye, 2003; for IBIS: Foley et al., 1996 and Kuchrik et al., 2000 |
| **Level of integration** | feedbacks between vegetation, crop and soil module |
| **Links to other models** | Agro-IBIS has not been linked to other models. |
| **Ease of use/accessibility** | IBIS can be downloaded, Agro-IBIS is not available |
| **Website** | none |

<table>
<tr><td>Model structure</td><td>


</td></tr>
</table>

| **Model name** | **CENTURY** |
|---|---|
| **Full model name** | |
| **Model type** | biogeochemistry models |
| **Subtype** | Agriculture, grasslands, forests |
| **Thematic coverage** | carbon, nutrient, and water dynamics |
| **Input (key drivers and pressures)** | climate, site conditions, land use/management (including fire, grazing, fertilization, irrigation, crop rotations, tillage practices) |
| **Output (key variables)** | soil water, decomposition, SOC, grass, tree and crop production, $CO_2$ flux, C, N, P and S balance |
| **Geographical coverage and resolution** | not spatially explicit, aggegation on the basis of land management (submodules: cropland and grassland, forest, savanna) |
| **Temporal coverage and resolution** | CENTURY simulates C, N, P, and S dynamics through an annual cycle over time scales of centuries and millenia.<br>time steps: monthly (there is also a version with daily time steps: DayCent) |
| **Analytical technique** | equilibrium model |
| **Model developers and/or owners** | Colorado State University |
| **Model development history** | 1st version: 1987, current version: CENTURY 5<br>software: the code has been rewritten in C++ for version 5, and modified to use platform-independent configuration and output files |
| **Target Group/users** | CENTURY has been used extensively for global change research. The model has been executed in over 22 different areas in the world. It can be used to assess the impacts of regional climate change on a variety of important grassland ecosystems. |
| **Calibration** | http://www.iemss.org/iemss2006/papers/w2/333_Liu_2.pdf |
| **Validation** | Parton et al., 1993, Gilmanov et al., 1997, Kamoni et al., 2007 |
| **Uncertainty analysis** | Not available |
| **Key reference** | Parton et al., 1988, Parton et al., 1994, a complete list of references is given at http://www.nrel.colostate.edu/projects/century5/ |
| **Level of integration** | soil, water, grassland and forest sub-models, interactions via C and N cycle, shading and competition |
| **Links to other models** | CENTURY has been coupled to vegetation growth models (Laurenroth et al., |

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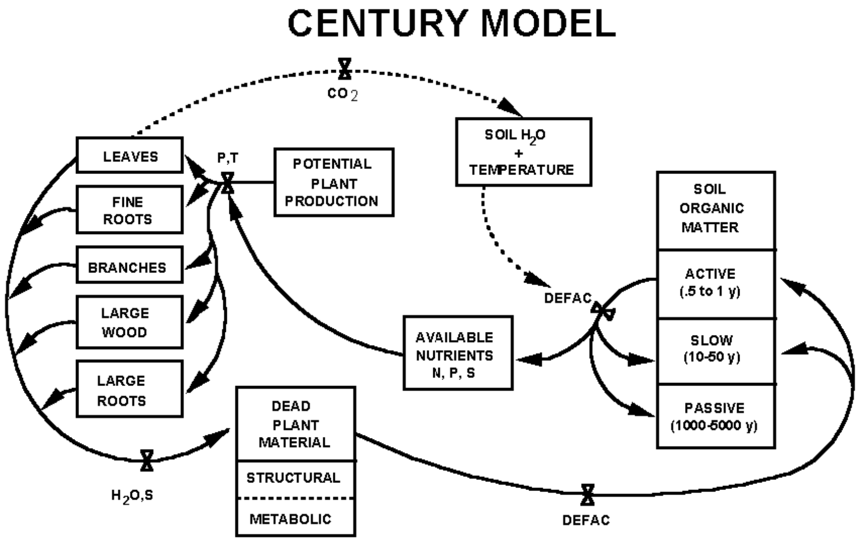
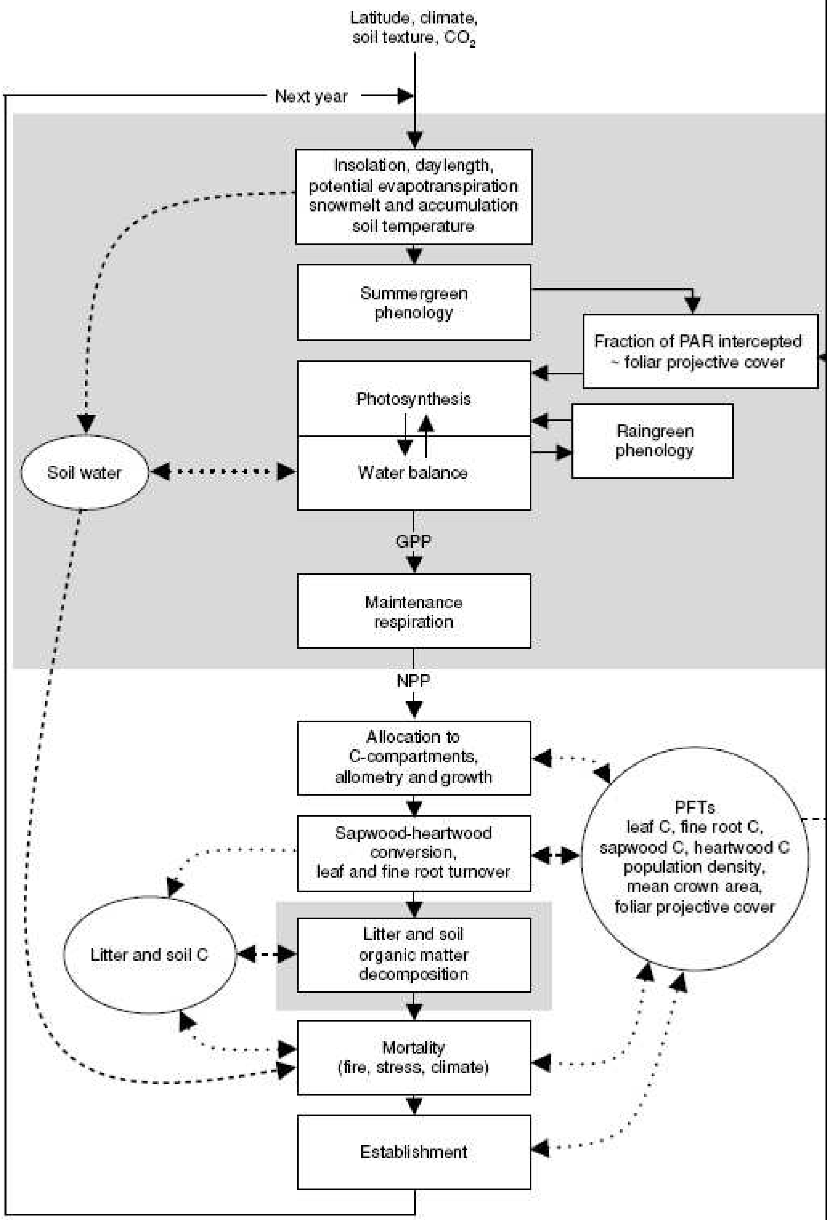
| | 1993) such as STEPPE. |
| **Ease of use/accessibility** | Century 5 is a research version of the model, it can be obtained upon request, Century 4 is freely available at: http://www.nrel.colostate.edu/projects/century/ |
| **Website** | http://www.nrel.colostate.edu/projects/century5/ |
| **Comments/remarks** | CENTURY was especially developed to deal with a wide range of cropping system rotations and tillage practices for system analysis of the effects of management and global change on productivity and sustainability of agroecosystems. |
| **Model structure** |   |

| | |
|---|---|
| **Model name** | **IBIS** |
| **Full model name** | integrated biosphere simulator model |
| **Model type** | biogeochemistry model |
| **Subtype** | Dynamic global vegetation model |
| **Thematic coverage** | terrestrial ecosystems (vegetation with energy, water and carbon exchange, nutrient cycling) |
| **Input (key drivers and pressures)** | climate, soil texture |
| **Output (key variables)** | energy, water and $CO_2$ exchange between plants and atmosphere, plant growth and competition, nutrient cycling and soil physics |
| **Geographical coverage and resolution** | Global, 0.5 - 4° |
| **Temporal coverage and resolution** | time steps: day/month, aggregation: annual |
| **Analytical technique** | Dynamic system model (process-based) |
| **Model developers and/or owners** | SAGE- Center for Sustainability and the Global Environment, University of Wisconsin-Madison |
| **Model development history** | 1st version described: 1996, current version: IBIS 2.6 (2008). IBIS was designed to explicitly link land surface and hydrological processes, terrestrial biogeochemical cycles, and vegetation dynamics within a single physically consistent framework |
| **Target Group/users** | IBIS was developed as a first step toward gaining an improved understanding of global biospheric processes and studying their potential response to human activity. |
| **Calibration** | IBIS has been calibrated for several to field data (energy and carbon flux, Delire & Foley, 1999) and biome averages (e.g. NPP, SOC, LAI, Kucharik et al., 2000). |
| **Validation** | Kucharik et al., 2000: Comparision of model results with historical data from 1965 to 1994, for several ecosystems all over the globe |

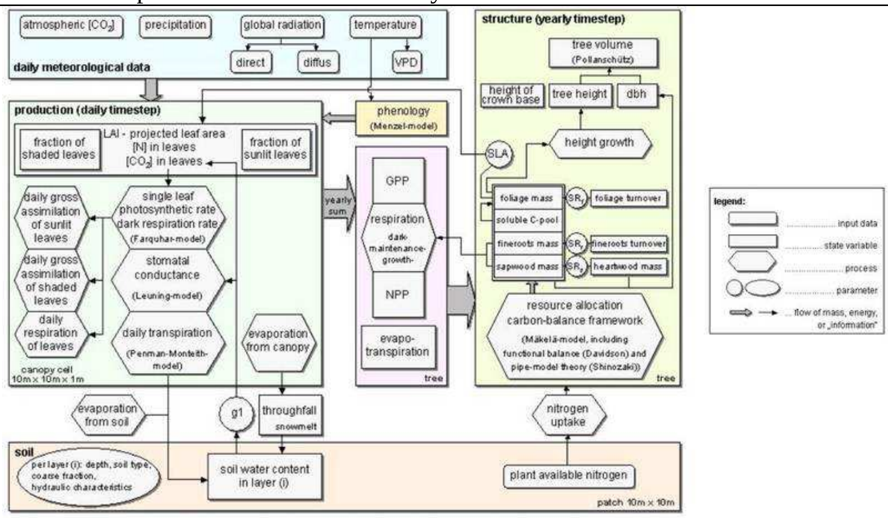
| | |
|---|---|
| **Uncertainty analysis** | unknown |
| **Key reference** | Kucharik et al., 2000, Foley et al., 1996 |
| **Level of integration** | IBIS was constructed to link explicitly land surface and hydrological processes, terrestrial biogeochemical cycles, and vegetation dynamics within a single, physically consistent framework. An agricultural submodule has been included: Agro-IBIS |
| **Links to other models** | unknown |
| **Ease of use/accessibility** | IBIS 2.6 and input files can be downloaded inclusive user guide at http://www.sage.wisc.edu/download/IBIS/ibis.html but no help is provided, listserve and user discussions exist, http://daac.ornl.gov/MODELS/guides/IBIS_Guide.html |
| **Website** | http://www.sage.wisc.edu/download/IBIS/ibis.html |
| **Model structure** | Not available |

| **Model name** | **LPJmL** |
|---|---|
| **Full model name** | Lund-Potsdam-Jena dynamic global vegetation model including managed land |
| **Model type** | biogeochemistry models |
| **Subtype** | Dynamic general vegetation model |
| **Thematic coverage** | Dynamic global vegetation model, including agriculture |
| **Input (key drivers and pressures)** | monthly climate, soil type and atmospheric $CO_2$ concentration, land management, land use change |
| **Output (key variables)** | vegetation cover (fraction of different plant functional types per grid cell), $CO_2$ exchange, seasonal water balance (runoff volumes), annual NPP, crop production |
| **Geographical coverage and resolution** | global, 10' or 0.5° grid cells |
| **Temporal coverage and resolution** | time steps: day/month |
| **Analytical technique** | Dynamic systems model |
| **Model developers and/or owners** | Potsdam Institute for Climate Impact Research. The LPJ model was originally developed by a consortium led by I. Colin Prentice (then Max-Planck-Institute for Biogeochemistry, Jena; now at Bristol University), Wolfgang Cramer (PIK), and Martin Sykes (Lund University). The name derives from the three locations Lund-Potsdam-Jena but is no longer to be interpreted that way. Managed by a small steering committee, the consortium conducted regular meetings and consultations with key users of LPJ. |
| **Model development history** | Originally a model to predict natural vegetation cover (based on the BIOME family), there is also a version including an agriculture module (LPJmL (managed lands)); current version LPJ3 (with and without managed lands). LPJ was originally written in FORTRAN, for LPJ version 2 C++ has been used, the current version LPJ 3 was programmed in C. |
| **Target Group/users** | LPJ has been used in numerous studies on responses and feedbacks of the biosphere in the Earth System (e.g., Brovkin et al., 2004; Lucht et al., 2002; Schaphoff et al., 2006; Sitch et al., 2005). |
| **Calibration** | NPP, biomass, NEP and seasonal carbon cycle have been calibrated against station measurements. |
| **Validation** | LPJ has been validated from the stand to the global scale (Hickler et al., 2004) Cramer et al., 2001: Comparison of 6 global vegetation models, Bondeau et al., 2007: comparison with historical data |
| **Uncertainty analysis** | Jung et al., 2007a, Jung et al., 2007b, Wolf et al., 2008 (for LPJ-Guess) |
| **Key references** | Sitch et al., 2003, Bondeau et al., 2007 |
| **Level of integration** | The different modules are well-integrated. |
| **Links to other models** | LPJ has been included in the ATEAM vulnerability assessment tool. Currently work is ongoing to link LPJ to IMAGE. |
| **Ease of use/accessibility** | open and unrestricted access, LPJ can be downloaded (upon request) at http://www.pik-potsdam.de/research/cooperations/lpjweb/lpj-lpjml-versions |

| | |
|---|---|
| **Website** | http://www.pik-potsdam.de/research/cooperations/lpjweb |
| **Comments/remarks** | Decline in stand productivity in mature forests is not simulated as age structure is not modelled. Nitrogen cycling and uptake is not modelled, nitrogen limitation is therefore not included in vegetation growth. |
| **Model structure** |  |



| | |
|---|---|
| **Model name** | **PICUS** |
| **Full model name** | |
| **Model type** | biogeochemistry models |
| **Subtype** | forestry |
| **Thematic coverage** | stand-level foresty model (dynamic succession) (managed plantations and natural forest, multi- and single species) |
| **Input (key drivers and pressures)** | climate, forestry management, disturbances, N deposition |
| **Output (key variables)** | timber yield, vegetation composition, carbon, nitrogen cycle |
| **Geographical coverage and** | temperate forests, Europe, $100m^2$ patches |

| | |
|---|---|
| **resolution** | |
| **Temporal coverage and resolution** | monthly time steps with annual integration |
| **Analytical technique** | Dynamic systems model (process-based); individual tree-based model |
| **Model developers and/or owners** | University of Natural Resources and Apllied Life Sciences, Vienna |
| **Model development history** | published: 2001, current version: PICUS 2.0. PICUS 1.2 was a gap model to capture competition and canopy structre, PICUS 1.3 included an physiological growth function. PICUS 1.4 included soil C and N cycling. |
| **Target Group/users** | PICUS was originally developed as a decision support tool for forest managers. It simulates forest succession in the complex topography of the Eastern Alps in central Europe. The original gap-model was complemented with the 3-PG model in version 1.3. Current version PICUS v1.4 |
| **Calibration** | PICUS was calibrated against data from national forest inventory. |
| **Validation** | Testing against independent long-term growth and yield data revealed good correspondence between observed and predicted values of volume production and stand structure (Seidl et al., 2005, Badeck et al., 2001) |
| **Uncertainty analysis** | Not available |
| **Key reference** | Lexer & Honniger, 2001, Seidl et al., 2005, Seidl et al., 2007, Seidl et al., 2008 |
| **Level of integration** | The different modules are well-integrated. |
| **Links to other models** | PICUS has been used together with EURO-FOR, OSCAR (regional models), ForAG/FASOM (global), AROPAj (regional agriculture) and EFEM-DNDC (agriculture at farm level) in the ENFA/INSEA assessment. It has been combined with the wood products model (WPM) to evaluate carbon storage in wood products (Seidl et al., 2007). |
| **Ease of use/accessibility** | Model is not available |
| **Website** | http://wwwt3.boku.ac.at/picus.html?&L=1 |
| **Comments/remarks** | The hybridization of PICUS with 3-PG in version 1.3 aims at combining the abilities of gap models with regard to interand intra-specific competition, multi-species and multi-layered stand structure and general applicability with the benefits of a widely applied, robust stand-level estimate of forest production based on the concept of radiation use efficiency. |
| **Model structure** |  |

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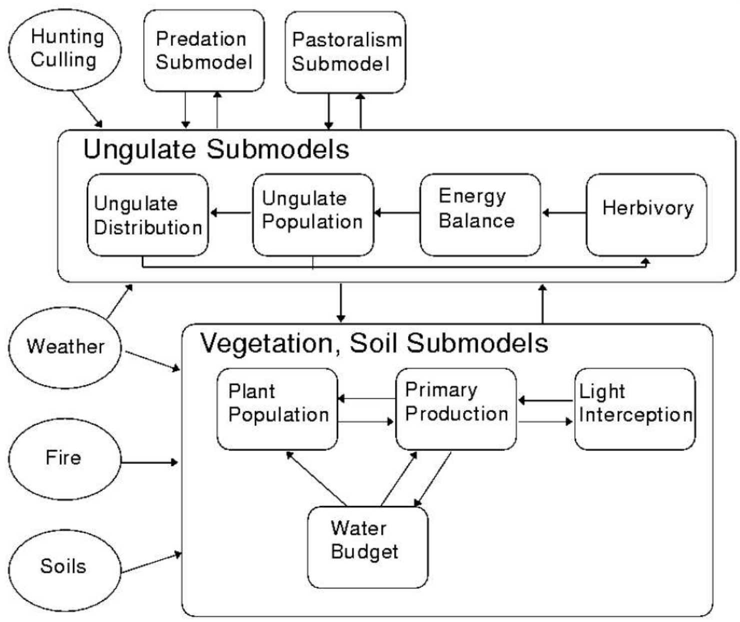
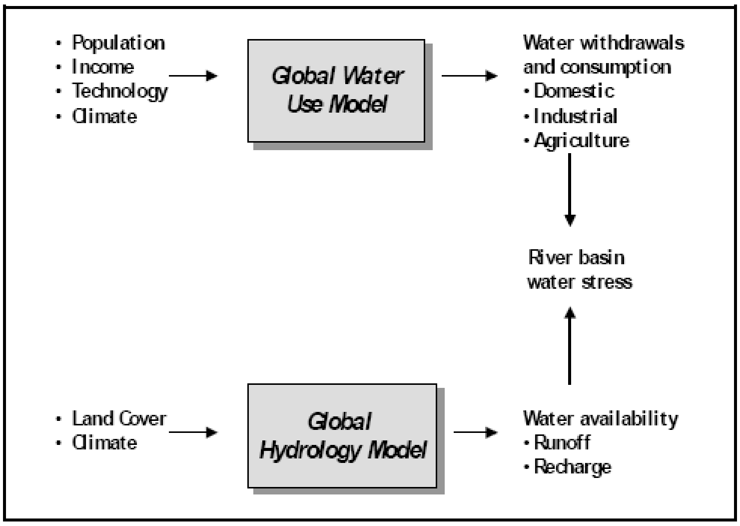
|---|---|
| **Model name** | **SAVANNA** |
| **Full model name** | |
| **Model type** | biogeochemistry models |
| **Subtype** | biome model |
| **Thematic coverage** | vegetation, animal population model and management in grassland, shrubland, savanna and forested ecosystems |
| **Input (key drivers and pressures)** | climate, vegetation type, topology, human management (stocking densities), fire |
| **Output (key variables)** | plant and animal distribution (for functional groups), water and nutrient cycling, livestock production, sustainability of systems, thresholds, habitat suitability |
| **Geographical coverage and resolution** | regional, resolution depending on input data and studied ecosystem (100-1000 grid cells) |
| **Temporal coverage and resolution** | time period: depending on climate input, time horizon: 5-50 years, time steps: weekly |
| **Analytical technique** | Process-based model (dynamic systems model) |
| **Model developers and/or owners** | Mike Coughenour, National Resource Ecology Laboratory, Colorado State University |
| **Model development history** | first published 1985, model has modified for various purposes. Originally developed for pastoralism in African savannas it has been applied to other ecosystems (Mongolian steppe, North American prairie, Rocky Mountain National Park) as well. |
| **Target Group/users** | Originally developed for African savannas (pastoralism), but has been applied extensively to North American national parks as ecosystem management tool. Includes forests and shrublands, too. |
| **Calibration** | Model was calibrated to plant growth data. |
| **Validation** | SAVANNA has been validated by comparing predicted with actual vegetation cover and NPP (e.g. Christensen et al., 2003) |
| **Uncertainty analysis** | Not available |
| **Key reference** | Coughenour & Chen, 1997, Ludwig et al., 2001 |
| **Level of integration** | High level of integration of plant and animal stystems with abiotic (water) and management factors. |
| **Links to other models** | Linked to PHEWS to model Household economics. |
| **Ease of use/accessibility** | available at http://www.nrel.colostate.edu/ftp/coughenour/pubs_lock/index.php?Directory=Manual_1993 |
| **Website** | http://www.nrel.colostate.edu/projects/savanna/ |
| **Model structure** |  Figure 1 |

### *1.1.6 Hydrological models*

| Model name | (E-) SWAT |
|---|---|
| Full model name | (Enhanced) Soil and Water Assessment Tool |
| Model type | Hydrological models |
| Subtype | |
| Thematic coverage | physically based, semi-distributed, continuous time, watershed model |
| Input (key drivers and pressures) | land use (including details on management), topography, soil and climate |
| Output (key variables) | runoff, sediment yield, deep aquifier recharge |
| Geographical coverage and resolution | calculations are done on the scale of sub-watersheds |
| Temporal coverage and resolution | daily time steps |
| Analytical technique | empirical-statistical |
| Model developers and/or owners | public domain model, actively supported by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas, USA |
| Model development history | 1st version: 1998, current version SWAT 2005, see also: http://www.card.iastate.edu/environment/items/asabe_swat.pdf |
| Target Group/users | SWAT was developed to assess the impact of land management and climate patterns on water supply and nonpoint source pollution in large, complex watersheds with varying soil, landcover, and management conditions over long periods. |
| Calibration | SWAT has beeen calibrated for application to many different watersheds, e.g. http://www.mssanz.org.au/MODSIM07/papers/49_s11/InfluenceOfScales11_Heathman_.pdf; http://www.card.iastate.edu/publications/DBS/PDFFiles/05wp396.pdf |
| Validation | SWAT has been validated for many single watersheds, e.g. http://www.card.iastate.edu/publications/DBS/PDFFiles/05wp396.pdf |
| Uncertainty analysis | Yang et al., 2008 |
| Key reference | http://www.card.iastate.edu/environment/items/asabe_swat.pdf |
| Level of integration | The different modules are well-integrated. |
| Links to other models | unknown |
| Ease of use/accessibility | SWAT can be downloaded at: http://www.brc.tamus.edu/swat/ |
| Website | http://www.brc.tamus.edu/swat/ |
| Model structure | Not available |

| Model name | WaterGAP |
|---|---|
| Full model name | Water – Global Assessment and Prognosis |
| Model type | hydrological model |
| Subtype | |
| Thematic coverage | Water availability, water use, water quality (industry, agriculture and domestic) |
| Input (key drivers and pressures) | climate, land cover (livestock density, area irrigated), population size and electricity production |
| Output (key variables) | Water withdawals and water availability (discharge, annual renewable water resources) |
| Geographical coverage and resolution | global, country, river basin (1162 basins included), grid cells 0.5° by 0.5° |

| | |
|---|---|
| **Temporal coverage and resolution** | Base: 1995, Climate base 1961-1990, daily time steps for water balance, annual time steps for industrial and livestock water use, results for 1995, 2025 and 2075 |
| **Analytical technique** | Empirical-statistical |
| **Model developers and/or owners** | Developed by the Centre for Environmental Systems Research of the University of Kassel, Germany, in cooperation with the National Institute of Public Health and the Environment of The Netherlands (RIVM). Development since 2003 by the Universities of Kassel and Frankfurt. |
| **Model development history** | 1st version 1996, current version: WaterGAP 2 |
| **Target Group/users** | Developed as a tool for global analysis of water resources. Used in various global and continental resource assessment (World in Transition, World Water Vision, World Water Developement Report (UNSECO), MA) |
| **Calibration** | Hydrological model was calibrated to 30 years data from 724 discharge measurement stations; where data are available, socio-economic model parameters are calibrated for countries. |
| **Validation** | For validation, the predicted annual discharge values were compared to measured values at the 724 calibration stations and with data from other basins (Alcamo et al., 2003a). Validation for socio-economic estimates was done as well (Döll & Siebert, 2002). |
| **Uncertainty analysis** | a first estimate of the geographical variation in uncertainty of calculations is made, based on the “goodness of-fit” of the model to observed historical data |
| **Key reference** | www.usf.uni-kassel.de/usf/forschung/projekte/watergap.en.htm Alcamo et al. (2003); Alcamo et al., (2003b) |
| **Level of integration** | feedbacks between water cycle and water use submodel |
| **Links to other models** | WaterGAP has been used in several assessments (OECD, GEO, MA) in combination with IMAGE, IMPACT and EcoSim and AIM. Based on WaterGAP, a global model of terrestrial nitrogen (WaterGAP-N) has been developed. |
| **Ease of use/accessibility** | Model is not available for download. |
| **Website** | http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/WaterGAP/index.html |
| **Model structure** | <br>**Fig. 1** Block diagram of the WaterGAP model. |

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|---|---|
| **Model name** | **WBM (+)** |
| **Full model name** | Water Balance Model |
| **Model type** | Hydrological models |
| **Subtype** | |
| **Thematic coverage** | water cycle |
| **Input (key drivers** | climate and surface cover, population, irrigated area |

| | |
|---|---|
| **and pressures)** | |
| **Output (key variables)** | sustainable water use: water use/withdrawl (agriculture, domestic, industry) versus water discharge |
| **Geographical coverage and resolution** | 0.5° by 0.5° grid |
| **Temporal coverage and resolution** | daily time steps, output on annual basis |
| **Analytical technique** | empirical-statistical |
| **Model developers and/or owners** | M. Vörösmarty, Water System Analysis Group, Universityof New Hampshire |
| **Model development history** | unknown |
| **Target Group/users** | unknown |
| **Calibration** | unknown |
| **Validation** | unknown |
| **Uncertainty analysis** | unknown |
| **Key reference** | Vörösmarty et al., 1989, Vörösmarty et al., 2000 |
| **Level of integration** | unknown |
| **Links to other models** | unknown |
| **Ease of use/accessibility** | A detailed description of the model is available at: http://www.asb.cgiar.org/BNPP/phase2/ifpri/description_ water_ balance_model_10jul2003.doc |
| **Website** | Not available |
| **Model structure** | Not available |

### *1.1.7 Biodiversity models*

| **Model name** | **BII** |
|---|---|
| **Full model name** | **Biodiversity intactness index** |
| **Model type** | Biodiversity model |
| **Subtype** | Indicator model |
| **Thematic coverage** | biodiversity loss due to land use change |
| **Input (key drivers and pressures)** | land use (also needed: reference conditions for biodiversity)<br>land use types: protected, moderately used, degraded, cultivated, plantation and urban |
| **Output (key variables)** | relative measure of biodiversity intactness (percentage of original population)<br>BII is a richness-and-area weighted average of the population impact of a set of land use activities, on a given groups of organisms, in a given area. |
| **Geographical coverage and resolution** | Regional (Southern Africa), scale of aggregation: $10^4$ to $10^6$ $km^2$ |
| **Temporal coverage and resolution** | dependent on input (land use maps/predictions) |
| **Analytical technique** | empirical-statistical: expert opinion |
| **Model developers and/or owners** | The biodiversity intactness index was first developed by R. J. Scholes and R. Biggs for the Southern African Millennium Ecosystem Assessment (case study for MA). |
| **Model development history** | Different approaches have been proposed by several authors (including species occurence versus abundance) |
| **Target Group/users** | The BBI is an assessment tool designed to give an indication of current state and past changes in biodiversity. The BII is an aggregate index, intended to provide an intuitive, high-level synthetic overview for the public and policy makers. It can be disaggregated in several ways to meet the information needs of particular users: by ecosystem or political units, taxonomic group, functional type, or land use activity. |
| **Calibration** | The BBI has been calibrated on data for Southern Africa. |

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| **Validation** | Valuation in biodiversity monitoring programmes: Lamb et al., 2009 |
| **Uncertainty analysis** | Hui et al., 2008: biodiversity intactness variance as formal measure of uncertainty (case study: South Africa) |
| **Key reference** | Scholes & Biggs, 2004, Buckland et al., 2005, Nielsen et al., 2007 |
| **Level of integration** | Not applicable (only land use as driver) |
| **Links to other models** | Not available (potential links to land use models) |
| **Ease of use/accessibility** | Calculation algorithm is given in Scholes & Biggs, 2004. Species richness information is needed for calculation. |
| **Website** | Not available |
| **Model structure** | The BII is calculated as: $BII = (\sum_i \sum_j \sum_k R_{ij} A_{jk} I_{ijk}) / (\sum_i \sum_j \sum_k R_{ij} A_{jk})$ where $R_{ij}$ = richness (number of species) of taxon i in ecosystem j, and $A_{jk}$ = area of land use k in ecosystem j |

| | |
|---|---|
| **Model name** | **EUROMOVE** |
| **Full model name** | |
| **Model type** | Biodiversity model |
| **Subtype** | Bioclimatic envelope model |
| **Thematic coverage** | biodiversity in relation to climate change |
| **Input (key drivers and pressures)** | climate change, current plant distributions |
| **Output (key variables)** | changes in plant species number and distribution (stable, increase, decrease) |
| **Geographical coverage and resolution** | Europe, 2500km$^2$ grid cells (dependent on input data) |
| **Temporal coverage and resolution** | baseline: 1990/1995, results reported for 2025, 2050 and 2100, annual time steps |
| **Analytical technique** | 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 |
| **Model developers and/or owners** | Netherlands Environmental Assessment Agency |
| **Model development history** | published: 2002 |
| **Target Group/users** | Used to support climate change impact research at European level; including applications for the European Environment Agency, evaluation of policies to halt biodiversity loss |
| **Calibration** | Calibrated on 1990 data – all multiple logistic regression analyses resulted in statistically significant models ($\alpha = 0.01$). On average, the deviance explained (D) was 42%, indicating a relatively high predictive power. |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Bakkenes et al., 2002, Bakkenes et al., 2006 |
| **Level of integration** | Not applicable |
| **Links to other models** | EUROMOVE uses climate data from IMAGE model. |
| **Ease of use/accessibility** | Model not available online. |
| **Website** | Not available |
| **Comments/remarks** | Description copied from EEA, 2008 |
| **Model structure** | Not available |

| | |
|---|---|
| **Model name** | **GARP-based species distribution models** |
| **Full model name** | GARP=Genetic Algorithm for Rule-set Production |
| **Model type** | Biodiversity model |
| **Subtype** | Bioclimatic envelope model |
| **Thematic coverage** | biodiversity in relation to climate change |

| | |
|---|---|
| **Input (key drivers and pressures)** | climate change, also required: plant species distribution |
| **Output (key variables)** | number of species, species distribution maps |
| **Geographical coverage and resolution** | GIS-based, spatial explicit approach, local/regional, depending on input (species presence data) |
| **Temporal coverage and resolution** | Depending on climate change input |
| **Analytical technique** | ecological niche modelling, based on genetic algorithms |
| **Model developers and/or owners** | D. Stockwell and A. Boston (University of California, San Diego, Environmental Resources Information Network (ERIN)) |
| **Model development history** | The GARP was first implemented at the Environmental Resources Information Network (ERIN) (Boston and Stockwell 1994). |
| **Target Group/users** | |
| **Calibration** | Model is calibrated based on presence data of species in relation to environmental variables |
| **Validation** | Stockman et al. (2006) tested the performance of GARP to predict spider distribution in California based on a limited number of museum specimens. Conclusion: simple bioclimatic envelope models perfomed better than GARP. |
| **Uncertainty analysis** | unknown |
| **Key reference** | Boston & Stockwell, 1995, Stockwell, 2006 |
| **Level of integration** | Not applicable |
| **Links to other models** | Not applicable |
| **Ease of use/accessibility** | methodology is available online: www.lifemapper.org/desktopgarp |
| **Website** | Not available |
| **Comments/remarks** | The GARP models are a model family, not a single model with different equations. |
| **Model structure** | Not available |

| **Model name** | **GLOBIO** |
|---|---|
| **Full model name** | Global Methodology for Mapping Human Impacts on the Biosphere |
| **Model type** | Biodiversity model |
| **Subtype** | Indicator model |
| **Thematic coverage** | effects of climate change, land use change, infrastructure development and nitrogen deposition on biodiversity |
| **Input (key drivers and pressures)** | Land cover, land use and land use intensity, infrastructure, atmospheric N deposition, climate (precipitation and temperature) |
| **Output (key variables)** | Mean Species Abundance (MSA) |
| **Geographical coverage and resolution** | global, (0.5º by 0.5º for climatic data, 1km by 1km for land use data) |
| **Temporal coverage and resolution** | Depending on input data |
| **Analytical technique** | empirical-statistical model: Dose-response relationships between fragmentation, infrastructural development |
| **Model developers and/or owners** | UNEP-DEWA, UNEP-WCMC, UNEP-GRID-Arendal, Netherlands Environmental Assessment Agency |
| **Model development history** | 1st version: 2001, current version GLOBIO3 |
| **Target Group/users** | GLOBIO is aimed at providing information for understanding ongoing trends and depicting future trends in regional and global assessments. GLOBIO3 is a quantitative model used in the assessment of policy options for reducing global biodiversity loss. The model is used in global studies, such as the OECD Environmental Outlook, GEO4 and COPI/TEEB. |
| **Calibration** | Not applicable |

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|---|---|
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Alkemade et al. (2009) |
| **Level of integration** | Different pressures (land use change and fragementation, pollution) are well-integrated, double-counting is avoided (pollution affects biodiversity only in natural areas while it is included in land use effects for managed land). |
| **Links to other models** | Uses land use and N emission output from IMAGE and is thereby linked to land use/land cover and economics |
| **Ease of use/accessibility** | not available, however description of the parameters used can be found in Alkemade et al. (in press) and Alkemade et al. (2006) |
| **Website** | http://www.globio.info/ |
| **Model structure** | Not available |

| **Model name** | **MIRABEL** |
|---|---|
| **Full model name** | Models for Integrated Review and Assessment of Biodiversity in European Landscapes |
| **Model type** | Biodiversity model |
| **Subtype** | Indicator model |
| **Thematic coverage** | biodiversity |
| **Input (key drivers and pressures)** | pollution (eutrophication, nitrogen deposition, acidification, climate change) and land use (urbanization trasnport, farming intensification, drainage irrigation, land abandonment, afforestation, habitat fragmentation) |
| **Output (key variables)** | trends in pressures, status of threatened habitats |
| **Geographical coverage and resolution** | 28 European countries, 13 ecological regions, using CORINE land cover map |
| **Temporal coverage and resolution** | Impact forecasts for 2010 and 2050 (climate) |
| **Analytical technique** | empirical-statistical model: based on expert opinion |
| **Model developers and/or owners** | Centre for Ecology and Hydrology Merlewood Research Station, UK, |
| **Model development history** | Model was developed for the European Environment Agency (EEA) |
| **Target Group/users** | MIRABEL was initially developed in response to a requirement to predict habitat change in the context of a 1998 assessment of the state of the environment in Europe. |
| **Calibration** | Not available |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Petit et al., 2001 |
| **Level of integration** | unknown (effects based on expert opinion) |
| **Links to other models** | uses input from CARMEN, RAINS, IMAGE, EUTREND and LARCH for pressures/drivers |
| **Ease of use/accessibility** | Model is not available |
| **Website** | Not available |
| **Model structure** | Not available |

| **Model name** | **SAR** |
|---|---|
| **Full model name** | Species area relationship |
| **Model type** | Biodiversity model |
| **Subtype** | Indicator model |
| **Thematic coverage** | Biodiversity loss due to habitat loss |
| **Input (key drivers and pressures)** | habitat loss (climate change via IMAGE, van Vuuren et al., 2006), N deposition |

| | |
|---|---|
| **Output (key variables)** | number of species |
| **Geographical coverage and resolution** | global, calculated for different biogeographical units (biomes, ecoregions), not spatially explicit |
| **Temporal coverage and resolution** | For the MA projections were done until 2050. |
| **Analytical technique** | empirical-statistical (based on species area relationship $S = cA^z$), where S= number of species, A= area, z and = constants |
| **Model developers and/or owners** | Relationship is based on ecological theory discussed by for example Arrhenius, 1921, McArthur & Wilson, 1967 and Rosenzweig, 1995. |
| **Model development history** | The species area relationship was applied as an indicator of biodiversity in the Millennium Ecosystem Assessment (MA, 2005a). |
| **Target Group/users** | The SAR has not been applied for large-scale biodiversity assessments after the MA. |
| **Calibration** | Not available |
| **Validation** | Not available |
| **Uncertainty analysis** | uncertainty analysis was done by van Vuuren et al., 2006 |
| **Key reference** | Pimm et al., 1995, Pimm et al., 2006, van Vuuren et al, 2006 |
| **Level of integration** | Next to the species-area relationship, in the MA methodology also nitrogen deposition was incorporated as pressure on biodiversity (MA, 2005e). |
| **Links to other models** | During the MA the changes in the species area relationship was based on land use changes calcualted by the IMAGE model. |
| **Ease of use/accessibility** | Equations have been published and calculations can easily by done. |
| **Website** | none |
| **Model structure** | Not available |

### *1.1.8 Ocean Models*

| **Model name** | **ASSETS** |
|---|---|
| **Full model name** | Assessment of Estuarine Trophic Status |
| **Model type** | Biogeochemistry models |
| **Subtype** | Hydrology |
| **Thematic coverage** | Water quality, Trophic status, Human influence |
| **Input (key drivers and pressures)** | Comparison of anthropogenic land-based and oceanic nutrient loading with natural background concentrations, estimates of susceptibility; Nitrogen and Phosphorous levels, Chlorophyll a and macroalgae growth, algal dominance changes, loss of SAV, dissolved oxygen, harmful algae coverage; susceptibility, capacity of the system to dilute and/or flush nutrients, predictions of nutrient loading based on expected population increase, planned management actions, and expected change sin watershed uses. |
| **Output (key variables)** | Indicator of Overall Human Influence on the system; An assessment of the current state of the system; and the future Response of the system under different scenarios. |
| **Geographical coverage and resolution** | Estuarine/Watershed level. Currently, there are 157 assessed estuarine systems in ASSETS primarily based in the U.S. But there are a number of international records. Resolution of output is based the the bathymetry grid used, however the details are not specified in the peer-reviewed methodology. |
| **Temporal coverage and resolution** | Provides an assessment of current state (sets reference conditions) and forecasts future outlook based on the susceptibilty of the system and one of three options: 1) Future nutrient pressures decrease; Future nutrient pressures are unchanged; and Future nutrient pressures are increase. Temporal resolution is not specifically defined and is referred to as 'Future Outlook' based on data such as demographic projections. |
| **Analytical technique** | A screening model that uses a Pressure-State-Response framework |
| **Model developers and/or owners** | ASSETS was devloped from the National Estuarine Eutrophication Assessment (NEEA) methodology originally developed by a team of people from NOAA, other federal and state agencies, private organisations, colleges and universities. ASSETS was |

| | |
|---|---|
| | developed by a team of NOAA scientists and researchers from the EU, working at the Institute for Marine Research (IMAR). |
| **Model development history** | ASSETS was developed from the National Estuarine Eutrophication Assessment (NEEA) that was lauched in 1990. 1990 - 1998: Data and information of 138 estuaries and coastal waters was collected from approximately 400 scientists using an expert knowledge engineering approach. Five regional reports detailed conditions and trends of 16 indicator variables within US estuarine and coastal systems. 1998 - 1999: Data and information from the Estuarine Eutrophication Survey Synthesis to NEAA and development of eutrophication assessment method. 2001: Improvement of NEAA and development into ASSETS. 2002: NEEA Update workshop and guidance document. 2003 - 2005: Application of NEAA/ASSETS methodology to update 13 North and Mid-Atlantic systems and development of a human use indicator to complement the ASSETS eutrophication indicators through a partnership with UMD, UNH, UMASS, Maine State Planning Office, and EPA (funding through CICEET). 2003: Application of the NEEA/ASSETS methodology to 10 estuarine and coastal systems in the European Union (Portugal); Research into the addition of typology criteria for eutrophication symptom range definitions. 2004: Development of the http://www.eutro.org website, listing ASSETS scores for systems from the US, EU (Germany, Ireland, Portugal), and China. COMPASS initiative, bringing together ad hoc group from the EU and the US in order to examine a possibel harmonization between OSPAR-COMPP and ASSETS. 2005: Application of ASSETS methodology to North East National Estuarine Research Reserve(NERR) systems using the System Wide Monitoring Data (SWMP) (funding through CICEET – Cooperative Institute for Coastal and Estuarine Environmental Technology). Preparation of a University of Maryland Center for Environmental Studies – NOAA partnership in order to apply the NEEA/ASSETS methodology via an online survey and National Workshop to update the National Estuarine Eutrophication Assessment for 138 US estuaries and coastal waterbodies. Preparation of a joint US-EU-China initiative (NOAA-IMAR-SOA) in order to apply ASSETS to Chinese coastal systems, and further develop and test the methodogy. |
| **Target Group/users** | Managers and Policy-makers: NEEA's aim was to define the United States national resource base and develop a national assessment capability and the aim of the ASSETS project was to provide an update and improve NEEA, using real data that was consistent with the philosophy of the original work but more robust in methodology. |
| **Calibration** | The ASSETS approach has been intercalibrated with the original NEEA work is demonstrated for 82 U.S. Estuaries in the key reference paper. |
| **Validation** | Conclusions are validated against a more extensive set of data from the original NEEA survey. |
| **Uncertainty analysis** | Not Specified |
| **Key reference** | Bricker et al. (2003). |
| **Level of integration** | Limited - based on assessment of eutrophication/water quality only. |
| **Links to other models** | No links with other models are specified. Related assessments and programmes include: Comparison and Assessment of Eutrophication (COMPASS); EPA National Coastal Assessment (NCA); CICEET Gulf of Maine Project:data acquisition and development of metrics and indices to describe the status and track trends of nutrient related water quality in estuaries and coastal waters; NOAA National estuarine Eutrophication Assessment Update Program. |
| **Ease of use/accessibility** | Good - use of clear, colour-coded system. ASSETS application is freely available for download at: http://www.eutro.org/register/. It is available in four languages including Chinese. Results for the applications of ASSETS are available through the website: http://www.eutro.org/syslist.aspx. User manual is not available however the ASSETS programme includes a tutorial. |
| **Website** | http://www.eutro.org/ |
| **Comments/remarks** | By focusing on commonalities and differences between U.S. And E.U. estuarine systems and coastal zones, ASSETs may provide a stepping stone towards a unified system or systems which may accomodate the diversity of pressure, state, and responses of both regions. |

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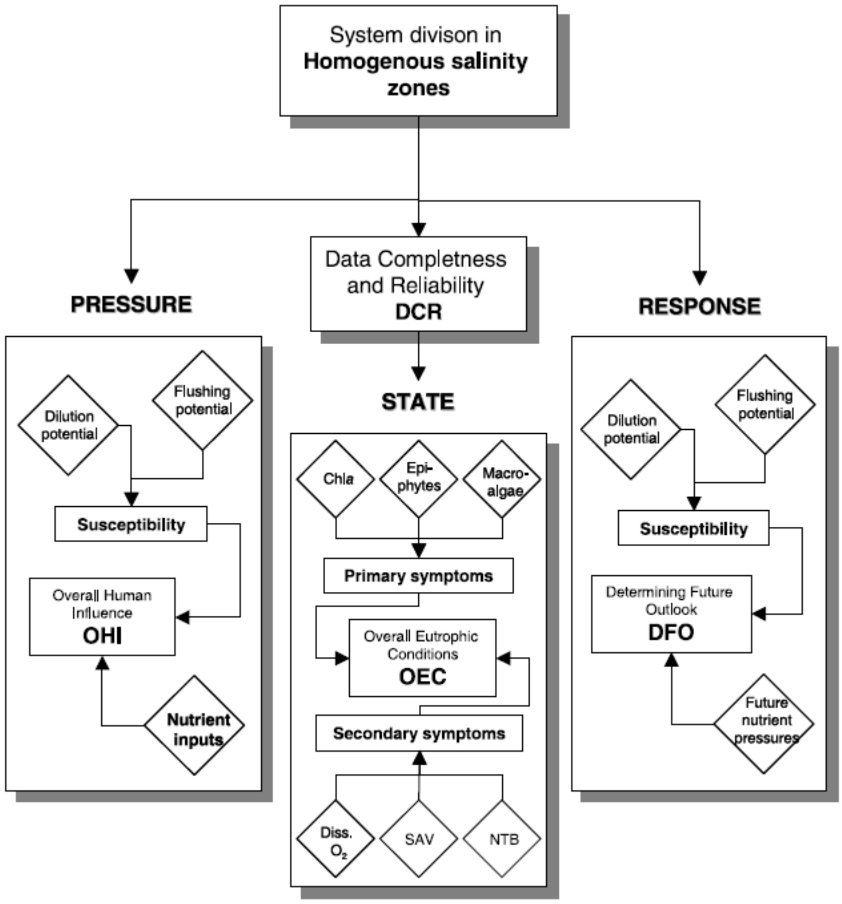
| **Model structure** |  <br>Fig. 1. Flow chart of the ASSETS methodology. |

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|---|---|
| **Model name** | **Atlantis** |
| **Full model name** | |
| **Model type** | Biogeochemical |
| **Subtype** | |
| **Thematic coverage** | Ecosystem modelling, fisheries management |
| **Input (key drivers and pressures)** | Biogeochemical ecosystem model (consumption, production, waste production, migration, predaqtion, recruitment, habitat dependency, and natural andd fishing mortality); Hydrographic transport model; Fisheries fleet statistics (target, byproduct and bycatch groups, gear type (and associated selectivity curve and habitat impacts), habitat dependency, discarding, and effort allocation submodels). |
| **Output (key variables)** | Marine ecosystem dynamics are represented by spatially explicit submodels that simulate hydrographic processes, biogeochemical factors driving primary production, food web relations among functional groups, crude habitat interactions, and fishing fleet behaviour. |
| **Geographical coverage and resolution** | Atlantis has been applied at a fine scale (specific bays/current systems) in a number of locations, initially around Australia but also the Californian Current. The spatial geometry of the model is one made up of polygons which correspond to the geographical form of the study area. The area and shape of the polygons reflect the speed with which physical variables change with particular parts of the study area. This modelling approach is advantageous as it can be modified to nest fine-scale models within a coarser scale resolution. |
| **Temporal coverage and resolution** | For computational efficiency, a daily time step is used wherever possible. Within the biological modules however, a daily timestep may make the |

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| | variables with fast dynamics become unstable. Therefore, while some groups (e.g. Fish) work on a daily time step other groups (e.g. phytoplankton) use an adaptive timestep, which is repeated until a full 24-h period has been completed. In the orginal Bay Model 2 (BM2), from which Atlantis was derived, the model runs span a 20-yr time period (beginning after a 10 yr burn-in period) with output recorded every 14 days. Simulations lasting 100 yrs were also undertaken to check for long period cycles and to verify that the models had reached a representative state at the end of the 30 yr period. |
| **Analytical technique** | Deterministic, spatially explicit model. |
| **Model developers and/or owners** | Elizabeth A. Fulton, Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Marine Research, Australia. Funding for Atlantis is provided by NOAA NMFS, NOAA Fisheries and the Environment (FATE), NOAA NMFS Economic Program, Moore Foundation, and the Packard Foundation. |
| **Model development history** | Atlantis was developed from a series of models that explored optimal ecosystem model complexity. A precursor to Atlantis, the integrated Generic Bay Ecosystem Model (IGBEM) (Fulton et al. 2004a), was a combination of the biological modules of the European Regional Seas Ecosystem Model (ERSEM) and the physical processes and spatial layout of the Port Philip Bay Integrated Model. Efforts to simplify the physiological processes in IGBEM resulted in the Bay Model 2 (BM2), a more parsimonious framework that still effectively captures system dynamics. Atlantis is a modified version of BM2, established to improve upon ecosystem based fishery management tools (text taken from Brand et al. 2007). |
| **Target Group/users** | Atlantis is targetted at those involved in ecosystem/fisheries Management Strategy Evaluation (MSE), in which management policies and assessment methods are tested against simulations that represent a real ecosystem and its complexities. For example, the model can identify trade offs between species, fleets and management goals, and to identify effects of management policies. It is not intended for tactical management, for instance setting quotas for target stocks. Atlantis has been applied to more than 15 ecosystems, primarily in the temperate waters of Australia and the US, and has been rated in high regard by the United Nations Food and Agriculture Organisation (FAO). |
| **Calibration** | Atlantis is calibrated to a wide range of data depending upon the area to which it is being applied. Tuning needs to be carried out until all groups persist and numerical stability is acheived. Model calibration currently involves trial and error and some users have calibrated the model manually due to long model run times that prevent the searching of the parameter space with automated procedures (Brand et al. 2007). The tuning procedure can use, as a reference point, values from the literature or outputs of other models such as Ecopath. |
| **Validation** | Model outputs are referenced against actual environmental data available for the area. This does potentially restrict the model to use in areas where a great deal of information is already available. |
| **Uncertainty analysis** | As Atlantis incorporates a great many parameters (despite being originally scaled down from the IGBEM model) a systematic sensitivity analysis is impractical. However, Fulton et al. (2004) recommends the use of factor screening to identify the most sensitive parts of the model and the exploration of the effects of the resulting restricted set of parameters. |
| **Key reference** | Fulton et al., 2004a; Fulton et al., 2004b; Fulton et al., 2005; Brand et al. 2007 |
| **Level of integration** | Good - links biological, chemical, ecological, and fisheries data. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. Atlantis is built from a number of biological, physical, and fisheries sub-models. |
| **Ease of use/accessibility** | Modelling process is complex and would need to be carried out by a specialist. Background publications are readily available in the scientific literature, however technical papers are relatively inaccessible and the model developers would need to be contacted for further information. The model |

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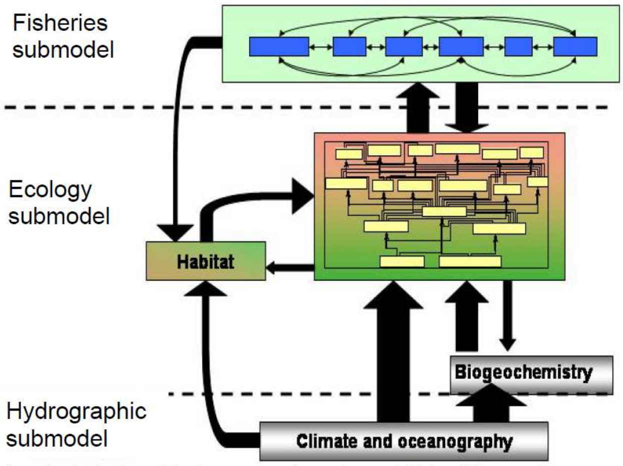
| | cannot be downloaded. |
| **Website** | http://www.csiro.au/science/ps3i4.html |
| **Model structure** | <br><br>Figure 1. Schematic of Atlantis modules for oceanography, ecology, and fishing. This paper discusses the ecology and hydrographic submodels. |

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| **Model name** | **Aus-ConnIe** |
| **Full model name** | Australian Connectivity Interface |
| **Model type** | Biogeochemistry models |
| **Subtype** | Oceanography, Connectivity |
| **Thematic coverage** | Ocean circulation, larval dispersal, larvel recruitment, contaminant dispersal. |
| **Input (key drivers and pressures)** | Sea level (Altimeter and Tide gauges); Wind fields; Particle trajectories; Geostrophic currents; Wind forced components; Estimates of ocean currents; |
| **Output (key variables)** | Maps showing land masses, the 200m depth contour, and spatial connectivity statistics for the user specified source or sink. |
| **Geographical coverage and resolution** | Australia; 0.5 degree geographical grid; All statistics were based on currents and trajectories computed at a fixed depth of Z = 20m, which was taken to be representative of surface waters where larval concentrations tend to be highest. |
| **Temporal coverage and resolution** | Monthly and quarterly statistics are available, calculated as T (dispersion period = 10 and 20 days for monthly, and 30, 40, 60, and 80 days for the quarterly. Probailities were calculated from day 1 of the calender month/quarter to day T, then from day 2 to day T+1, until reaching the last day of the month/quarter. The probabilities were then avergaed to give a probability distribution representative of that month/quarter. |
| **Analytical technique** | Statistical model which analyzes of the particle trajectory information to give the following for each grid cell: 1) The probablilty that particles beginning within any user specified region willl be inside the grid cell at the end of the dispersion period (i.e. lifetime); 2) The probability that particles beginning within any user specified region will reach the grid celll before the end of the dispersion period; 3) The probability that particles arriving within any user specified region were inside the grid cell exactly one dispersion period previously; and 4) The probability that particles arriving within any specified region were inside the grid cell anytime within the previos dispersion period. |
| **Model developers and/or owners** | Aus-Connie was developed as part of the Strategic marine Fund for the Marine Environment (SRFME), a joint venture between CSIRO and the Western Australian State Government. Team: Scott Condie (Project leader), Jim Mansbridge (Statistical Programming), Jason Waring (Senior Web Interface/Designer), Irshad Nainar (Web Interface/Database), and Madeleine Cahill (Altimetry Analysis). |
| **Model development history** | Aus-Connie was developed in 2003 and is based on JEMS-Connie, a connectivity tool developed by CSIRO Marine Research as part of the North West Shelf Joint Environmental Management Study (NWSJEMS). JEMS- |

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| | Connie differs in that the domain is restricted to the North West Shelf of Western Australia, and the statistics were derived particle trajectories using hydrodynamic current fields. Access to JEMS-Connie is restricted. |
| **Target Group/users** | Aus-ConnIe has been developed as a web-tool for marine scientists and managers to investigate the large-scale patterns of spatial connectivity around Australia associated with ocean currents. |
| **Calibration** | Ocean current data are calibrated from: sea level anomolies (Topex/Poseidon satellite altimeter (9.9 day global cycle); ERS satellite altimeter (35 day global cycle); and tide-gauges from the Australian coastline); Temperature and Salinity measurements (a range of sources including the NODC World Ocean Atlas 1994 hydrographic data; CSIRO RV Franklin; RV Southern Surveyor; and SRV Aurora Australis); and Wind fields (NCEP-NCAR 40-year Reanalysis data set). |
| **Validation** | The model has been validated through comparisons with all the World Ocean Circulation Experiment (WOCE) satellite tracked surface drogued drifters in the region from January 1994 to December 1999. |
| **Uncertainty analysis** | Not Specified |
| **Key reference** | Condie et al., 2005 |
| **Level of integration** | Limited - based on oceanographic variables of ocean currents. |
| **Links to other models** | No links with other models are specified. Aus-ConnIe was developed from the JEMS-Connie model. |
| **Ease of use/accessibility** | Relatively simple, the user must select: 1) A region of interest on the map (0.5 degree resolution); 2) Whether the selected region represents a source or a sink; 3) The year and month(s) on which the connectivity statistics will be based; 4) The dispersion period (10, 0r 20 days fro monthly or 30, 40, 60 or 80 days for quarterly); and 5) Whether the connectivity probabilities are based only on particle distribution at the end of the dispersion period (after lifetime), or on all the particle distributions that occur over the dispersion period (within lifetime). |
| **Website** | http://www.per.marine.csiro.au/aus-connie/index.html |
| **Model structure** | Not available |

| **Model name** | **Cumulative Threat Model for the global ocean** |
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| **Full model name** | |
| **Model type** | Biodiversity model |
| **Subtype** | Indicator model |
| **Thematic coverage** | Human influence, ecological change, threat indices |
| **Input (key drivers and pressures)** | Expert survey; 17 anthropogenic drivers of ecosystem change - weighted by their estimated ecological impact; maps of 14 marine ecosystems; models of 6 marine ecosystems. |
| **Output (key variables)** | A single comparable estimate of cumulative human impact on 20 ecosystem types. |
| **Geographical coverage and resolution** | Global but can be applied at the local- and regional-scale; 1$km^2$ resolution grid. |
| **Temporal coverage and resolution** | Datasets used are from a number of different year-ranges and so no specific output time is specified. The model implies that is it representing a reference level for current (2008) cumulative human impact, however this is not specifically discussed in the published paper or the supplementary materials. |
| **Analytical technique** | Ecosystem-specific, multi-scale, spatial, additive model |
| **Model developers and/or owners** | Benjamin S. Halpern and team at UCSB. The work was funded by the National Center for Ecological analysis and Synthesis (NCEAS) and supported by the National Science Foundation and a grant from the David and Lucile Packard Foundation to evaluate ecosystem based management in coastal areas. |
| **Model development history** | Model published in 2008. |
| **Target Group/users** | The model is aimed at managers, conservation groups, and policymakers, and has been widely used by many organisations since its publication (Web of Knowledge records |

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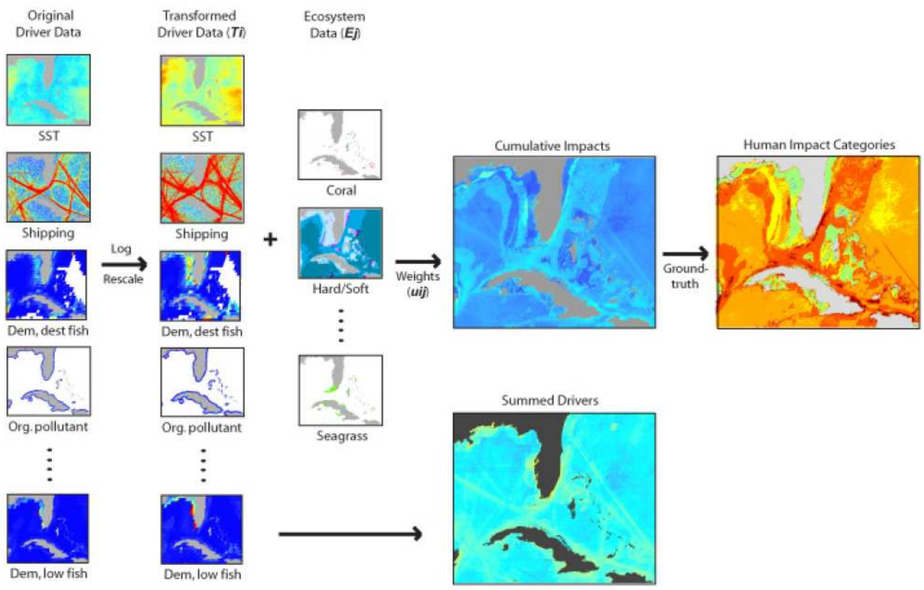
| | 33 citations for this paper since February 2008). The model has been as a layer in documents designed to inform policy makers on threats and protection priorities for marine systems. |
| **Calibration** | Weighting of the different datasets was calibrated through an expert survey that assessed the vulnerability of each ecosystem to each driver on the basis of 5 ecological traits. |
| **Validation** | Impact scores were 'ground-truthed' using global estimates of the condition of marine ecosystems from previous studies; Results with weighting values from the expert survey (which assessed the vulnerability of each ecosystem to each driver on the basis of 5 ecological traits) were very similar to simulated values, with values slightly but significantly different from null expectations for the categories of very low, medium, medium high, and very high impact. Also, tested an alternative cumulative impact model based on the average driver-by-ecosystem impact scores rather than the sum. There was a very high correlation between outputs of the summed vs. average models showing that the spatial pattern of relative impact is very similar under either model. There was also a positive correlation between the average cumulative impact scores and ocean condition in the ground truth regions. Using the new regression equation from this groundtruth correlation led to very similar percents of the ocean in each impact category compared to the summed model. |
| **Uncertainty analysis** | Good - Model considers a broad range of anthropogenic drivers including climate change, pollution, invasive species, and fisheries. |
| **Key reference** | Halpern et al., 2008 |
| **Level of integration** | Good - Model considers a broad range of anthropogenic drivers including climate change, pollution, invasive species, and fisheries. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. Previously published models were used to develop data layers and dstribution models of 6 marine ecosystems were created through this process. |
| **Ease of use/accessibility** | Modelling process is relatively complex, however the final outputs and data layers are available for download through the internet and the cumulative index is easily understandable with the following categories: Very Low impact, Low impact, Medium impact, Medium High impact, High impact, and Very High impact. |
| **Website** | http://www.nceas.ucsb.edu/GlobalMarine |
| **Model structure** |  |

| Model name | ERSEM II |
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| **Full model name** | European Regional Seas Ecosystem Model |
| **Model type** | Biogeochemical model |
| **Subtype** | ocean |
| **Thematic coverage** | Annual nutrient cycling, Regional Seas, physical parameters, biological parameters, benthic and pelagic coupling. |

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| **Input (key drivers and pressures)** | Pelagic model: Phytoplankton (regulating factors; carbon dynamics; phosphorous dynamics; nitrogen dynamics; silicate dynamics; sinking of phytoplankton); Pelagic bacteria (Environmental regulating factors; Carbon dynamics; Nutrient Dynamics); Microzooplankton (Carbon dynamics; Nutrient dynamics); Mesozooplankton (Carbon dynamics; Nutrient dynamics; The assimilation balance); Pelagic nutrients; Dissolved oxygen and reduction equivalents (Oxgen re-aeration); and Dissolved and particulate organic matter. Benthic model: Benthic organisms (Environmental regulating factors; Carbon dynamics; Filter feeders; Nutrient dynamics; Assimilation balance); Benthic decomposers (Environmental regulating factors; Carbon dynamics; Nutrient dynamics; Assimilation balance); The organic matter in the sediments; Benthic nutrients and other dissolved components (Inputs to the benthic nutrients model; Ammonium; Nitrate; Phosphate; Silicate; Reduction equivalents; Dissolved organic matter); Oxygen distribution in the sediments; Shifting of the layers. |
| **Output (key variables)** | Simulations of the annual cycles of carbon, nitrogen, phosphorus and silicon in the pelagic and benthic components of the marine ecosystem. |
| **Geographical coverage and resolution** | Dependent on resolution of the model that it is coupled to. ERSEM's upper boxes extend from the surface to 30 m, the lower boxes from 30 m to the bottom. When coupled to high resolution hydrodynamic models, ERSEM can be applied over large geographical scales. ERSEM could be adapted for other regions as it is essentially a generic model which is then coupled to an appropriate physical model for a region, such as the General Ocean Turbulence Model (GOTM). ERSEM has been shown to be equally applicable in tropical and warm temperate systems such as the Arabian Sea, Mediterranean and Irish Seas (Allen, Blackford and Radford, 1998; Allen, Sommerfield and Siddorn, 2002; Crise et al., 1999). Studies of land-ocean interaction have ranged from shallow coastal lagoons to an assessment of riverine influence on the North Sea basin. Basin scale and open ocean applications in 1, 2 and 3 dimensions |
| **Temporal coverage and resolution** | Dependent on resolution of the model that it is coupled to. When coupled to high resolution hydrodynamic models, ERSEM can be applied over large temporal scales. ERSEM also provides a model mesocosm environment that can be expected to react in a qualitatively correct manner to seasonal, regional and inter-annual variations. ERSEM model can reproduce long term inter-annual variations in mesozooplankton biomass seen in the CPR dataset. |
| **Analytical technique** | Statistical analysis of ecosystem dynamics. |
| **Model developers and/or owners** | ERSEM II was developed by a consortium of organisations, namely: Netherlands Institute for Sea Research (NIOZ); Plymouth Marine Laboratory (PML); Institut fur Meereskunde, University of Hamburg; Scottish Office Agriculture and Fisheries Department Marine Laboratory; Culterty Field Station, University of Aberdeen; Department of Statistics and Modelling Science, University of Strathclyde; Ecological Modelling Centre, Joint Department of DHI/VKI; Carl von Ossietzky University. ERSEM II was an EU Project in the Marine Science and Technology programme (MAST). |
| **Model development history** | ERSEM I was developed from 1990-1993. ERSEM II was developed from 1993-1996 with the objective of developing a generic model system of the cycling of carbon and the macro-nutrients nitrate, ammonium, phosphate and silicate in the temperate shelf seas of Europe. ERSEM II has since been applied to a range of other environments. Details of the versions of ERSEM are as follows: the 15-box version ERSEM I, based on a subdivision of the North Sea simulation area into 10 upper and 5 lower boxes; the 130-box version ERSEM II, based on a subdivision of the North Sea into 85 upper and 45 lower boxes; the 138-box version of ERSEM, called COCOA (COntinental COastal Application), based on a subdivision of the North Sea into 93 upper and 45 lower boxes with refined boxes in the southern North Sea and along the British and Danish coasts. Programming language: FORTRAN |
| **Target Group/users** | Scientists, policy-makers and managers. One of the main objectives of the ERSEM II project was to develop a model system with a prognostic |

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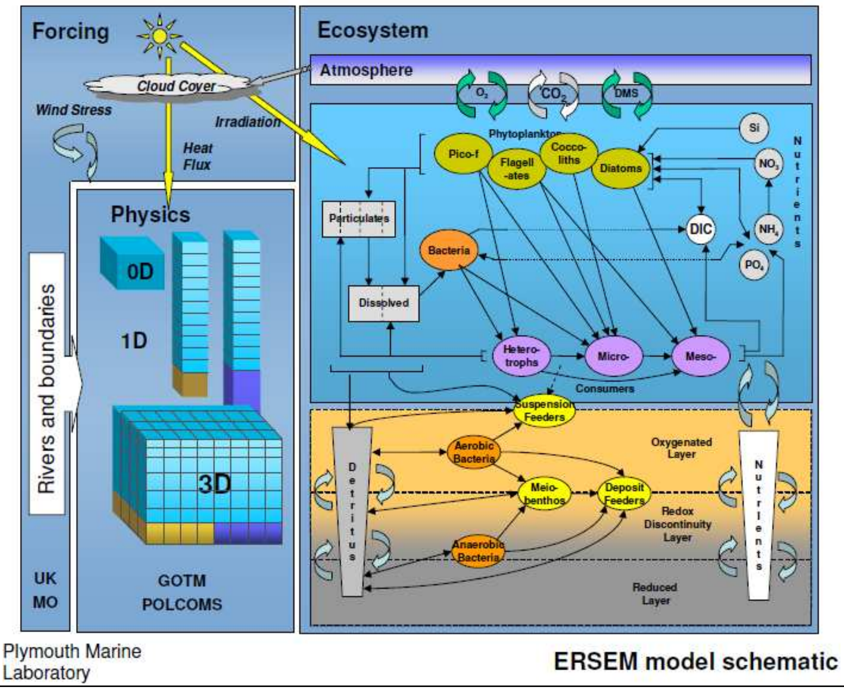
| | capability in order for it to be useful as a decision-support tool. |
| **Calibration** | The major data sources that were used to calibrate the ERSEM datasets were a) datasets of original observations compiled in the ECOMOD database of the Institut für Meereskunde (IfM) of the University of Hamburg and b) a dataset of monthly mean values of phosphate, nitrate, ammonium, silicate and chlorophyll, provided by the International Council of the Sea (ICES) for IfM. The dataset from ICES was based on data of the years 1985-1994 from the north-west European shelf, using a 1° x 1° resolution, as for ERSEM II. ICES provided climatological arithmetic means, medians, standard deviations and quantiles for the five parameters mentioned. |
| **Validation** | The ERSEM model's range of processes provides confidence in its predictive capabilities. For example, recent work has demonstrated that the ERSEM model can reproduce long term inter-annual variations in mesozooplankton biomass seen in the Continuous Plankton Recorder (CPR) dataset. ERSEM's prognostic capability has been tested by making a 40-year-long hindcast with realistic physical forcing and realistic river inputs. |
| **Uncertainty analysis** | Not specified |
| **Key reference** | ERSEM-II European Regional Seas Ecosystem Model II (1993-1996), Journal of Sea Research (special issue), 1997, 38(3-4). |
| **Level of integration** | Limited - focuses on lower trophic levels of pelagic and benthic systems. However this model is deemed generic when coupled with a qualitatively accurate physical model and so exhibits high interoperability with other types of data. |
| **Links to other models** | ERSEM was conceived as a generic model, which, when coupled to a qualitatively correct physical model, such as the General Ocean Turbulence Model (GOTM), should be capable of correctly simulating the spatial pattern of ecological fluxes throughout the seasonal cycle and across eutrophic to oligotrophic gradients of the North Sea. |
| **Ease of use/accessibility** | Modelling process is complex and would need to be carried out by a specialist. All methods are fully and transparently published and discussed in the scientific literature and ftp site (http://web.pml.ac.uk/ecomodels/ersem.htm). The model is not yet downloadable from the PML website although there is a link to it meaning that it possibly may be available in the future - for further information on this contact modelling@pml.ac.uk. |
| **Website** | http://web.pml.ac.uk/ecomodels/index.html |
| **Model structure** |  |

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| **Model name** | **EwE, Ecospace & EcoOcean** |
| **Full model name** | **Ecopath with Ecosim, Ecospace & EcoOcean** |
| **Model type** | Biogeochemical model |
| **Subtype** | Ecosystem model |
| **Thematic coverage** | Trophic interactions, population dynamics, ecosystem valuation, simulations. |
| **Input (key drivers and pressures)** | Ecopath requires input of three of the following four parameters: Biomass; Production/Biomass ratio (or total mortality); Consumption/Biomass ratio; and Ecotrophic efficiency for each of the functional groups in the model. Ecosim inherits its initial key parameters from the base Ecopath model, and can incorporate (and benefits from) time series data, e.g. those available from single species stock assessments. This can include fishing effort or fishing mortality data. Ecospace also relies on the Ecopath mass-balance approach for most of its parameterisation. Additional inputs are movement rates used to compute exchanges between grid cells, estimates of the importance of trophic interactions (top-down vs. bottom-up control), and habitat preferences for each of the functional groups included in the model. EcoOcean builds on EwE by incorporating 43 functional groupings, global datasets of catches, ex-vessel prices, biomass and distant water fleets from teh Sea Around Us project and the fleet statistics from FAO. |
| **Output (key variables)** | Ecopath creates a static mass-balanced snapshot of the resources in an ecosystem and their interactions, represented by trophically linked biomass 'pools'. The biomass pools consist of single species, or species groups representing ecological guilds. Pools may then be further split into ontogentic (juvenile/adult) groups that can then be linked together in Ecosim. Ecosim provides a dynamic simulation capability at the ecosystem level. Biomass flux rates among pools are expressed as a function of time varying biomass and harvest rates. Ecosim allows variable speed splitting to enable efficient modelling of the dynamics of both 'fast' (phytoplankton) and 'slow' groups (whales). It computes the effects of micro-scale behaviours on macro-scale rates: top-down vs. bottom-up control incorporated explicitly. Ecosim also includes biomass and size structure dynamics for key ecosystem groups (incorporating: multi-stanza life stage structure by monthly cohorts, density- and risk-dependent growth; adult numbers, biomass, mean size accounting via delay-difference equations; stock-recruitment relationship as an 'emergent' property of competition/predation interactions of juveniles. Predator prey interactions are moderated by prey behaviour to limit exposure to predation, such that biomass flux patterns can show either bottom-up or top-down control. This is a critical concept in Ecosim - that consumption rates or flows may be limited by 'risk management' behaviours of prey and predators at very small space-time scales. Through repeated simulations Ecosim allows for the fitting of predicted biomasses to time series data. Together, EwE build on the traditional stock assessment, using much more of the information available from these, while integrating to the ecosystem level. Ecospace represents biomass dynamics over two-dimensional space as well as time, i.e. biomasses are represented by equations and as varying with spatial coordinates as well as with time. EcoOcean provides a global database of fishing effort thus providing the opportunity to look at the future of marine biodiversity using a depletion index as a proxy for changes in species composition and abundance under different scenarios. |
| **Geographical coverage and resolution** | Multi-scale, ecosystem models. Ecospace is the only component that provides spatial representation and uses user-defined grid cells. EcoOcean uses the 19 FAO statistical areas of the world as its finest geographical scale. These areas can then be aggregated to a global total. |
| **Temporal coverage and resolution** | Ecopath does not have a temporal component. Ecosim provides data in monthly intervals in order to allow for seasonality and short life-spans. Ecospace time intervals are user defined, ranging from relatively short timescales (0.2 years) to longer time scales (2yrs). EcoOcean is run from monthly time steps from the year 1950. |
| **Analytical technique** | Ecopath = mass-balance model; Ecosim = time-dynamic model; Ecospace = spatial simulation model; EcoOcean = stratified global model. |
| **Model developers and/or owners** | Fisheries Centre, University of British Columbia. Key developers include Daniel Pauly, Carl Walters and Villy Christensen. EwE is sponsored by the Sea Around Us Project, the UBC Fisheries Centre, and Lenfest Ocean Futures. |
| **Model development** | 1992: Ecopath methodology published; 1997: Ecosim methodology published; 1999: |

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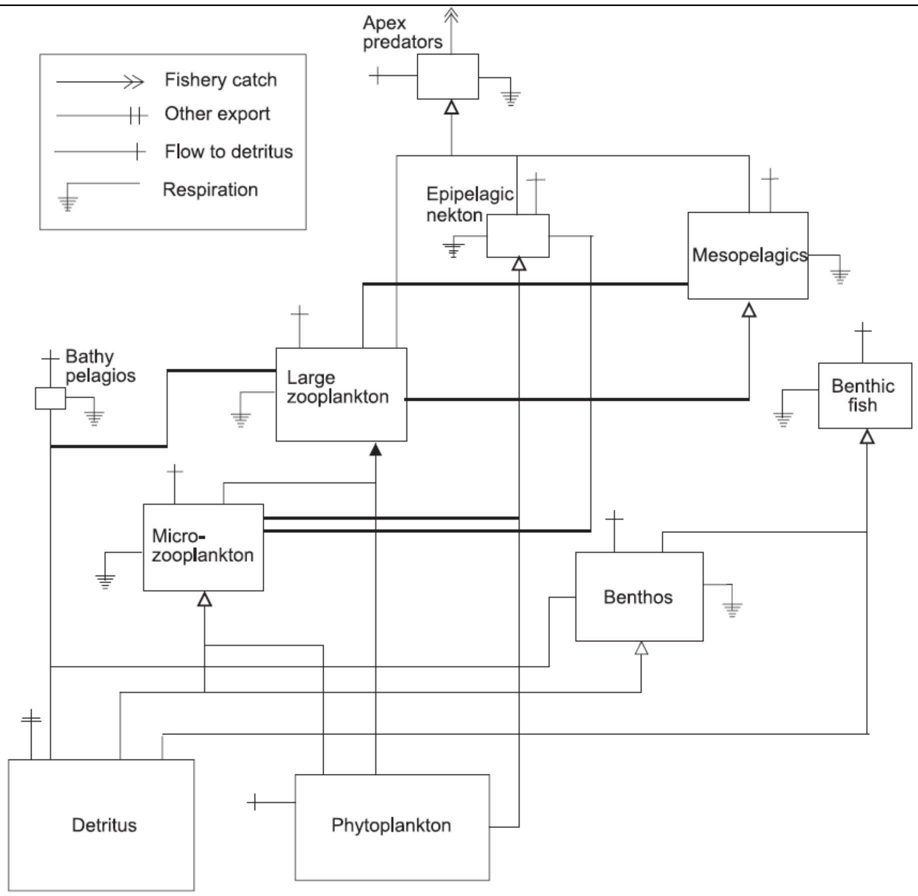
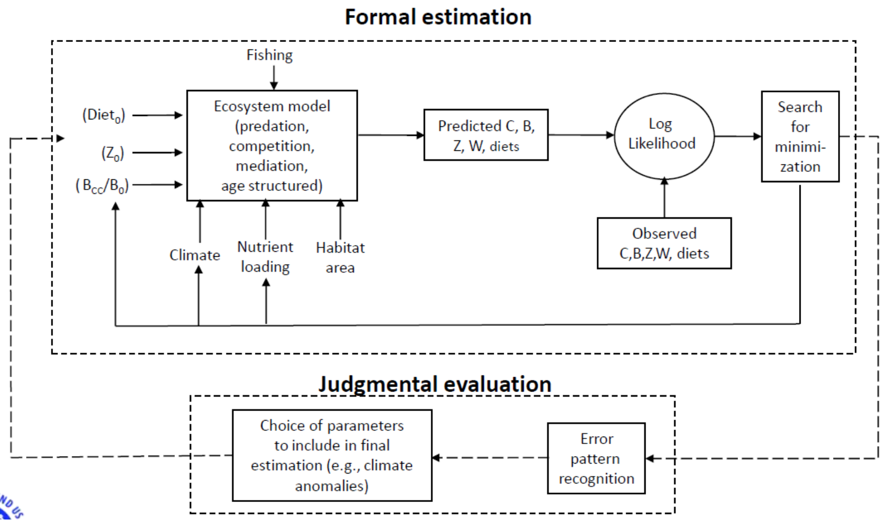
| **history** | Ecospace methodology published; 2000: Ecosim II methodology published; 2007: EcoOcean methodology published. |
| **Target Group/users** | EwE is aimed at policy-makers, scientists, and managers. EwE has been used in fisheries policy exploration exercises with the FAO at a workshop at University of British Columbia in 2000. EwE has also been a component of global environmental assessments, in particular the Millennium Ecosystem Assessment and the GEO-3 and -4. EcoOcean has been included in the scenario exploration for GEO-4. |
| **Calibration** | The core routine of Ecopath is calibrated from the Ecopath program of Polovina (1984a; 1984b) modified to render superfluous its original assumption of steady state. Ecopath no longer assumes steady state but instead bases the parameterization on an assumption of mass balance over an arbitrary period, usually a year. Ecosim and Ecospace are both calibrated to the outputs of Ecopath. Ecopath is in turn recalibrated based upon the outputs of Ecosim and Ecospace and rerun until exernal validation is achieved. EcoOcean is parameterised using an array of global databases, most of which are developed/made available through the Sea Around Us Project (www.seaaroundus.org). |
| **Validation** | Models are fitted to time series refernece data with a long a reference period, with as many different disturbance patterns, as it is possible to assemble. Developers recommend an iterative, stepwise procedure for model fitting: Set up an Ecosim model and reference time series (of forcing inputs like fishing rates, and indices of temporal system response like relative biomasses and estimated total mortality rates). Examine the simulated and observed time patterns of response indices, look for groups that show large discrepancies in time pattern (trend), with particular emphasis on groups that have high biomass and are important prey or predator for other groups. As an example, sardines and anchovy in a Benguela model (Shannon et al., 2004) showed upward trend in data but not in initial simulation results. Focus in turn on each such group, and examine alternative hypotheses for the discrepancy (by varying appropriate parameters to see if the model fit is improved). EcoOcean modelled fisheries effort for 1950-2003 were validated against the reported totals for this period and fell within 10% of the reported total. |
| **Uncertainty analysis** | Semi-Bayesian sampling routine is employed to explicitly consider the numerical uncertainty associated with the inputs. |
| **Key reference** | Ecopath: Christensen & Pauly (1992),Ecosim: Walters et al. (1997)72; Ecosim II: Walters et al., (2000); Ecospace: Walters et al. (1999); EwE overview: Pauly et al., (2000), –Christensen et al. (2000), Christensen et al., (2005); EcoOcean: Alder et al., (2007) |
| **Level of integration** | Good - links traditional stock assessment data with actual population dynamics to provide a realistic system model that is integrated at the ecosystem level. This can then be combined with management regimes in Ecospace (e.g. Marine protected areas) and fisheries data in EcoOcean. The models in this series are linked in a hierarchical manner (i.e. outputs of Ecopath feed into Ecosim, outputs of EwE feed into Ecospace, and these outputs feed into Ecoval). |
| **Links to other models** | EwE has also been soft linked with a number of other models to develop the Millennium Ecosystem Assessment scenarios and the GEO-3 and -4 projections. In the MA, these models were IMPACT, WaterGAP, IMAGE, a Freshwater Biodiversity Model, a Terrestrial Biodiversity Model, and AIM, and in the GEO analyses the models were International Futures, IMAGE, IMPACT, WaterGAP, GLOBIO, LandSHIFT, CLUE-S, and AIM. EcoOcean was also used to inform the IAASTD (AgAssessment). EcoOcean is also being developed as a marine equivalent of the MSA produced by the GLOBIO assessment. |
| **Ease of use/accessibility** | Modelling process is complex and would need to be carried out by a specialist. However, all methods are fully and transparently published and discussed in the scientific literature. All data sets and the model are freely available to download online at: http://www.nceas.ucsb.edu/GlobalMarine |
| **Website** | http://www.ecopath.org/ |
| **Model structure** | Ecopath: |




EcoSim:




EcoOcean:

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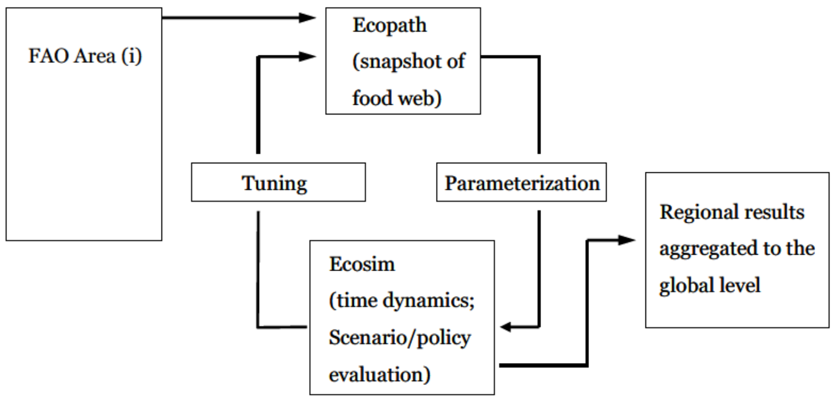
| |   **Figure 1**. Process for EcoOcean model |

| **Model name** | **GEEM** |
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| **Full model name** | General Equilibrium Ecosystem Model |
| **Model type** | Biogeochemical model |
| **Subtype** | Ecosystem model |
| **Thematic coverage** | Trophic interactions, population dynamics, fisheries management, resource valuation, simulations. |
| **Input (key drivers and pressures)** | For each species in the food web being studied the following energy parameters are used: embodied energy; energy supplies; variable respiration; fixed respiration; and growth rates. |
| **Output (key variables)** | For each species in the food web being studied the following energy parameters are calculated for period t: populations; energy demands; energy prices; and net energies. |
| **Geographical coverage and resolution** | Multi-scale, ecosystem model based around food webs. Resolution measures are not applicable as spatial representation of outputs is not available. |
| **Temporal coverage and resolution** | For the individual organism the model is non-stochastic and time is omitted. Omitting time eliminates dynamic aspects such as age structure issues, however it is necessary for tractability and to be consistent with applied general equilibrium (AGE) models. The model has two components: short-run and long-run equilibrium. The short run is defined as that time over which the populations of all species are constant. In the long-run, populations of species are variable; they adjust to move toward a long-run equilibrium in which all organisms have zero net energy and the short run equilibrium conditions hold. In long-run outputs, time steps are defined by period t. |
| **Analytical technique** | Statistical model which captures salient biological functions and provides numerical simulations of marine food webs, which can be then integrated with extant economic models. |
| **Model developers and/or owners** | The model was originally developed by John Tschirhart at the Department of Economics and Finance, University of Wyoming. This research was supported by a U.S. Environmental Protection Agency grant and by the State of Wyoming. |
| **Model development history** | The GEEM methodology was originally published in the Journal of Theoretical Biology in 2000. It has since been built on and applied by many members of the scientific community. |
| **Target Group/users** | The model is recognised as being primarily aimed at policy-makers as it is assumed that improved policies will follow from models that incorporate both economies and ecosystems. As models of economies already exist, the aim of this approach was develop an ecosystem model that is compatible with these economic models and which also captures salient biological features. Besides these benifits, the GEEM is also identified as being useful for addressing purely biological issues and so is also targetted at the scientific community. GEEM has been recognised by FAO as an approach for |

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| | integrating ecosystem considerations into their fisheries models. |
| **Calibration** | Parameters within the boundaries defined by the validation methodology can be calibrated through statistical estimation applied to sample data from well defined populations. E.g. To estimate a supply function for an organism, data would include calories of energy and grams of biomess exchenged between predator and prey under varying climatic conditions and abiotic surroundings. |
| **Validation** | The bounds on parameters can be set through validation by the following data: observations about the relationships between population densities and predation; necessary and sufficient conditions for a maximum to the net energy problem; and estimates of ecological efficiences. In the simulations, parameter values were chosen so that the computed ecological efficiences were within an order of magnitude of efficiences observed in field work. |
| **Uncertainty analysis** | Not specified |
| **Key reference** | Tschirhart, 2008 |
| **Level of integration** | Limited - model only considers energy interactions and the trophic dynamics of an ecosystem. However, when linked with an economic model, economic valuation of these relationships under change can be quantified and thus provide an end result with a much higher level of integration. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. The model is designed to be linked with a general equilibrium economic model by identifying key variables that influence both systems and determining where to incorporate them. Humans interact with ecosystems in a myriad of ways that can be addressed by augmenting the net energy expression in the GEEM. Species populations are the most likely candidates for ecosystem variables that can be included in economic models. |
| **Ease of use/accessibility** | Modelling process is complex and would need to be carried out by a specialist. However, all methods and results are fully and transparently published and discussed in the scientific literature. The model cannot be downloaded. |
| **Website** | Not applicable |
| **Comments/remarks** | The overall goal is to develop a general equilibrium ecosystem model that yields organisms' demands for and supplied of biomass, and to design the model in a way that allows it to be integrated with a general equilibrium model of an economy. Numerical simulations in the key reference use a marine food web in Alaska to illustrate the model and to show several simultaneeous predator/prey relationships, prey switching of the top predator, and energy flows through the web. |
| **Model structure** | Not available |

| **Model name** | **ICTHYOP** |
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| **Full model name** | |
| **Model type** | Biogeochemistry model |
| **Subtype** | Biodiversity, population dynamics and connectivity |
| **Thematic coverage** | Icthyoplankton dynamics, connectivity, species transport |
| **Input (key drivers and pressures)** | Individuals are characterised by state variables: age (day), length (mm), stage (egg, yolk-sac larva, or feeding larva), location (longitude/latitude) and depth (m), and status (alive or dead). The physical environment is characterised by ocean state variables: current velocities (m s-1), temperature (*C), and salinity. The physical inputs are archived from oceanic simulations of the "Regional Oceanic Modelling System" (ROMS) or the "Model for Applications at Regional Scale" (MARS). |
| **Output (key variables)** | Icthyop offers two functioning modes. The first allows a visualisation of the transport of virtual eggs and larvae in a user friendly graphic interface. The second mode enables the running of a series of simulations based on pre-defined sets of parameters, with a minimalist interface. |
| **Geographical coverage and** | The environmental state variables are provided on a discrete three-dimensional grid by archived simulations of the ROMS or MARS oceanic |

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| **resolution** | models. An example of a typical spatial scale used to characterise the environment is the ROMS southern Benguela configuration grid. It extends from 28 - 40*S and from 10 - 24*E. The horizontal resolution ranges from 9km at the coast to 16km offshore. The vertical resolution ranges from 1 to 4.7m at the surface and from 3.1 to 1030m at the bottom of the ocean. The Icthyop model sees the Eulerian velocity field at the same spatial scale as the Eulerian primitive equation models. Subgridscale parameterisations can be added in the IBM to address scales unresolved by the primitive equation models. The fields of salinity, current velocities, and temperature are interpolated in space to provide values at any individual location in Icthyop. |
| **Temporal coverage and resolution** | In ROMS, the current velocities, temperature, and salinity are typically averaged over time and stored every day or so. In Icthyop, they are interpolated in time to feed the Icthyop IBM time step. Simulations consist of tracking the locations and properties of the individuals (typically during a few weeks or months). 'Daytime' in Icthyop is defined as from 7am to 7pm. All temporal variables can be adjusted in Icthyop by the user. |
| **Analytical technique** | individual-based model (IBM) designed to study the effects of physical and biological factors on the dynamics of fish eggs and larvae. |
| **Model developers and/or owners** | This Java piece of software is a collaborative work between Institut de Recherche pour le Developpement (IRD, teams R079 GEODES and R097 ECO-UP) from France, University of Cape Town (UCT) and Marine & Coastal Management (MCM) from South Africa, and Instituto del Mar del Peru (IMARPE) from Peru. The main contact for this work is Christophe Lett (IRD) and can be contacted at christophe.lett@ird.fr. PREVIMER provided financial support for this project. |
| **Model development history** | The program is written in Java and requires the Java Runtime Environment (JRE). The tool is distributed as a package that contains the program code, libraries and a basic example of ROMS output file. The Ichthyop project also includes the Public javadoc. Icthyop was most recently updated/redeveloped in 2008. Previous/modified versions of this method have been used since 2002 and 10 peer-reviewed publications concerning Icthyop have been released in this 6 year period. All references can be found at http://www.ur097.ird.fr/projects/ichthyop/index.php. |
| **Target Group/users** | The aim of Icthyop is to provide an easily available, user-friendly model for icthyoplankton dynamics. Through providing this tool, Icthyop aims to help structure the community (assumed to be primarily academic and government scientists) that uses such tools. Previous (prior to 2008)/modified versions of this tool have been used to investigate the effects of physical and biological factors on the dynamics of anchovy (Engraulis encrasicolus, Engraulis ringens) and sardine (Sardinops sagax) ichthyoplankton in the southern Benguela and in the northern Humboldt upwelling systems. These works associated Institut de Recherche pour le Développement (IRD, teams R079 GEODES and R097 ECO-UP) from France, University of Cape Town (UCT) and Marine & Coastal Management (MCM) from South Africa, and Instituto del Mar del Perú (IMARPE) from Peru. All references can be found at http://www.ur097.ird.fr/projects/ichthyop/index.php. |
| **Calibration** | Icthyop is calibrated to user defined variables on icthyoplankton and to the ROMS/MAR physical variables on temperature, salinity and current velocity. |
| **Validation** | The advection part of the movement submodel has been tested by recording trajectories of individuals and comparing them to trajectories obtained using two other Langrarian tools ("Roff" and "Ariane"). |
| **Uncertainty analysis** | Not specified |
| **Key reference** | Lett et al., 2008 |
| **Level of integration** | Limited - focuses primarily on the biological aspects of icthyoplankton and the physical parameters that affect their dynamics. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. Icthyop is designed to be linked to either the ROMS or MARS models to supply physical parameters, and can also be linked to models that have been integrated with ROMS or MARS. For example, plankton concentrations can be provided if a NPZD biogeochemical model is coupled to ROMS. Icthyop |

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| | itself is a product of five integrated sub-models. |
| **Ease of use/accessibility** | Good - Icthyop is designed to be accessible and easy to use. The software is freely available for download and a user manual is available at http://www.ur097.ird.fr/projects/icthyop/. Output files are in netcdf format and can be post-processed easily. Routines in R can be sent upon request for plotting trajectories or computing the numbers of individuals transported from pre-defined release (spawning) areas to pre-defined destination (recruitment) areas. Ichthyop is a tool designed to be shared within the community using models coupling physics with ichthyoplankton dynamics. Though it has been historically developed to study the dynamics of small pelagic fish ichthyoplankton in upwelling systems, Ichthyop is a generic tool in the sense that it incorporates the most important processes involved in ichthyoplankton dynamics. Using Ichthyop for other species in other systems may imply a few changes in the source code (e.g., changing the growth function, implementing a specific larval vertical migration scheme, etc.). This code is organized simply, commented and documented, which should make it easy to modify by a user with basic programming skills. |
| **Website** | http://www.ur097.ird.fr/projects/ichthyop/index.php |
| **Model structure** | Not available. Icthyop consists of five sub-models: Spawning, Movement, Growth, Mortality, and Recruitment. |

| **Model name** | **Impact of Climate Change on Global Biodiversity** |
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| **Full model name** | |
| **Model type** | Biodiversity model |
| **Subtype** | Bioclimatic Envelope Model |
| **Thematic coverage** | Climate change, global marine biodiversity, species turnover, niche-based model |
| **Input (key drivers and pressures)** | Current species distribution (latitudinal range; depth range; affinity to certain habitats; known distribution boundaries from published literature or expert knowledge); Environmnetal preferences of species (sea water temperature; bathymetry; habitats; and distance from sea ice); Population dynamics (Larval and adult dispersals; immigration; intrinsic population growth and extirpation; carrying capacity of area); Climate change projections to 2050 (NOAA/GFDL Coupled Model amd SRES Scenarios); Logistic population growth model. |
| **Output (key variables)** | Predicted changes in species distributions (changes in abundance per time/cell/species) - results for summer and winter distributions are provided seperately; Average frequency of invasion and local extinction events to identify hotspots of climate induced impacts; Median polward shift in distribution centroids. |
| **Geographical coverage and resolution** | Global; 30' X 30' grid cell size. Can be scaled to local and regional levels. |
| **Temporal coverage and resolution** | Species preferences are calculated from environmental data from 1980 to 2000. Model provides current species richness (average from 2001 to 2005), then future predictions for 2050 (average from 2040 to 2060). |
| **Analytical technique** | Bioclimatic Envelope Modelling |
| **Model developers and/or owners** | The model was developed by William Cheung, Vicky Lam, and Daniel Pauly at the Sea Around Us Project, Fisheries Centre, Aquatic Ecosystems Research Laboratory University of British Columbia. The model development was funded partially by the University of Western Australia and is a contribution of the Sea Around Us Project, which was initiated and is funded by the Pew Charitable Trusts. The application of the model to assessing the impact of climate change on marine biodiversity was funded by the Pew Charitable trusts through the Sea Around Us Project. |
| **Model development history** | Model published in 2008. This publication will be the first of several planned articles on global warming effects on marine communities and fisheries, with the model at its core being gradually modified and improved as applications |

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| | are completed. |
| **Target Group/users** | The model currently gives policy-makers, the scientific Community, and the public a quantitative picture of the scale of the issue. The authors consider that the global analysis presented in the paper is a first step towards developing marine conservation policy in the face of climate change. This global picture is also effective in building consensus and initiating actions among nations, societies and stakeholders to address this problem. As the model is developed to be accurate at finer scales, the results can help design management systems and develop indicators and monitoring programmes. |
| **Calibration** | Species distributions were initially calibrated to the Sea Around Us Project (http://www.seaaroundus.org) data and were then further refined by incorporating habitat preference data from FishBase (http://www.fishbase.org) for fish and SeaLifeBase for other taxa (http://www.sealifebase.org). Climate scenarios were calibrated to the NOAA Geophysical Fluid Dynamics Laboratory (GFDL). |
| **Validation** | The model was validated in the following ways: Simulated changes in distributions of four commercially exploited species in 30 years under two scenarios of global sea temperature change from SeaLifeBase and FishBase datasets as well as from Phillips et al. (1992) for the Western Australian rock Lobster; the possible effects of climate-change induced shifting of coral reefs on associated species was evaluated using the UNEP-WCMC coral reef dataset; key aggregate features of the results (e.g. Annual rate of latitudinal shift) correspond to the available field estimates; finally the effect of change in sea ice coverage on polar species was tested based on information from perr-reviewed literature. Future results from local and regional studies can be used to validate the model, and past climate and species distribution data can be used to assess the accuracy of predictions from the model. |
| **Uncertainty analysis** | The model is suitable for undertaking uncertainty analyses. Sensitivity analyis of major parameters showed that the direction of the projections are robust to the uncertainty of those parameters. |
| **Key reference** | For Model Background: Cheung et al., 2008<br>For Model Application: Cheung et al., (in press) |
| **Level of integration** | Good - Biodiversity data (bioclimate model is combined with population dynamics making it more robust) is integrated with oceanographic measures, and climate change scenarios. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. The overall model described is formed through the linking of a range of models and scenarios: NOAA/GFDL Coupled Models; SRES Climate Scenarios; Logistic population growth model; Population-dynamic model; Advection-diffusion reaction model for larval dispersal; ECOSPACE (Eulerian spatial ecosystem simulation model) |
| **Ease of use/accessibility** | Complex modelling process, however the output distribution maps are simple to understand. All distribution maps are available through the http://www.seaaroundus.org website. All methods are fully and transparently published and discussed in the scientific literature, however, output maps are not yet freely available online. |
| **Website** | Not applicable |

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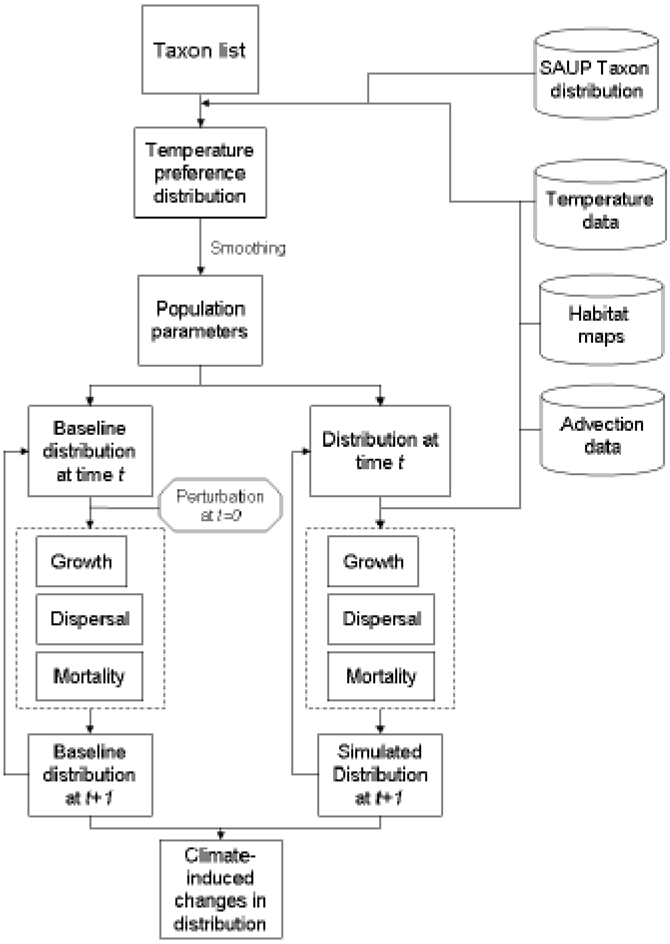
| **Model structure** |   |

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| **Model name** | **RamCo** |
| **Full model name** | |
| **Model type** | Integrated dynamic model |
| **Subtype** | Decision Support System |
| **Thematic coverage** | Coastal zone, assessment, decision support, management |
| **Input (key drivers and pressures)** | Spatial information from GIS and static and/or descriptiveGIS operations. This occurs on two scales: Micro-scale drivers include sea use functions (seagrass; coral reef); Land Use functions (Agriculture; Rice culture; Shrimp culture; Industry; Tourism; Urban residential; Rural residential; Mangrove; Nature/forest); and Land use features (Sea; Inland water; Airport; Harbour; Beach); and Macro-scale drivers based around land use, water, ecology and the economy. |
| **Output (key variables)** | An almost complete integrated model of the coastal zone, from which the user can specify which variables are most relevant to their needs. |
| **Geographical coverage and resolution** | Version 1.0 and 2.0 are applied to the Coastal zone of SW Sulawesi (Indonesia). RAMCO can handle cellular models with dimensions up to 500 by 500 cells. In its actual form, it is most useful for modelling problems on grids which resolution varies from 50 to 500 meters. RamCo has the capability to deal with spatial dynamics at different levels within the same integral models. More in particular RAMCO models will generally have two strongly coupled components: one for macro-level, long range and large scale processes and a second one for processes operating on the micro-level, short range and micro-scale. Sub-models will in general operate at one level, but may exchange information with sub-models at the other level. |
| **Temporal coverage and resolution** | Model allows for a multi-temporal dynamic modelling framework. The time horizon is 25 years. |
| **Analytical technique** | Integrated spatial models in which natural, social and economic processes are fully |

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| | linked on an appropriate detailed scale. A RAMCO model consists of Model Building Blocks (MBB's) that contains the code required to calculate and execute mathematical operations varying from a single operation (such as the sum of two numbers) to a list of operations (set of mathematical equations). MBB's are connected to one another by means of MBB Connectors. |
| **Model developers and/or owners** | RamCo was financed by and is a product of the National Institute for Coastal and Marine Management (RIKZ) and the associated Coastal Zone Management centre (CZM), the Hague, the Netherlands. It was developed by the consortium consisting of INFRAM BV (Zeewolde, the Netherlands), RIKS, Twente University (Enschede) and Maastricht University. RamCo 1.0 - was developed as part of the project: "RAMCO: Generic Decision Support System for the Rapid Assessment phase of Sustainable Coastal Zone Management" financed by the National Institute for Coastal and Marine Management (RIKZ), Rijkswaterstaat, and the associated Coastal Zone Management Centre (CZMc), Contract RKZ-308 and carried out by the consortium consisting of INFRAM bv (Zeewolde, main contractor), and RIKS bv (Maastricht). RamCo 2.0 - 2.0 of RAMCO is the result of the Land Water Environment Information technology (LWI) - Project "Integral Systems Analysis", in the "LWI - Estuaria and Coasts" project group. The developers group consists of: INFRAM bv, RIKS bv, and WL\|Delft Hydraulics (Delft). The Technical University of Twente, Department of Civil Engineering Technology & Management, (Enschede) participated as a sub-contractor of INFRAM bv. |
| **Model development history** | RAMCO was originally developed in October 1996 for the National Institute for Coastal and Marine Management (RIKZ) and the associated Coastal Zone Management Centre (CZMc). The version 2.0 of RAMCO is the result of the Land Water Environment Information technology (LWI) - Project "Integral Systems Analysis", in the "LWI - Estuaria and Coasts" project group (user manual is dated 1999). The SW Sulawesi model makes extensive use of knowledge gathered in project W01.60 of the Netherlands Organization for the Advancement of Tropical Research (WOTRO). This scientific material remains the full property of WOTRO. |
| **Target Group/users** | RamCo is aimed primarily at policy makers working in coastal zone management. The end-users of RamCo 2.0 are: National Institute for Coastal and Marine Management (RIKZ) and the associated Coastal Zone Management Centre (CZMc), and the Netherlands Organization for the Advancement of Tropical Research (WOTRO). RamCo has been applied to a coastal zone near Ujung Pandang in south-west Sulawesi (Indonesia). It shows how - in the next 25 years - the coastal zone strongly urbanizes under the influence of a growing population (annual growth ± 3%) and the external economic growth. RamCo allows policy-makers to test their policy choices under the influence of climate changes, demographic growth, or changing economic demand. |
| **Calibration** | Not specified |
| **Validation** | The model has a validity interval incorporated within which the parameters must be kept. |
| **Uncertainty analysis** | Not Specified |
| **Key reference** | Uljee et al., 1999, available at:<br>http://www.riks.nl/RiksGeo/projects/ramco/RamCo2.pdf<br>For the Sulu Sulawesi Case study: de Kok & Wind, 1996 and de Kok & Wind, 1999 |
| **Level of integration** | Excellent - physical, environmental, economic and social processes that typical coastal zone dynamics generally, and those of Sulawesi in particular. To achieve this, use is made as much as possible of existing scientific knowledge, methods, models and databases. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. RamCo integrates existing models dealing with physical, ecological and socio-economic impacts of coastal zones have been reviewed and adapted in view of their integration into a multi-scale, multi-temporal dynamic modelling framework |
| **Ease of use/accessibility** | Demos of the model and the user's guide are available through the RIKS website (http://www.riks.nl/projects/RamCo). Appears relatively easy to use, but presently is only applicable for the SW Sulawesi region. Neither software development with the tools provided in the RAMCO package nor the application of the RAMCO package to a case study is permitted. Software or application development and |

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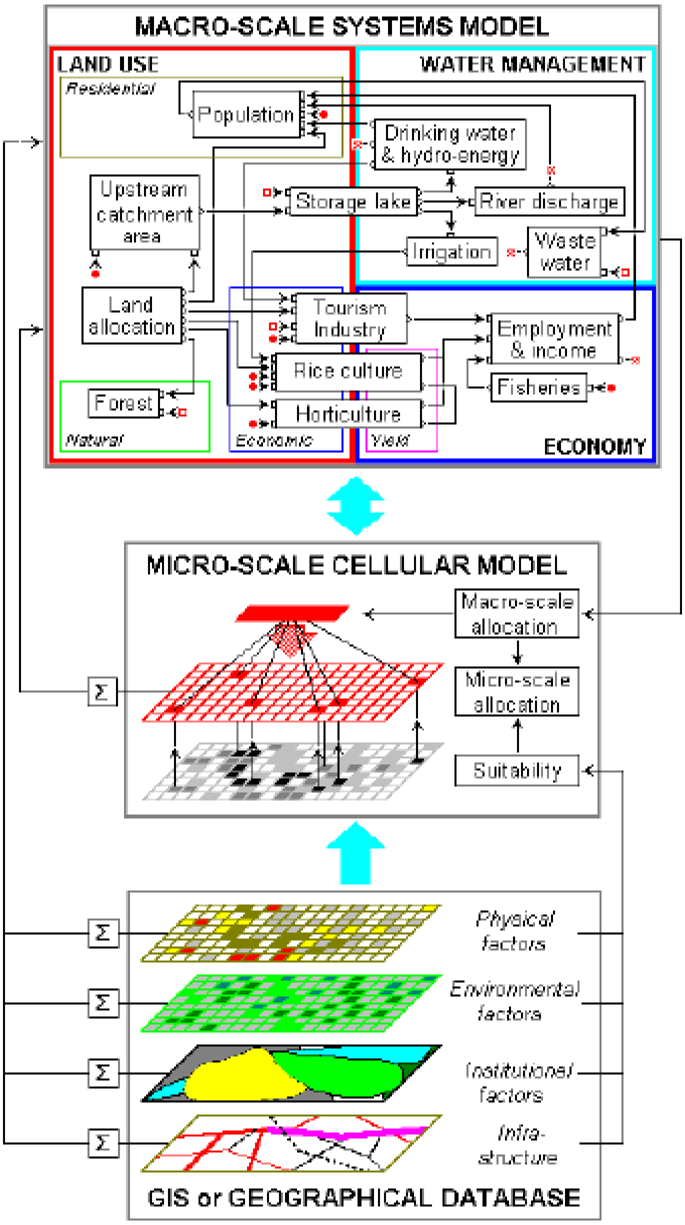
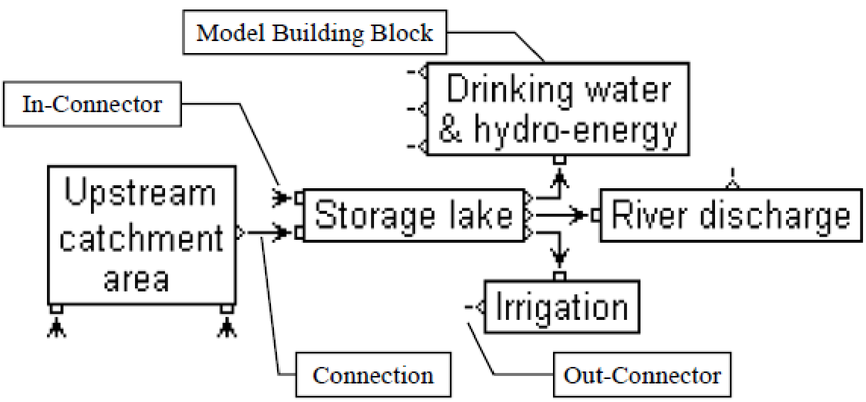
| | further usage or marketing of the RAMCO package will only be accepted following the purchase of a full version of the package. |
| **Website** | http://www.riks.nl/projects/ramco |
| **Model structure** | <br><br><br> |

| Model name | Reefs at Risk |
|---|---|
| Full model name | |
| Model type | Biodiversity model |
| Subtype | Indicator model |
| Thematic coverage | Coral reefs, marine biodiversity, human influence, threat indices |
| Input (key drivers and pressures) | Coastal development threat factors (Cities; Settlements; Airports and Military bases; Mines; Tourist resorts; Embayments); Marine-based Pollution threat factor (Ports; Oil-related threats; Shipping-related threats); Overexploitation threat factor (Overfishing; Destructive fishing); Inland Pollution and Erosion threat factor (Hydrological modelling and geographic overlays). |
| Output (key variables) | A map based indicator of problem areas around the world where in the absence of good management, coral reef degradation might be expected, or predicted to occur shortly, given ongoing levels of human activity. |
| Geographical coverage and resolution | Global coral reefs; 4km resolution |
| Temporal coverage and resolution | Assessment of current state (1998) - does not include likely future threats posed by population growth or climate change. |
| Analytical technique | Results are based on a series of distance relationships correlating mapped locations of human activity such as ports and towns, oil wells, coastal mining activities, and shipping lanes, with predicted risk zones of likely environment degradation. Detailed subnational statistics on population density, size of urban areas, and land cover type were also incorporated into the analysis. Data on rainfall and topography was also used to help estimate potential run-off within watersheds. Distance rules defining threat zones were established for each component indicator using information on the known locations of more than 800 reef sites documented as degraded by human activity by one of the four factors. Minimum distances were esblished through expert review and input, and by determining the most conservative set of rules that, when taken in aggregation for any one of the four threat categories, encompassed at least two-thirds of all known degraded sites affected by activities related to that category. Reefs are graded as under "low", "medium" or "high" threat. |
| Model developers and/or owners | The initial Reefs at Risk Global Analysis was published as a joint venture by the World Resources Institute (WRI), International Center for Aquatic Living Resources Management (ICLARM), World Conservation Monitoring Centre (WCMC), and the United Nations Environment Programme (UNEP). Lead authors: Dirk Bryant, Lauretta Burke, John McManus and Mark Spalding. The report received funding from UNEP, The Bay Foundation, The David & Lucile Packard Foundation, The Henry Foundation, The Swedish International Development Cooperation Agency, and the United States Environment Protection Agency. |
| Model development history | 1998: "Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs" published; 2002: "Reefs at Risk in South-East Asia" regional analysis was released; 2003: Methodology was used for a local analysis on "Highlighting coral reefs in Coastal Planning and Management in Sabah, Malaysia"; 2004: "Reefs at Risk in the Caribbean" regional analysis was released; 2005: methodology was used to produce the "Belize Coastal Threat Atlas". The Reefs at Risk model is still being further developed for a Reefs at Risk Revisited analysis to provide an update of the original Reefs at Risk analysis a decade on. The update will use improved modeling methods and higher-resolution data to provide a detailed examination of human pressures on coral reefs, implications for reef condition, and projections of associated economic impacts in coastal communities. This analysis will be 20 times more detailed than the original Reefs at Risk and will also include climate-related threats, such as coral bleaching and ocean acidification. |
| Target Group/users | The model was calibrated to a standard four kilometre resolution consistent with the dataset of shallow coral reefs from the World Conservation Monitoring Centre. This was carried out to mitigate spatial accuracy issues associated with using a range of different datasets. |
| Calibration | The model was calibrated to a standard four kilometre resolution consistent |

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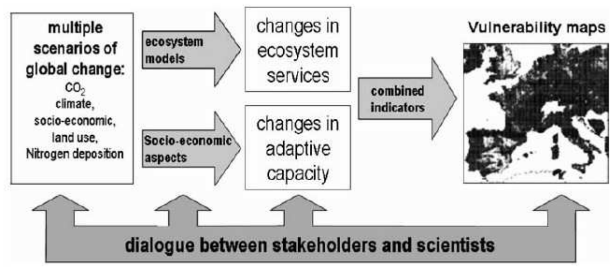
| | with the dataset of shallow coral reefs from the World Conservation Monitoring Centre. This was carried out to mitigate spatial accuracy issues associated with using a range of different datasets. |
| **Validation** | Draft risk maps were revised and vetted at a global workshop attended by coral reef experts from around the world. Final draft maps underwent a second series of review by these and other experts. Overall, the Reefs at Risk indicator accurately classifies over 80 percent of sites known to be degraded by humans as "at risk". This was based on a comparison between Reefs at Risk results and 800 sites documented in ICLARM's Reefbase (v.2) as having been degraded by human activity. |
| **Uncertainty analysis** | Not specified, however, uncertainties are recognised based on the inconsistencies, age, and lack of availability of datasets. A number of regions are identified in the Technical Notes of the report where actual threats may not be accurately represented by the Reefs at Risk indicator based on expert review. |
| **Key reference** | Bryant et al., 1998 Available online: http://pdf.wri.org/reefs.pdf |
| **Level of integration** | Good - uses a variety of datesets to represent anthropogenic threat including data on population, resources, tourism, pollution from fuel and transport, fisheries including destructive fishing practices, and hydrological models to represent inland pollution and erosion. |
| **Links to other models** | The model has not yet been integrated into a wider assessment process. Hydrological modelling was used in the development of the inland pollution and erosion threat factor and then integrated into the overall Reefs at Risk model. |
| **Ease of use/accessibility** | Modelling process is clear and well described in the online report. Outputs are easy to understand as spatial maps with the threat indices being categorised as low, medium, or high risk. The publication is free to access at: http://www.wri.org/publication/reefs-risk-map-based-indicator-potential-threats-worlds-coral-reefs and some of the data layers and GIS models are available to download for free from the WRI website. CDRom with all the data layers and GIS models used in the analysis are available from WRI fon request. Contact Lauretta Burke for more information: lauretta@wri.org . |
| **Website** | http://www.wri.org/publication/reefs-risk-map-based-indicator-potential-threats-worlds-coral-reefs |
| **Model structure** | Not available |

### *1.1.9 Regional models/assessments*

| **Model name** | **ATEAM** |
|---|---|
| **Full model name** | Advanced Terrestrial Ecosystem Analysis and Modeling |
| **Model type** | regional assessment |
| **Subtype** | |
| **Thematic coverage** | vulnerability of ecosystem services: agriculture, forestry, carbon storage and energy, water, biodiversity and tourism |
| **Input (key drivers and pressures)** | socioeconomic factors, atmospheric greenhouse gas concentrations, climate factors, and land use |
| **Output (key variables)** | vulnerability maps for different ecosystem services (agriculture, wood production, carbon storage, soil fertility, biodiversity, natural beauty) |
| **Geographical coverage and resolution** | Europe 15 + Norway and Switzerland, 10' by 10' grid |
| **Temporal coverage and resolution** | 1990, 2020, 2050, 2080 |
| **Analytical technique** | link between ecosystem service provision and land use (socio-economic indicators extrapolated via regression models and aggregated via fuzzy models) meta-model |
| **Model developers and/or owners** | Potsdam Institute for climate impact research (PIK), Centre d'Ecologie Fonctionelle et Evolutive (CEFE), ETH Zürich, Wageningen University, Max Planck Institute für Biogeochemie, Lund University, Université Catholique de Louvain, Centre de Recerca Ecológica i Aplicacions Forestals (CREAF), Institute for arable crops research (RES), University of Southamption (SOTON), Universidad de Castilla-La Mancha (UCLM), European Forest Institute (EFI), |
| **Model development history** | first results published: 2005 |
| **Target Group/users** | The goal of the ATEAM project was to develop climate scenarios for Europe, employed a suite of ecosystem and hydrological models in order to test estimate the sensitivity of systems to these changes, developed indicators of adaptive capacity for the potential risks, engaged in an extensive, projectlong dialogue with stakeholders about methods and results, and initiated a high-level training component for its methods, leading to five international summer schools |
| **Calibration** | Not available |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Metzger et al., 2005 (Int J Appl Earth Observ Geoinf 7, 253-267), Metzger et al., 2006 (Agric Ecosyst Environ 114, 69-85), Metzger et al., 2008 (Reg Environ Change 8, 91-107), |
| **Level of integration** | Different models were included in this work, the level of integration between thos is unknown. |
| **Links to other models** | IMAGE outputs were used for land use change and driving forces for different scenarios, LPJ was used for water and carbon |
| **Ease of use/accessibility** | The ATEAM vulnerability-mapping tool can be downloaded from: http://www.pik-potsdam.de/ateam/. |
| **Website** | http://www.pik-potsdam.de/ateam/ |
| **Model structure** | **Fig. 1** The structure of the ATEAM project with the specific interactions between scientists and stakeholders (from Schröter et al. 2004)   |
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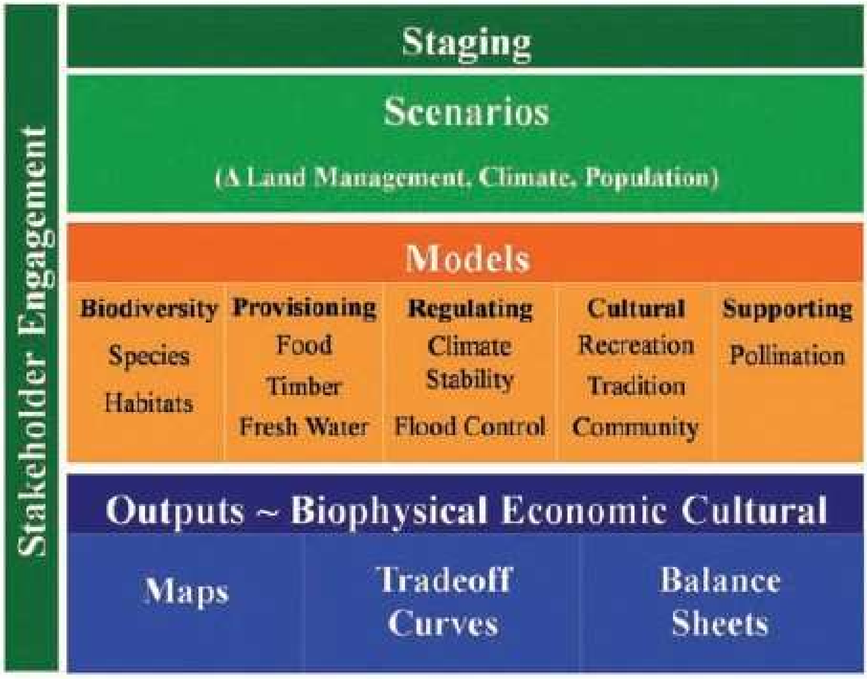
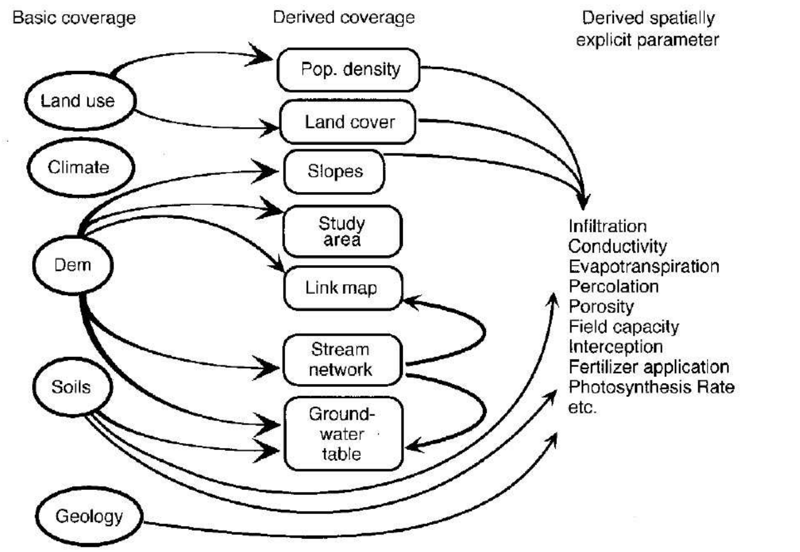
| **Model name** | **InVEST** |
| **Full model name** | integrated valuation of ecosystem services and tradeoffs |
| **Model type** | regional assessment |
| **Subtype** | |
| **Thematic coverage** | ecosystem services, biodiversity conservation, commodity production and tradeoffs |
| **Input (key drivers and pressures)** | drivers: market conditions and incentive-based conservation payments (policies), inputs: land use maps; basic information about the landscape, land quality, management practices, infrastructure and governance (simple or complex model, depending on data availability) |
| **Output (key variables)** | future land use, potential water yield, carbon sequestration, agricultural production, biodiversity, balance sheets for trade-offs between ecosystem services, optimal land allocation for different services |
| **Geographical coverage and resolution** | regional, resolution flexible; case studies: Willamette Basin, Oregon, USA (30 m x 30 m grid, for results: 500 ha units); Amazon basin. Currently a global assessment of ecosystem services is done with InVEST. Results have not been published yet. |
| **Temporal coverage and resolution** | Calibration depending on land use maps available; 50 year projections, results on annual basis |
| **Analytical technique** | empirical-statistical models |
| **Model developers and/or owners** | Natural Capital Project (Stanford University), The Nature Conservancy, and World Wildlife Fund |
| **Model development history** | published: 2008 |
| **Target Group/users** | Local managers and stakeholders. The aim of the Natural Capital Project is to align economic forces with conservation. |
| **Calibration** | Model was calibrated based on historical data on land use change, calibration data needed for each regional application. |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Nelson et al. 2009 (Frontiers in Ecology and Evolution 7, 4-11) Nelson et al. 2008 (PNAS 105, 9471-9476) |
| **Level of integration** | Low integration between different submodels: land use model predicts land use based on economic considerations and policies, after that changes in ecosystem services and biodiversity are calculated; no feedback between ecosystem services and land use change incorporated yet |
| **Links to other models** | unknown |
| **Ease of use/accessibility** | Available at: http://www.naturalcapitalproject.org/InVEST.html, Model equations are given in Nelson et al., 2009 (supplement) Running InVEST effectively does not require knowledge of Python programming, but it does require basic to intermediate skills in ArcGIS. |
| **Website** | http://www.naturalcapitalproject.org/InVEST.html |
| **Comments/remarks** | Global assessment with InVEST is forthcoming. |

| | |
|---|---|
| **Model structure** | <br>*Figure 1: The InVEST Process* |

| | |
|---|---|
| **Model name** | **Naidoo et al., 2008** |
| **Full model name** | |
| **Model type** | global assessment (mapping) |
| **Subtype** | |
| **Thematic coverage** | mapping of ecosystem services, partly based on biophysical models, synergies with biodiversity conservation |
| **Input (key drivers and pressures)** | land cover, climate, soil |
| **Output (key variables)** | carbon sequestration, carbon storage livestock production, water supply, species distribution |
| **Geographical coverage and resolution** | global, maximum resolution 0.5° |
| **Temporal coverage and resolution** | No future predictions, current situation only |
| **Analytical technique** | linear optimalization approach for habitat protection |
| **Model developers and/or owners** | see reference |
| **Model development history** | |
| **Target Group/users** | For exploratory purposes only, scientists |
| **Calibration** | Not applicable |
| **Validation** | Not applicable |
| **Uncertainty analysis** | Not applicable |
| **Key reference** | Naidoo et al., 2008 (PNAS 105, 9495-9500) |
| **Level of integration** | The different models/methods used are not integrated. They were used for mapping of present situation only and not for predictions. |
| **Links to other models** | TEM (terrestrial ecosystem model) was used to estimate annual carbon exchange rates, water provision was estimated using WaterGAP. |
| **Ease of use/accessibility** | The approach and input data have been described (Naidoo et al, 2008) and could be repeated |

| | |
|---|---|
| **Website** | Not applicable |
| **Model structure** | Not available |

| | |
|---|---|
| **Model name** | **PLM** |
| **Full model name** | Patuxent landscape model |
| **Model type** | Integrated assessment model |
| **Subtype** | regional assessment |
| **Thematic coverage** | land use effects on ecosystem services (linked ecological economic model) |
| **Input (key drivers and pressures)** | human land use policies (socio-economic), land management (N input), climate |
| **Output (key variables)** | land use pattern, water quality, NPP, water cycle, soil nutrients, land prices based on surroundings |
| **Geographical coverage and resolution** | Patuxent River watershed, Maryland, USA; variable resolution, maximum resolution: 200 by 200m |
| **Temporal coverage and resolution** | baseline: 1990, historial data (from 1650) and future projections, time steps differ between model components: daily (hydrology) to annual (economics) |
| **Analytical technique** | |
| **Model developers and/or owners** | R. Costanza |
| **Model development history** | software: STELLA |
| **Target Group/users** | Local managers |
| **Calibration** | A modular, multiscale approach was used to calibrate and test the model. Model results showed good agreement with data for several components of the model at several scales. Calibration was done against field data sets for forest growth and hydrological parameters and against results from EPIC for crop yields. |
| **Validation** | Historical validation (time series data). |
| **Uncertainty analysis** | sensitivity analysis done for different modules |
| **Key reference** | Costanza et al., 2002 (Ecol. Monogr. 72, 203-231) |
| **Level of integration** | Socio-economic component and general ecosystem model with modules for hydrology, nutrient, plant, consumers and human-dominated systems |
| **Links to other models** | Unknown (PLM formed the basis for GUMBO) |
| **Ease of use/accessibility** | Not available online |
| **Website** | http://www.uvm.edu/giee/PLM/home.html |

| | |
|---|---|
| **Model structure** | 210 ROBERT COSTANZA ET AL. Ecological Monographs Vol. 72, No. 2<br><br><br>FIG. 4. Patuxent landscape model (PLM) spatial coverages. There are six basic coverages: land use, climate, digital elevation model (DEM), soils, and geology. The arrows connect basic coverages with derived coverages. Additional maps are created during preprocessing and model initialization. Other spatial parameters and variables are calculated and updated during model runs. |

| **Model name** | **Swallow et al., 2009** |
|---|---|
| **Full model name** | |
| **Model type** | regional assessment |
| **Subtype** | |
| **Thematic coverage** | tradeoffs and synergies among ecosystem services |
| **Input (key drivers and pressures)** | land use change, agricultural production |
| **Output (key variables)** | water yield and reguation, erosion control |
| **Geographical coverage and resolution** | Lake Victory basin; multiple spatial scales, smallest: 5km by 2.5km (arial photograph), sub-basin, country division, river basin |
| **Temporal coverage and resolution** | no predictive modeling, current and past situation only |
| **Analytical technique** | empirical-statistical |
| **Model developers and/or owners** | See reference |
| **Model development history** | Not applicable |
| **Target Group/users** | Results from the study are meant for agencies, both state and non-state, concerned with rural development and environmental conservation in the Kenya portion of the Lake Victoria basin |
| **Calibration** | SWAT-model was calibrated for the Vicotria basin. |
| **Validation** | Not available |
| **Uncertainty analysis** | Not available |
| **Key reference** | Swallow *et al.*, 2009 |
| **Level of integration** | The SWAT model and the agricultural data were not integrated. |
| **Links to other models** | SWAT was used to model water and sediment yield |
| **Ease of use/accessibility** | Methodology has been described and could be repeated. |
| **Website** | Not applicable |
| **Model structure** | Not applicable |

## 1.2 Can the model results be interpreted in terms of ecosystem goods and services?

### *1.2.1 Integrated assessment models*

| | Model name | AIM | GUMBO | IFs | IGSM | IIASA models | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|---|
| Ecosystem services | **Provisioning services** | water supply, food and timber production | harvested organic matter, water supply, mined ores, and extracted fossil fuel | Agricultural production, including marine fishing and aquaculture | agricultural production (can be separated into crops, livestock and forestry) | timber production, agricultural food production, renewable water resources | Agricultural production, including grass/fodder production and livestock/milk production, demand for wood products, timber, fuelwood | Food production, production of raw materials |
| | **Supporting services** | Not available | Soil formation (decomposition), nutrient (N) cycling, disturbance regulation | Not available | SOC (soil organic carbon) | Not available | Soil fertility | Soil formation, nutrient cycling |
| | **Regulating services** | greenhouse gas emissions, air pollution, carbon sequestration, human health (malaria | gas regulation (C flux), climate regulation (temperature), waste assimilation, disturbance regulation | Human health, $CO_2$ emissions | human health impacts, sea level, air pollution, carbon emissions | carbon sequestration | Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution, soil | climate regulation, waste assimilation , disturbance regulation |

| | Model name | AIM | GUMBO | IFs | IGSM | IIASA models | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|---|
| | | distribution), flood damage | (variation in total biomass) | | and stocks | | moisture | |
| | **Cultural services** | Not available | recreation, cultural (positively related to total biomass and density of social network, negatively related to human population size) | Not available | Not available | Not available | Not available | recreation, cultural |
| **biodiversity** | **Species diversity** | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable | MSA via GLOBIO | Not applicable |
| | **Genetic diversity** | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable |
| | **Ecosystem diversity** | Vegetation distribution | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable |

### *1.2.2 Economic models, scenario-building tools, IMPACT-WATER and CLUE*

| | Model name | PoleStar | Treshold 21 | GTAP | ENV-Linkages | IMPACT-WATER | CLUE |
|---|---|---|---|---|---|---|---|
| **Ecosystem services** | **Provisioning services** | water resources, raw materials and agriculture | agriculture, consumption of natural resources (renewable and nonrenewable), resource depletion (e.g. forests) | agricultural food production | timber production, agricultural production (crops and livestock, intensive and extensive production) | agricultural food production (crops and livestock), water supply | None (but land used for agriculture, grazing, forestry) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Supporting services** | Not available | land degradation | Not available | Not available | Not available | Not available |
| | **Regulating services** | solid waste management, environmental loadings | soil erosion, greenhouse gas emissions, air and water quality (pollution) | Not available | Not available | Not available | Not available |
| | **Cultural services** | Not available | Not available | Not available | Not available | Not available | Not available |
| **biodiversity** | **Species diversity** | Not available | Not available | Not available | Not available | Not available | Not available |
| | **Genetic diversity** | Not available | Not available | Not available | Not available | Not available | Not available |
| | **Ecosystem diversity** | Not available | Not available | Not available | Not available | Not available | Land cover diversity explicit |

### *1.2.3 Biogeochemical models*

| | **Model name** | **IBIS** | **Agro-IBIS** | **CENTURY** | **LPJmL** | **PICUS** | **SAVANNA** |
|---|---|---|---|---|---|---|---|
| **Ecosystem services** | **Provisioning services** | water runoff | water supply, crop production | grass, tree and crop production, water supply (stream discharge) | runoff volumes, crop production | timber production | livestock production, grass and timber production, water supply (runoff, deep drainage) |
| | **Supporting services** | NPP, SOC, N balance | NPP, SOC, N balance | N, P and S balance, SOC | annual NPP | nitrogen cycling in forests | NPP, nutrient cycling |
| | **Regulating services** | carbon balance (carbon fluxes, SOC), water regulation | carbon flux, N leaching, water regulation | Water balance, decomposition, $CO_2$ flux, erosion | $CO_2$ exchange, water balance | carbon sequestration, soil moisture (water cycling) | water balance |
| | **Cultural services** | Not available | Not available | Not available | Not available | Not available | Not available |
| **bi** | **Species** | Vegetation | Vegetation | Not available | vegetation cover | forest species | Species distribution |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **diversity** | composition (functional types) | composition (functional types) | | (fraction of different plant functional types per grid cell), | composition (diversity, naturalness indicators) | and abundance (plants + animals) |
| | **Genetic diversity** | Not available | Not available | Not available | Not available | Not available | Not available |
| | **Ecosystem diversity** | Vegetation composition | Vegetation composition | Not available | Vegetation composition | forest species composition | community composition |

### *1.2.4 Hydrological models*

| | **Model name** | **WaterGAP** | **E-SWAT** | **WBM** |
|---|---|---|---|---|
| **Ecosystem services** | **Provisioning services** | water supply | water supply | water supply, livestock production |
| | **Supporting services** | Not available | Not available | Not available |
| | **Regulating services** | Not available | erosion control | soil water content |
| | **Cultural services** | Not available | Not available | Not available |
| **biodiversity** | **Species diversity** | not applicable | not applicable | not applicable |
| | **Genetic diversity** | not applicable | not applicable | not applicable |
| | **Ecosystem diversity** | not applicable | not applicable | not applicable |

### *1.2.5 Biodiversity models*

| **model name** | **GLOBIO** | **MIRABEL** | **Biodiversity** | **SAR species** | **GARP-type** | **EUROMOVE** |
|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | **intactness index** | **area relationship** | **models** | |
| Ecosystem services | **provisioning** | not applicable | not applicable | not applicable | not applicable | not applicable | not applicable |
| | **supporting** | not applicable | not applicable | not applicable | not applicable | not applicable | not applicable |
| | **regulating** | not applicable | not applicable | not applicable | not applicable | not applicable | not applicable |
| | **cultural and spiritual** | not applicable | not applicable | not applicable | not applicable | not applicable | not applicable |
| biodiversity | **species diversity** | mean species abundance (MSA) | Not available | biodiversity intactness index | number of species | number of species | number of species |
| | **genetic diversity** | Not available | Not available | Not available | Not available | Not available | Not available |
| | **ecosystem diversity** | Not available | habitats at risk | Not available | Not available | Vegetation composition/species distribution | Vegetation composition/species distribution |

## *7.1.6 Ocean models I*

| | **Model name** | **ASSETS** | **Atlantis** | **Aus-Connie - Australian Connectivity Interface** | **Cumulative Threat Model for the global ocean** | **EwE, EcoSpace & EcoOcean** | **GEEM** |
|---|---|---|---|---|---|---|---|
| **Ecosystem services** | **Provisioning services** | Estuarine fisheries/aquaculture | Fisheries (inc. their ecosystem effects). | Ecosystem connectivity through genetic diversification (partial match to provisioning services) | Impacts on fisheries/aquaculture; ability of ecosystems to provide non-living resources. | Fisheries (inc. their ecosystem effects). | Fisheries (inc. their ecosystem effects). |
| | **Supporting services** | Primary production, nutrient cycling | Population dynamics (Trophic controls); changes | Nutrient cycling; Larval recruitment to fisheries | Reduction in nutrient cycling ability (e.g. through dead | Population dynamics (Trophic | Population dynamics (trophic |

| | Model name | ASSETS | Atlantis | Aus-Connie - Australian Connectivity Interface | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|---|
| | | | to ecosystem community structure may impact on other ecosystem services; Ecological fluxes (biomass and nutrient limitations) | | zones/pollution); Impacts on habitats and their services. | controls); Biomass and Fluxes. | controls); biological maintenance of resilience; changes to ecosystem community structure may impact on other ecosystem services; |
| | **Regulating services** | water quality | Not applicable | Not applicable | Impact ability of ecosystem to provide regulating services generally. | Not applicable | Not applicable |
| | **Cultural services** | Recreation | Economic valuation of resources | Not applicable | Impacts on recreation, aesthetic values and experience, spiritual enrichment etc. | Economic valuation of resources | Not applicable |
| **biodiversity** | **Species diversity** | dominance by most prolific algal species out-competes all others leading to a loss of species diversity overall. Also, localised dead zones. | Population dynamics and trophic structure. | larval dispersal and recruitment | Not applicable | Population dynamics and trophic structure. | Population dynamics and trophic structure |
| | **Genetic diversity** | dominance by most prolific algal | Not applicable | genetic connectivity | Not applicable | Not applicable | Not applicable |

| | Model name | ASSETS | Atlantis | Aus-Connie - Australian Connectivity Interface | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|---|
| | | species, reducing genetic diversity of system. | | between ecosystems | | | |
| | **Ecosystem diversity** | eutrophication leading to dead zones | 'within ecosystem' diversity based primarily around trophic links and potential fisheries impacts on these. | ecosystem connectivity, dispersion of contaminants between ecosystems | Cumulative human impact scores for 20 marine ecosystems. | 'within ecosystem' diversity based primarily around trophic links (EwE) and movement of species (Ecospace). | 'within ecosystem' diversity based primarily around trophic links and potential human impacts on these. |

### 1.2.7 *Ocean models II*

| | Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|---|
| **Ecosystem services** | **Provisioning services** | Fisheries (commercial and artisanal). | Food security of coastal systems; Water provisioning/water quality; commercial | Coral reef fisheries; Raw materials for medicines; Other raw materials | Fisheries (understanding environmental drivers and bottom-up processes | Ecosystem connectivity i.e. Genetic diversification (partial match to provisioning |

| | Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|---|
| | | | products provided by coastal zones. | (seaweed and algae for agar, manure etc.); Curio and jewellry; Live fish and coral collected for aquarium trade. | impacting fish populations; impacts of fisheries). | services) |
| | **Supporting services** | Changes to ecosystem community structure may impact on other ecosystem services. | Supporting services related to coastal zones generally, e.g. Primary production, nutrient cycling, maintenance of habitats, population dynamics etc. | Maintenance of habitats; maintenance of biodiversity and genetic library; biological maintenance of resilience; mobile links between ecosystems; export of organic production between ecosystems; protection of adjacent shorelines - in doing so supporting wetlands, | Ecological fluxes (biomass and nutrient limitations); Lower trophic level habitat modelling for pelagic and benthic systems; | Larval dispersal and recruitment to fisheries; Nutrient cycling; Bottom-up support of food webs. |

| | Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|---|
| | | | | seagrass beds, mangrove fisheries, population centres etc.; generation of coral sand; build up of land; Nitrogen fixation; CO2/Ca budget control | | |
| | **Regulating services** | Not applicable | Ability of coastal zone to provide regulating services generally; Water provisioning/water quality; | Waste assimilation. | Not applicable | Not applicable |
| | **Cultural services** | Artisanal fishing practices | Ability of coastal zone to provide cultural and spiritual services generally. | Recreational Value; ecotourism; sustaining livelihoods of local communities; aesthetic value; support of cultural, religious and spiritual values. | Not applicable | Not applicable |

| | Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|---|
| biodiversity | **Species diversity** | shifts in species distributions, invasions and extinctions. | impacts of socioeconomic drivers on species diversity in the coastal zone. | Threats to species diversity | lower trophic species (phytoplankton, zooplankton etc.) of pelagic and benthic systems. | larval dispersal and recruitment |
| | **Genetic diversity** | Not applicable | Not applicable | Threats to genetic diversity | Not applicable | genetic connectivity between ecosystems |
| | **Ecosystem diversity** | community shifts in ecosystems. | impacts of socioeconomic drivers on ecosystem diversity in the coastal zone. | Threats to ecosystem (the coral reef) diversity | Ecological fluxes within ecosystems, dynamics of viruses, marine trophodynamics. | ecosystem connectivity |

### *1.2.8 Regional models/assessments*

| | Model name | ATEAM | InVEST | Naidoo et al. | Swallow et al. | Costanza et al. |
|---|---|---|---|---|---|---|
| Ecos yste | **Provisioning services** | food production, wood production, | drinking water, irrigation water, food production, | grassland production of livestock, water | food production, (water supply) | water supply, primary production of |

| | **Model name** | **ATEAM** | **InVEST** | **Naidoo et al.** | **Swallow et al.** | **Costanza et al.** |
|---|---|---|---|---|---|---|
| | | energy production, water supply | timber production, non-timber forest products | supply | | natural vegetation, plantations, grasslands, agriculture |
| | **Supporting services** | soil fertility maintenance (soil organic carbon), pollination | pollination (contribution to yield) | Not available | Not available | soil nutrients |
| | **Regulating services** | carbon storage (LPJ model), drought and flood prevention, water quality | flood mitigation, carbon sequestration, erosion control, water quality | carbon sequestration and carbon storage | erosion control, (flood mitigation, water quality) | water quality |
| | **Cultural services** | recreation, sense of place, beauty | recreation and tourism, cultural and aethetic values, real estate prices as indicator of valuation of nature | Not available | Not available | land prices based on surroundings |
| **biodiversity** | **Species diversity** | statistical niche modelling | species richness (feeding and breeding habitat regquirements of 37 terrestrial vertebrate species, dispersal ability) | mammal, bird, reptile, and amphibian species distribution | Not available | Not available |

| | Model name | ATEAM | InVEST | Naidoo et al. | Swallow et al. | Costanza et al. |
|---|---|---|---|---|---|---|
| | **Genetic diversity** | Not available | Not available | Not available | Not available | Not available |
| | **Ecosystem diversity** | Not available | Not available | Not available | Not available | Not available |

## 1.3 Usability of selected models for TEEB

### *1.3.1 Integrated assessment models*

| **Model name** | **AIM** | **GUMBO** | **IFs** | **IGSM** | **IIASA Integrated Assessment Modeling Framework** | **IMAGE** | **MIMES** |
|---|---|---|---|---|---|---|---|
| **International acknowledgement** | Has been used in many assessments (IPCC, GEO), widely accepted (esp. in Asia), little scientific literature. | One peer-reviewed article, widely cited, large number of collaborators | widely accepted, broad range of users, many assessments | widely accepted, many publications | Widely accepted, used in IIASA assessments | widely accepted, publications: 2 books, > 100 papers, used in MA, IPCC, OECD outlook, GEO, GBO | not published yet, large number of collaborators, high level of publicity, including politics (see website) |
| **width of spectrum of drivers** | broad range of socio-economic drivers | Key drivers are human population development and investment | broad range of socio-economic drivers, including socio-political | broad range of socio-economic drivers | broad range of socio-economic drivers | broad range of socio-economic drivers | Key drivers are human population development and investment |
| **width of spectrum of goods and services covered** | Provisioning (water, timber, food), and regulating (climate regulation, air quality, human health, flood damage) | The dynamics of eleven major ecosystem goods and services for each of the biomes are simulated and evaluated: provisioning, | Only provisioning services including fisheries, carbon emissions, water use, human health | agriculture, climate regulation , air quality, human health, sea level | provisioning, climate regualation | provisioning (crop + livestock production), regulating (carbon) supporting (nitrogen cycling) | very large, all areas covered |

| Model name | AIM | GUMBO | IFs | IGSM | IIASA Integrated Assessment Modeling Framework | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|
| | | supporting, regulating, cultural, biodiversity. | | | | | |
| **richness of detail including sectoral detail** | high | high number of parameters and variables in the socio-economic as well as the biophysical sub-models (economic sectors are aggregated into one, diverse energy resources, simple food demand and land use sub-model) | High, six economic sectors: (agriculture, materials, energy, industry, services, and information/co mmunications technology or ICT), eduction, healt, socio-political, | High amount of sectoral detail, especially in the energy sector (different energy sources), agriculture, transport, plus biogeochemical modelling | high | high | very high: large number of variables and parameters |
| **Possibility of upscaling/ downscaling** | 5º by 5º resolution, application on scale close to this or lower does not provide useful results | Not spatially explicit, 11 biome types | Not spatially explicit, not below country-level | 0.5º by 0.5º resolution, application on scale close to this or lower does not provide useful results | 5’ by 5’ resolution, application on scale close to this or lower does not provide useful results | 0.5º by 0.5º resolution, application on scale close to this or lower does not provide useful results | The MIMES at this stage represented a general model scalable in time and space to be applied in global, regional and local models |
| **effects of European** | Yes | Not known | Yes- Model is focussed on | Yes | Yes | Yes – several studies already on | Not known |

| Model name | AIM | GUMBO | IFs | IGSM | IIASA Integrated Assessment Modeling Framework | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|
| **policies on global level?** | | | estimating direct and indirect effects of different policies, interactions between different policies. | | | effects of national and multinational policies | |
| **operational access for TEEB** | Model not available online | The model can be downloaded and run on the average PC to allow users to explore for themselves the complex dynamics of the system and the full range of policy assumptions and scenarios. Commercial and consultancy uses have to be coordinated with developers/University of Vermont. | Model is available online: www.ifs.du.edu | Model not available online | Models not available online | model not available, requires a well-trained multidisciplinary team | Model is available for download: http://www.uvm.edu/giee/mimes2/downloads.html |
| **known plans for** | Improvement of | calculate the | Enhancement | Improvements on | Various | by 2010 the | The different |

| Model name | AIM | GUMBO | IFs | IGSM | IIASA Integrated Assessment Modeling Framework | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|
| **maintenance and development** | carbon cycle module; estimate the impacts of climate change on water resources, flood risks, forests, agriculture, coastal zones, human health (vector-born diseases) (especially in Asia); further developments concern water demand and trade modelling and a detailed crop production model with fertilizer and pesticide loads and $N_2O$ emissions; fruit production | 'shadow prices' of ecological resources based on 'optimal' (rather than 'actual') levels of resource use. | aiming at better scenario-testing and policy analysis | the resolution of the climate submodel | activities are ongoing related to bio-energy production, REDD-related carbon trade options, analysis of organic and precision farming and natural hazard mitigation strategies | incorporation of a biophysical water and vegetation module (LPJ) is planned | submodels for the ecosystem services are constantly improved by the users, including marine |

### *1.3.2 Economic models, scenario building tools and others*

| **Model name** | **PoleStar** | **Treshold 21** | **GTAP** | **ENV-Linkages** | **IMPACT-WATER** | **CLUE** |
|---|---|---|---|---|---|---|
| **International acknowledgement** | Widely accepted, used in GEO assessment | Used for national application mainly | widely accepted, many publications, used in several assessments | Specially developed for assessments, used by World bank | widely used | widely used, many peer-reviewed publications |
| **width of spectrum of drivers** | high: socio-economic as well as environmental, users may define extra drivers | broad range of socio-economic drivers | range of economic drivers | broad range of socio-economic drivers | broad range of socio-economic drivers | covers a wide range of biophysical and human drivers at different temporal and spatial scales |
| **width of spectrum of goods and services covered** | Provisioning services (water, raw materials, agriculture) | Provisioning services (agriculture) | Provisioning services (agriculture) | Provisioning services (crops, livestock timber) | Provisioning services (crops, livestock, water) | none |
| **richness of detail including sectoral detail** | high, data can be disaggregated into regions, subsectors and processes | high | high | 26 economic sectors considered, different types of agriculture (intensive, extensive) | IMPACT covers 32 commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, meals, vegetables, fruits, sugar and sweeteners, and fish in a partial equilibrium framework. It is specified as a set of country-level supply and demand equations where each country model is linked to the rest | limited consideration of economic variables |

| Model name | PoleStar | Treshold 21 | GTAP | ENV-Linkages | IMPACT-WATER | CLUE |
|---|---|---|---|---|---|---|
| | | | | | of the world through trade. | |
| **Possibility of upscaling/downscaling** | applicable at national, regional and global scales; own data sources can be incorporated into basic model structure | National and global level only | Global or country level | Global or country level | 281 spatial units | CLUE an be scaled up or down, CLUE-S for regional modelling purposes |
| **effects of European policies on global level?** | Via drivers, can be specified explicitly | Via drivers, can be specified explicitly | yes, diverse policy options | yes, diverse policy options | yes, diverse policy options | yes |
| **operational access for TEEB** | easy to use software tool for sustainability studies, both scenario-building tool and database of current indicators, flexible and user-friendly framework for building and assessing alternative development scenarios, user manual (http://www.seib.org/polestar) | PC-based, user-friendly tool , open source, library for download, requires active role of user in the definition of the model structure. | GTAP6.2a can be downloaded at: https://www.gtap.agecon.purdue.edu/models/current.asp | Model not available online. | Ease-of-use is very limited (i.e. referring to the full version of IMPACT). IFPRI has developed a distributional version (IMPACT-D) that can be downloaded free of charge (www.IFPRI.org/themes/impact/impactd.asp). | Full version with technical support of the model is only available for collaborative projects. Others may use the model signing a memorandum of understanding excluding the commercial use of the model and requirement of proper referencing. |
| **known plans for maintenance and development** | unknown | unknown | There is a project to extend the GTAP Model for the analysis of poverty issues, inclusion of bio-fuel as energy | Carbon sequestration and storage will be included, as well as greenhouse gas emissions due to changes in land use. The energy sector is going to be | Ongoing developments aim at integrating various models of food supply and demand at the | Future developments of the model include a crop (management)-specific approach and the application of |

| Model name | PoleStar | Treshold 21 | GTAP | ENV-Linkages | IMPACT-WATER | CLUE |
|---|---|---|---|---|---|---|
| | | | source (production, consumption and trade) | disaggregated into nuclear, fossil fuel, hydro-energy and various renewable energy sources. | macro- and micro-level, both from the socio-economic as well as the biophysical modelling side. Interaction between both components will be incorporated. Interfaces with national and global level general equilibrium models are developed. | spatially specific attainable yields. Other planned developments are the modelling of biophysical landscape processes, further implementation of socio-economic processes, and the use of remote sensing images. |

### *1.3.3 Biogeochemical models*

| Model name | IBIS | Agro-IBIS | CENTURY | LPJmL | PICUS | SAVANNA |
|---|---|---|---|---|---|---|
| **International acknowledgement** | widely used, many peer-reviewed publications | widely used, many peer-reviewed publications | widely used, many peer-reviewed publications | widely used, many peer-reviewed publications | several peer-reviewed publications | widely used, many peer-reviewed publications |
| **width of spectrum of drivers** | environmental drivers | environmental drivers and land use | environmental drivers and land use | environmental drivers and land use | climate and human management (flexible at individual tree level) | Climate, disturbance and human management |
| **width of spectrum of goods and services covered** | water, plant production, carbon flux, N balance | water, plant production, carbon flux, N balance | water, plant production, carbon flux | Water balance, plant production, carbon flux | good coverage of all forest-related services: timber production, nutrient, water cycling, carbon | plant production, animal production, water supply |

| Model name | IBIS | Agro-IBIS | CENTURY | LPJmL | PICUS | SAVANNA |
|---|---|---|---|---|---|---|
| | | | | | sequestration | |
| **richness of detail including sectoral detail** | no economics, detailed biogeochemical model | no economics, detailed but biogeochemical model | no economics, detailed biogeochemical model | no economics, detailed biogeochemical model | limited to forestry sector, detailed biological processes | plant and animal dynamics are modelled based on nutrient supply |
| **Possibility of upscaling/ downscaling** | unknown | Precision agricultural version PALMS for $5m^2$ | Not applicable: not spatially explicit | GUESS for regional modeling | Upscaling possible | Scale-independent (dependent on input), limited number of grid-cells |
| **effects of European policies on global level?** | No policy options | No policy options (via land use maps only) | No policy options, but possible via different land management practices | No policy options, only via land use change | Not specified, but possible via forest management | Yes, via land management options, economics |
| **operational access for TEEB** | can be downloaded but not modified, http://www.sage.wisc.edu/download/IBIS/ibis.html | model and input files can be downloaded, but no help is provided, listserve and user discussions exist, http://daac.ornl.gov/MODELS/guides/IBIS_Guide.html | Century 5 is a research version of the model, it can be obtained upon request, Century 4 is freely available at: http://www.nrel.colostate.edu/projects/century/ | open and unrestricted access, LPJ can be downloaded (upon request) at http://www.pik-potsdam.de/research/cooperations/lpjweb/lpj-lpjml-versions | can be acquired from the authors | available at http://www.nrel.colostate.edu/ftp/coughenour/pubs_lock/index.php?Directory=Manual_1993 |
| **known plans for maintenance and development** | unknown | Smaller scale resolution, more detailed management | Develop a spatially explicit version, improve model details | Inclusion of forestry, furthermore LPJmL is linked with MAgPIE (land use model) and REMIND (macro-economic model) to model food production, land use | unknown | unknown |

| Model name | IBIS | Agro-IBIS | CENTURY | LPJmL | PICUS | SAVANNA |
|---|---|---|---|---|---|---|
| | | | | change and water constraints. | | |

### 1.3.4 *Hydrological models*

| Model name | WaterGAP | (E-) SWAT | WBM |
|---|---|---|---|
| **International acknowledgement** | high, several peer reviewed publications, used in many global and national assessments | widely used, many peer-reviewed publications | widely used, many peer-reviewed publications |
| **width of spectrum of drivers** | WaterGAP simulates the impact of demographic, socioeconomic and technological change on water use as well as the impact of climate change and variability on water availability and irrigation water use | environmental drivers only | environmental drivers |
| **width of spectrum of goods and services covered** | focussed on water (quantity) | water-related | water-related, livestock production |
| **richness of detail including sectoral detail** | high, the only comprehensive global water use model which computes sectoral water uses in grid cells | no economics, detailed biophysical model | no economics, detailed biophysical model |
| **Possibility of upscaling/downscaling** | Basic level is river basin, so it is rather-small-scaled and results can be integrated to global-level. It is not advisable to use model results for developing a water management plan for a particular river basin. But different basins can be compared. | Large amount of data necessary for calibration, high detail of land use/management | 0.5° by 0.5° resolution, can not be used for smaller scales |
| **effects of European policies on global level?** | Via socio-economic drivers or climate input | Via climate input or land use input | Via socio-economic drivers or climate input |
| **operational access for TEEB** | Not available | SWAT can be downloaded at: http://www.brc.tamus.edu/swat/ | Detailed descirption available at http://www.asb.cgiar.org/BNPP/phase2/ifpri/ description_water_balance_model_10jul2003. |

| Model name | WaterGAP | (E-) SWAT | WBM |
|---|---|---|---|
| | | | doc |
| **known plans for maintenance and development** | water quality module is currently under development; for WaterGAP3: increase of spatial resolution | unknown | unknown |

### *1.3.5 Biodiversity models*

| Model name | GLOBIO | MIRABEL | Biodiversity intactness index | SAR species area relationship | GARP | EUROMOVE |
|---|---|---|---|---|---|---|
| **International acknowledgement** | recently published, used in global assessments | one publication | several peer-reviewed publications | widely accepted, many peer-reviewed publications, widely cited, used for MA | application still discussed in scientific literature | two peer-reviewed publications, widely cited |
| **width of spectrum of drivers** | land use, pollution, infrastructure and fragmentation, other drivers via IMAGE | land use, pollution | land use | climate change | climate change | climate only driver, via IMAGE policy options on climate can be used as impact, no effects of land use |
| **width of spectrum of goods and services covered** | biodiversity only | biodiversity only | biodiversity only | biodiversity only | biodiversity only | biodiversity only |
| **richness of detail including sectoral detail** | limited | limited | limited | limited | limited | limited |
| **Possibility of upscaling/downscaling** | Can be applied to smaller areas | Can be applied to smaller areas | The Biodiversity Intactness Index (BII) can be applied at scales at least down to 500 $km^2$ (*i.e.* to the level of local | scale-independent | Scale-independent | presence data for large number of species needed as input |

| Model name | GLOBIO | MIRABEL | Biodiversity intactness index | SAR species area relationship | GARP | EUROMOVE |
|---|---|---|---|---|---|---|
| | | | government) while retaining its intuitive meaning. | | | |
| **effects of European policies on global level?** | yes, via IMAGE | Via drivers (pollution, land use) | Via land use input | Via land use input | Via climate change inputs | yes, via effects on global climate change (IMAGE) (Europe only) |
| **operational access for TEEB** | not available | Not available | Methodology described in Scholes & Biggs, 2004 | Methodology described in Pimm et al., 1995 | methodology is available online: www.lifemapper.org/desktopgarp | Model not available online. |
| **known plans for maintenance and development** | Improvement of infrastructure module, refinement and inclusion of other pressures | No further development | unknown | unknown | unknown | Unknown!?!/none |

### *1.3.6 Ocean models I*

| Model name | ASSETS | Atlantis | Aus- Connie | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|
| **International acknowledgement** | International collaborations are being/have been forged in: 13 North and Mid-Atlantic systems through a partnership with the UMD, UNH, UMASS, Maine State Planning | Methodology has been accepted through the peer-review process. The model has been applied to upwards of 15 ecosystems and the UN Food and Agriculture | Methodology has been accepted through the peer-review process. | Published paper has been widely cited and used by many organisations including UNEP-WCMC. | The software has more than 2000 registered users representing 120 countries, more than a hundred ecosystem models applying the software have been published, see www.ecopath.org. The | Methodology has been accepted through the peer-review process and has since been applied and built upon by the scientific community. |

| **Model name** | **ASSETS** | **Atlantis** | **Aus- Connie** | **Cumulative Threat Model for the global ocean** | **EwE, EcoSpace & EcoOcean** | **GEEM** |
|---|---|---|---|---|---|---|
| | Office, and EPA (funding through CICEET); NEEA/ASSETS has been applied to 10 estuarine and coastal systems in the European Union; ASSETS scores have been developed for systems from the US, EU, and China; Possible harmonization is being investigated between OSPAR-COMPP and ASSETS (COMPASS Initiative); A joint US-EU-China Initiative is being prepared. | Organisation (FAO) has rated the model 'best in the world'. | | | approach is thoroughly documented in the scientific literature. | |
| **width of spectrum of drivers** | Good - ASSETS takes into account human pressures and biological parameters. | Excellent - takes into account chemical, biological, ecological and physical data as well as socioeconomic data in the form of fisheries fleet statistics. | Limited - Aus-ConnIe takes into account only those drivers based on ocean circulation and connectivity. | Good - 17 different drivers are used that fall into categories such as demersal and pelagic fisheries, climate change, pollution, and invasive species. | Good - The models take into account biological information from stock assessment data, including time series data. They build in dynamic population data linking to the ecosystem level, management regimes such as MPAs can be incorporated in Ecospace, and economic | Limited - GEEM takes into account energy (biomass) transfer between trophic levels in the food web and how these can be altered through human impacts. |

| Model name | ASSETS | Atlantis | Aus- Connie | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|
| | | | | | and fisheries data for resource valuation are considered through EcoOcean. | |
| **width of spectrum of goods and services covered** | Provisioning (estuarine fisheries/aquaculture), Regulating (Water quality), Supporting (Nutrient cycling, Primary Production), Cultural and Spiritual (Recreation). | Provisioning (Fisheries (inc. their ecosystem effects); Supporting (Population dynamics (Trophic controls); changes to ecosystem community structure may impact on other ecosystem services; Ecological fluxes (biomass and nutrient limitations)); Cultural (Economic valuation of resources). | Provisioning (larval recruitment for fisheries); Regulating (ecossytem connectivity (inc. Genetic and Nutrient flows); Larval dispersal and recruitment); Supporting (nutrient cycling). | All types of goods and services provided by the marine environment can be related to this model. | Provisioning (fisheries and their effects on ecosystems); Supporting (population dynamics); Cultural and Spiritual (valuation of ecosystem resources). | Provisioning (fisheries); Regulating (biomass and fluxes); and Supporting (Population dynamics (trophic controls); biological maintenance of resilience; changes to ecosystem community structure may impact on other ecosystem services). |
| **richness of detail including sectoral detail** | Not applicable | Good level of ecosystem detail. Sectoral aspect is currently limited to fisheries applications. | Limited detail - a number of applications are mentioned but not discussed. | Although not described in depth, this model is applicable multiple sectors and it provides a framework that can be developed and adapted for use by other sectors, e.g. by adding biodiversity information. | Although a suite of ecosystem models, the models are most applicable to commercial fisheries whereas other sectors have only limited detail. | Limited detail - some applications are described briefly which include the agricultural and fishing/hunting sectors. |
| **Possibility of upscaling/downs** | Applicable to any scale of estuary. | An advantage of the Atlantis modelling | Aus-ConnIe is for use in the Australian | A global model which can be applied at the local- | The models are applicable at multiple | GEEM is applicable at multiple, ecosystem |

| Model name | ASSETS | Atlantis | Aus- Connie | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|
| **caling** | | approach is that it can easily be modified to nest fine-scale models within a coarser coast-wide model. | region. Due to its fairly coarse resolution it is advised not to be used at too fine a scale. | and regional-scale | scales. | scales as it is based on food webs. |
| **effects of European policies on global level?** | Categories are colour-coded following the convention of the EU Water Framework Directive (2000/60/EC), and aims to contribute to the classification systems which are a requirement of the E.U. Water Framework Directive, providing a scale for setting eutrophication related reference conditions for different types of transitional waters. | Unknown. | Not applicable. | Unknown. | Application to FAO fisheries policies. | Application to FAO fisheries policies. |
| **operational access for TEEB** | ASSETS application is available for download at: http://www.eutro.org/register/. It is free and is available in four languages including Chinese. | Model descriptions are available in peer-reviewed published papers that can be accessed online. Technical documents are less easily available and the | Aus-Connie is freely available through the website at: http://www.per.marine.csiro.au/aus-connie/interface. Model is available through either an | All data sets and the model are freely available to download online at: http://www.nceas.ucsb.edu/GlobalMarine | Model descriptions are available in peer-reviewed published papers that can be accessed online. EwE is freely available for use and downloadable from www.ecopath.org | Modelling process is complex and would need to be carried out by a specialist. However, all methods and results are fully and transparently published and discussed in the scientific literature. |

| Model name | ASSETS | Atlantis | Aus- Connie | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM |
|---|---|---|---|---|---|---|
| | | model is not freely available for use. Contact Beth Fulton at Beth.Fulton@csiro.au for more information. | anonymous log-in with restricted access or through a registered users portal. | | | The model cannot be downloaded. |
| **known plans for maintenance and development** | NEEA/ASSETS Update Program is in operation. Type specific indicator variables and thresholds are being considered to improve the accuracy and management implications of the model. | Not specified. Developments may vary depending on the study area to which the model is applied. | Not specified, although the website does have a feedback form for the website itself and the model which indicates future development will take place. | Next key research step will be to compile regional and global databases of empirical measurements of ecosystem condition to further validate the efficiency of the approach. | Facilities are currently being implemented in EwE6 for using spatial drivers and reference data, e.g. Primary production, Salinity, Temperature, Nutrients, Advection, Fish distributions, and Survey data. EcoOcean is planned to be developed to a 0.5km grid cell resolution. The Depletion Index provided by EcoOcean is also being developed to represent a marine equivalent of the MSA used in the GLOBIO project. | Not specified. |

### *1.3.7 Ocean models II*

| Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| **International acknowledgement** | Model recently (2008/2009) published in peer-reviewed journals by an internationally recognised team of scientists and has recieved wide media interest. | RamCo has been applied to the south-west Sulu-Sulawesi region and this methodology has been published in two peer-reviewed scientific papers. | The Reefs at Risk series created high impact in the global media and are considered high profile documents internationally. The methodology has been applied internationally to help inform decision making regarding the management of coral reefs. | The ERSEM II methodologies and applications were published in a special edition of the Journal of Sea Research - an internationally renowned, peer-reviewed publication. The fact that ERSEM was an EU funded project also emphasises the international buy-in of the product. | Methodology has been accepted through the peer-review process. |
| **width of spectrum of drivers** | Good - Takes into account 1066 commercial fish species and includes habitat preferences, dynamic population measures, climate scenarios, and oceanographic variables. | Excellent - Integrated model taking into account socioeconomic data as well as environmental and physical components. | Good - takes into account four component indicators (Coastal development; Marine Pollution; Overexploitation and destructive fishing; Inland pollution and erosion). However the model does not take into account future threats of climate change or population growth, nor does it consider threats resulting from coral disease, bleaching, and other factors considered largely natural in origin. | Good - takes into account both biological data on the lower trophic levels of pelagic and benthic systems and the physical parameters that are affected by these communities, e.g. Carbon and nutrient dynamics of Microzooplankton. The data in this model can then be linked to physical models thus increasing the range of drivers. | Limited - Icthyop takes into account biological propoerties of icthyoplankton and the key physical variable that influence their dynamics. |
| **width of spectrum of goods and services covered** | Provisioning (commercial and artisanal); Supporting (changes to ecosystem | All types of goods and services provided by the coastal zone can be related to this model. | All types of goods and services provided by coral reefs can be related to this model. | Provisioning (fisheries through bottom up controls of fisheries populations; impacts of fisheries); | Provisioning (larval recruitment for fisheries); Regulating (ecosystem connectivity; Larval dispersal |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | community structure); and Cultural and Spiritual (impacts on artisanal fishing practices. | | | Regulating (ecological fluxes; nutrient limitations); Supporting (Lower trophic level habitat modelling for pelagic and benthic systems). | and recruitment); Supporting (bottom-up support of food webs). |
| **richness of detail including sectoral detail** | Limited detail - main application described is to fisheries and only commercial fish species are used in the model. | Good richness of detail regarding the economic impacts on coastal systems. This is based primarily around agriculture and direct use of resources, however also considers the tourism and transport sectors. | Good richness of detail of data used in technical notes, a number of sectors are considered in the model including fisheries, fuel, transport, and tourism. | Limited detail - a number of previous applications to sectors are briefly described, however the majority of information is provided through the ecosystem modelling of regional examples. | Not applicable |
| **Possibility of upscaling/downscaling** | The global model can be downscaled to regional and local scales with the aim of improving understanding of potential climate change impactsat finer spatial and temporal scales. The next step would be to obtain physical and biological data in finer resolution for regional scale studies, particularly in climate | RamCo is the first prototype of an information system, which is to evolve eventually into a Generic Decision Support System for the Integrated Assessment of Sustainable Coastal Zone Management problems. The ultimate aim is to develop a system that will be applicable for the purpose of (1) rapid assessment, to (2) a wide range of coastal zone | The Reefs at Risk model is relevant, and has been applied at, global, regional and national scales. | Several studies have shown that the model is equally applicable in warm temperate (e.g. Mediterranean) systems and tropical situations (such as the Arabian Sea). The versatility of ERSEM is demonstrated by the range of subjects to which it has been applied. Studies of land-ocean interaction have ranged from shallow coastal lagoons to an assessment of riverine influence on the North Sea basin. Basin scale | Though it has been historically developed to study the dynamics of small pelagic fish ichthyoplankton in upwelling systems, Ichthyop is a generic tool in the sense that it incorporates the most important processes involved in ichthyoplankton dynamics. Using Ichthyop for other species in other systems may imply a few changes in the source code (e.g., changing the growth function, implementing a specific larval vertical migration scheme, etc.). |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | sensitive areas. | management problems, in (3) most of the coastal zones of the world. | | and open ocean applications in 1, 2 and 3 dimensions have addressed issues varying from the dynamics of viruses to the influence of weather and climate on marine trophodynamics. ERSEM also provides a model mesocosm environment that can be expected to react in a qualitatively correct manner to seasonal, regional and inter-annual variations. | |
| **effects of European policies on global level?** | Unknown. | Not applicable. | Unknown. | Unknown. | Unknown. |
| **operational access for TEEB** | Model descriptions are available in peer-reviewed published papers that can be accessed online. The model is not available for use, however, Sea Around Us have an excellent collaborative history, making products available from their models for use by other organisations. | Demos of the model and the user's guide are available through the RIKS website (http://www.riks.nl/projects/RamCo). Neither software development with the tools provided in the RAMCO package nor the application of the RAMCO package to a case study is permitted. Software or application development and further usage or marketing of the | Details of the model and methodology are available in the Reefs at Risk publications available through the WRI website. CDROMs containing all the GIS data and models used in the analysis are available upon request. Contact Lauretta Burke for more information: lauretta@wri.org . | Details of the model and methodology are available through the ERSEM PML website (http://web.pml.ac.uk/ecomodels/ersem.htm). The model is not available for download and some of the website is still under development therefore there is instruction to contact modelling@pml.ac.uk for more information. | The software is freely available for download and a user manual is available at http://www.ur097.ird.fr/projects/icthyop/. Output files are in netcdf format and can be post-processed easily. This code is organized simply, commented and documented, which should make it easy to modify by a user with basic programming skills. |

| **Model name** | **Impact of Climate Change on Global Biodiversity** | **RamCo** | **Reefs at Risk** | **ERSEM II** | **ICTHYOP** |
|---|---|---|---|---|---|
| | | RAMCO package will only be accepted following the purchase of a full version of the package. | | | |
| **known plans for maintenance and development** | Plans are in place to: include the effects of salinity on species distribution in the model; to incorporate coastal upwelling as a factor to determine present and future distributions of marine species; to predict global maps of kelp forests and simulate how climate change may affect the distribution of kelp forests and their associated fauna; to use the model to investigate climate-induced changes in physiology and population dynamics; to account for the affects of ocean chemistry. | Building of the MBB building blocks into MBB-libraries, adding to and developing these as necessary; development of scenarios, policy options and policy impacts through input from policy makers; analysts will further develop and refine the model through calibration and parameterisation based on knowledge of coastal zone processes. Through this process, RAMCO could evolve into a storage tank of coastal management knowledge, from this specfic Libraries could be developed which will group the MBBs required for specific coasts. | WRI and ICRAN are leading a update of the 1998 analysis (Reefs at Risk + 10), which will provide a detailed examination of human pressures on coral reefs, implication for reef condition, and projections of associated economic impacts in coastal communities. WRI and ICRAN, in collaboration with a number of other partners, aim to raise public awareness to the location and severity of threats to coral reefs, and catalyse targeted, responsible, and informed decisions that protect coral reefs and the broad range of benefits they provide for people. | Ongoing work is investigating data assimilation as a technique for producing robust forecasts of ecosystem response to short term climatic influences. | Not specified |

### *1.3.8 Regional models/assessments*

| **Model name** | **ATEAM** | **InVEST** | **Naidoo et al., 2008** | **Swallow et al., 2009** | **Costanza et al. 2002** |
|---|---|---|---|---|---|
| **International acknowledgement** | several peer-reviewed articles, widely cited | recent project, first publications | peer-reviewed article recently published | peer-reviewed article recently published | peer-reviewed article, widely cited |
| **width of spectrum of drivers** | policy scenarios, climate change, socio-economic development | only land use change based on scenarios (others will be incorporated) | species conservation strategies | only land use change | land use effects on ecosystem services (linked ecological economic model) |
| **width of spectrum of goods and services covered** | provisioning (agriculture, forestry, water), regulating (water, carbon), supporting (soil fertility, pollination), cultural (recreation), biodiversity | all areas of services covered: provisioning (food, timer, non-timer forest products, water supply), regulating (water, erosion, carbon sequestration), supporting (pollination), cultural (recreation) and biodiversity | provisioning (livestock, water), regulating (carbon storage and sequestration), biodiversity | Provisioning (food and water), regulating (water quality, erosion control) | Provisioning (water), supporting (soil nutrients, NPP), regulating (water quality), cultural (house prices) |
| **richness of detail including sectoral detail** | limited, detailed biogechemical models | limited | no economics, only ecosystem processes | Detailed water model (SWAT), and agicultural production | Combined ecological and economic modelling |
| **Possibility of upscaling/downscaling** | | possible, input: land cover maps; model has both a simple and a complex (more data needed) version | used on global scale as well as regional (California ecoregion) | | Resolution variable |
| **effects of European policies on global level?** | Yes (European level only) | if speficied within scenarios | Not applicable (mapping, no modelling) | Not applicable | Not applicable |
| **operational access for TEEB** | yes | model is available at: http://www.naturalcapitalproject.org/InVEST.html | no | no | No |
| **known plans for maintenance and** | Unknown/none | Ongoing development on the different submodels (tiers 1 | unknown | unknown | unknown |

| **Model name** | **ATEAM** | **InVEST** | **Naidoo et al., 2008** | **Swallow et al., 2009** | **Costanza et al. 2002** |
|---|---|---|---|---|---|
| **development** | | to 3) | | | |

## 1.4 Description of selected scenarios

| **Scenario name** | **GSG: conventional worlds: market forces** |
|---|---|
| **Description** | gradual convergence in incomes and culture toward dominant market model, market-driven globalization, trade liberalization, institutional modernization |
| **Correspondence with other scenarios** | SRES A1, OECD baseline, MA global orchestration, GEO markets first, WWV business as usual, WBSCD FROG! |
| **Type of scenario** | normative |
| **Policies specified** | none, economical development shapes future |
| **Purpose** | A central theme the scenarios the identification of policies, actions and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopı´n et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | economy, markets |
| **comments** | The normative GSG scenarios stood at the basis for many other, explorative scenarios (SRES, MA, GEO 4). |

| **Scenario name** | **GSG: Barbarization: breakdown** |
|---|---|
| **Description** | social and environmental problems overwhelm market and policy response, unbridled conflict, institutional disintegration, and economic collapse |
| **Correspondence with other scenarios** | none |
| **Type of scenario** | normative |
| **Policies specified** | None, no stable political regime |
| **Purpose** | A central theme the scenarios the identification of policies, actions and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopı´n et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for |

| | |
|---|---|
| | synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | economy, individuals |
| **comments** | |

| **Scenario name** | **GSG: great transitions: eco-communalism** |
|---|---|
| **Description** | fundamental changes in values, lifestyles, and institutions, local focus and a bio-regional perspective |
| **Correspondence with other scenarios** | SRES B2 |
| **Type of scenario** | normative |
| **Policies specified** | retreat into localism |
| **Purpose** | A central theme the scenarios the identification of policies, actions and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopı´n et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | lifestyle change, individuals |
| **comments** | |

| **Scenario name** | **GSG: conventional worlds: policy reform** |
|---|---|
| **Description** | gradual convergence in incomes and culture toward dominant market model, strong policy focus on meeting social and environmental sustainability goals |
| **Correspondence with other scenarios** | MA techno garden, GEO policy first, OECD policy variants, WWV technology, WBSCD GEOpolity, |
| **Type of scenario** | normative |
| **Policies specified** | strong policies towards sustainability, social equity and environmental protection |
| **Purpose** | A central theme the scenarios the identification of policies, actions |

| | |
|---|---|
| | and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopı´n et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | global policies |
| **comments** | |

| **Scenario name** | **GSG: Barbarization: fortress world** |
|---|---|
| **Description** | social and environmental problems overwhelm market and policy response, authoritarian rule with elites in "fortresses", poverty and repression outside |
| **Correspondence with other scenarios** | SRES A2, MA order from strength, GEO security first, |
| **Type of scenario** | normative |
| **Policies specified** | strong policies towards regional security, trade barriers |
| **Purpose** | A central theme the scenarios the identification of policies, actions and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopin et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | national policies, economy |
| **comments** | |

| **Scenario name** | **GSG: great transitions: new sustainability** |
|---|---|

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|---|---|
| **Description** | fundamental changes in values, lifestyles, and institutions, new form of globalization that changes the character of industrial society |
| **Correspondence with other scenarios** | SRES B1, MA adapting mosaic, GEO sustainability first, WWV values and lifestyles, WBCSD Jazz |
| **Type of scenario** | normative |
| **Policies specified** | policies towards sustainability and equility |
| **Purpose** | A central theme the scenarios the identification of policies, actions and human choices required for a transition to a more sustainable and equitable future. The diversity and continuity of the GSG offers a unique resource to researchers, decision-makers and the general public. |
| **Authorizing environment** | GSG- global scenario group: Convened in 1995 by the Stockholm Environment Institute, the Global Scenario Group is an independent, international, interdisciplinary body that has been developing integrated global and regional scenarios (Raskin et al. 1998, 2002; Gallopı´n et al. 1997). The GSG scenario narratives are quantified with the use of the PoleStar System, a transparent tool for synthesizing global data sets, organizing sectoral linkages, and introducing assumptions (Raskin et al. 1999). This work has been used by a number of international assessments. Rsults are aimed at a global citizens movement. |
| **Stakeholders involved in the development** | no stakeholders involved |
| **Time horizon and resolution** | 1995-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population development, economics, government, individual lifestyle, sustainability |
| **Main actors** | lifestyle change, individuals, governments |
| **comments** | |

| **Scenario name** | **SRES A1** |
|---|---|
| **Description** | rapid economic growth, market-based solutions with weak governments, free trade, high technological development |
| **Correspondence with other scenarios** | GSG market forces, OECD baseline, MA global orchestration, GEO markets first, WWV business as usual, WBSCD FROG! |
| **Type of scenario** | explorative |
| **Policies specified** | open markets, no policies for greenhouse gas emissions |
| **Purpose** | climate change predictions, assessment of mitigation strategies, provide input for negotiations of possible measures/agreements |
| **Authorizing environment** | IPCC: 6 modelling groups for development from narrative to quantitative model inputs, however, there has been criticism that macro-economists were not involved in scenario development |
| **Stakeholders involved in the development** | none, scientists only |
| **Time horizon and resolution** | 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | trade, transport, manufacturing, agriculture, climate |
| **Main actors** | global economy |
| **comments** | SRES scenarios have been criticised for their negative attitude towards market-based solutions |

| **Scenario name** | **SRES A2** |
|---|---|
| **Description** | moderate economic growth, intermediate technological development, |

| | |
|---|---|
| | self-reliance of regions |
| **Correspondence with other scenarios** | GSG fortress world, MA order from strength, GEO security first, |
| **Type of scenario** | explorative |
| **Policies specified** | trade barriers, strong national policies, no policies for greenhouse gas emissions |
| **Purpose** | climate change predictions, assessment of mitigation strategies, provide input for negotiations of possible measures/agreements |
| **Authorizing environment** | IPCC: 6 modelling groups for development from narrative to quantitative model inputs, however, there has been criticism that macro-economists were not involved in scenario development |
| **Stakeholders involved in the development** | none, scientists only |
| **Time horizon and resolution** | 2100 |
| **Spatial coverage and resolution** | Global |
| **Domains mainly considered** | trade, transport, manufacturing, agriculture, climate |
| **Main actors** | global policies |
| **comments** | SRES scenarios have been criticised for their negative attitude towards market-based solutions |

| **Scenario name** | **SRES B1** |
|---|---|
| **Description** | rapid technological change, central strong governments, restrictive policies, convergent world towards global solutions to economic, social and environmental sustainability, moderate economic growth |
| **Correspondence with other scenarios** | GSG new sustainability, MA adapting mosaic, GEO sustainability first, WWV values and lifestyles, WBCSD Jazz |
| **Type of scenario** | explorative |
| **Policies specified** | strong global management, no policies for greenhouse gas emissions |
| **Purpose** | climate change predictions, assessment of mitigation strategies, provide input for negotiations of possible measures/agreements |
| **Authorizing environment** | IPCC: 6 modelling groups for development from narrative to quantitative model inputs, however, there has been criticism that macro-economists were not involved in scenario development |
| **Stakeholders involved in the development** | none, scientists only |
| **Time horizon and resolution** | 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | trade, transport, manufacturing, agriculture, climate |
| **Main actors** | local communities, "wellfare networks" |
| **comments** | SRES scenarios have been criticised for their negative attitude towards market-based solutions |

Table 4: General information on scenarios

| **Scenario name** | **SRES B2** |
|---|---|
| **Description** | technological change globally unevenly distributed, local solutions to economic, social and environmental sustainability, slow economic growth, decision-making on local/regional level, weak government |
| **Correspondence with other scenarios** | GSG eco-communalism |
| **Type of scenario** | explorative |
| **Policies specified** | trade barriers, local management, no policies for greenhouse gas emissions |

| | |
|---|---|
| **Purpose** | climate change predictions, assessment of mitigation strategies, provide input for negotiations of possible measures/agreements |
| **Authorizing environment** | IPCC: 6 modelling groups for development from narrative to quantitative model inputs, however, there has been criticism that macro-economists were not involved in scenario development |
| **Stakeholders involved in the development** | none, scientists only |
| **Time horizon and resolution** | 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | trade, transport, manufacturing, agriculture, climate |
| **Main actors** | local communities |
| **comments** | SRES scenarios have been criticised for their negative attitude towards market-based solutions |

| **Scenario name** | **MA: *Global Orchestration*** |
|---|---|
| **Description** | global economic policies are the primary approach to sustainability |
| **Correspondence with other scenarios** | GSG market forces, SRES A1, OECD baseline, GEO markets first, WWV business as usual, WBSCD FROG! |
| **Type of scenario** | mostly explorative |
| **Policies specified** | global economic policies towards sustainability |
| **Purpose** | primary aim was to draw out the consequences of several plausible future worlds for ecosystem services, we needed to provide plausible explanations that considered social and economic drivers of change. |
| **Authorizing environment** | Scenario guidance teams |
| **Stakeholders involved in the development** | The scenario guidance team conducted a series of interviews with potential users of the scenarios to obtain their input for developing the goals and focus of the scenarios. This effort included directly asking various users what questions they wanted the MA to address. Users who responded included representatives from the Convention on Biological Diversity, the Convention to Combat Desertification, Ramsar, and other national government representatives; individuals from the private sector; and members of international nongovernmental organizations, civil society, and indigenous groups. This effort led to a greater understanding of what the active stakeholders hoped to gain from the MA scenarios. Final scenarios were developed with interviews of 59 leaders in NGOs, governments, and business from five continents. |
| **Time horizon and resolution** | 2050, for some variables 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | focus on social policy, policy reforms focus on global trade and economic liberalization |
| **Main actors** | global policies, transnational companies, NGOs, multilateral organisations |
| **comments** | |

| **Scenario name** | **MA: *Order From Strength*** |
|---|---|
| **Description** | |
| **Correspondence with other scenarios** | GSG fortress world, SRES A2, GEO security first, |
| **Type of scenario** | mostly explorative |
| **Policies specified** | national policies for nature conservation (parks and reserves), trade barriers |
| **Purpose** | primary aim was to draw out the consequences of several plausible |

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|---|---|
| | future worlds for ecosystem services, we needed to provide plausible explanations that considered social and economic drivers of change. |
| **Authorizing environment** | Scenario guidance teams |
| **Stakeholders involved in the development** | The scenario guidance team conducted a series of interviews with potential users of the scenarios to obtain their input for developing the goals and focus of the scenarios. This effort included directly asking various users what questions they wanted the MA to address. Users who responded included representatives from the Convention on Biological Diversity, the Convention to Combat Desertification, Ramsar, and other national government representatives; individuals from the private sector; and members of international nongovernmental organizations, civil society, and indigenous groups. This effort led to a greater understanding of what the active stakeholders hoped to gain from the MA scenarios. Final scenarios were developed with interviews of 59 leaders in NGOs, governments, and business from five continents. |
| **Time horizon and resolution** | 2050, for some variables 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | focus on self interest, regionalized and fragmented world, concerned with security and protection |
| **Main actors** | national policies, multinational companies |
| **comments** | |

| **Scenario name** | **MA:** ***Adapting Mosaic*** |
|---|---|
| **Description** | |
| **Correspondence with other scenarios** | GSG new sustainability, SRES B1, GEO sustainability first, WWV values and lifestyles, WBCSD Jazz |
| **Type of scenario** | mostly explorative |
| **Policies specified** | local policies |
| **Purpose** | primary aim was to draw out the consequences of several plausible future worlds for ecosystem services, we needed to provide plausible explanations that considered social and economic drivers of change. |
| **Authorizing environment** | Scenario guidance teams |
| **Stakeholders involved in the development** | The scenario guidance team conducted a series of interviews with potential users of the scenarios to obtain their input for developing the goals and focus of the scenarios. This effort included directly asking various users what questions they wanted the MA to address. Users who responded included representatives from the Convention on Biological Diversity, the Convention to Combat Desertification, Ramsar, and other national government representatives; individuals from the private sector; and members of international nongovernmental organizations, civil society, and indigenous groups. This effort led to a greater understanding of what the active stakeholders hoped to gain from the MA scenarios. Final scenarios were developed with interviews of 59 leaders in NGOs, governments, and business from five continents. |
| **Time horizon and resolution** | 2050, for some variables 2100 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | focus on active learning, political and economic activity, local management |
| **Main actors** | local management, cooperatives, global organisations |
| **comments** | |

| Scenario name | MA: *TechnoGarden* |
|---|---|
| Description | |
| Correspondence with other scenarios | GSG policy reform, GEO policy first, OECD policy variants, WWV technology, WBSCD GEOpolity, |
| Type of scenario | mostly explorative |
| Policies specified | proactive, global management |
| Purpose | primary aim was to draw out the consequences of several plausible future worlds for ecosystem services, we needed to provide plausible explanations that considered social and economic drivers of change. |
| Authorizing environment | Scenario guidance teams |
| Stakeholders involved in the development | The scenario guidance team conducted a series of interviews with potential users of the scenarios to obtain their input for developing the goals and focus of the scenarios. This effort included directly asking various users what questions they wanted the MA to address. Users who responded included representatives from the Convention on Biological Diversity, the Convention to Combat Desertification, Ramsar, and other national government representatives; individuals from the private sector; and members of international nongovernmental organizations, civil society, and indigenous groups. This effort led to a greater understanding of what the active stakeholders hoped to gain from the MA scenarios. Final scenarios were developed with interviews of 59 leaders in NGOs, governments, and business from five continents. |
| Time horizon and resolution | 2050, for some variables 2100 |
| Spatial coverage and resolution | global |
| Domains mainly considered | focus on environmental technology, multifunctional agriculture, reduction of trade barriers and subsidies |
| Main actors | technological development, NGOs, professional associations |
| comments | Multi-functional aspects of agriculture and a global reduction of agricultural subsidies and trade barriers. |

| Scenario name | GEO4: *Markets First* |
|---|---|
| Description | Markets First pays lip service to sustainable development in terms of the ideals of the Brundtland Commission, Agenda 21 and other major policy decisions. There is a narrow focus on the sustainability of markets rather than in the context of the broader human-environment system |
| Correspondence with other scenarios | GSG market forces, SRES A1, OECD baseline, MA global orchestration, WWV business as usual, WBSCD FROG! |
| Type of scenario | explorative |
| Policies specified | open markets, environmental policies of national governments (air pollution), ideals of the Brundtland Commission, Agenda 21 and other major policy decisions |
| Purpose | UNEP GEO-4: Environment for Development shows how both current and possible future deterioration of the environment can limit people's development options and reduce their quality of life. This assessment emphasises the importance of a healthy environment, both for development and for combating poverty. |
| Authorizing environment | UNEP: The scenarios were developed through a lengthy collaborative process that began with four of the GSG scenarios, which were then refined through a series of regional and global meetings (Raskin and Kemp-Benedict 2002), with input from the IPCC's Special Report on Emissions Scenarios. The emphasis of the process was on refining the narratives and giving them regional texture. A consortium of modelling teams elaborated on different |

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| | aspects of the scenarios (Potting and Bakkes 2004). |
| **Stakeholders involved in the development** | Expert Group Meeting (Governments and relevant international organisations) |
| **Time horizon and resolution** | 2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population, economic activity, government (energy prices, taxes, environmental policies), lifestyle, technology, land use limitations |
| **Main actors** | economic sector |
| **comments** | |

| **Scenario name** | **GEO-4: *Policy First*** |
|---|---|
| **Description** | Policy First introduces some measures aimed at promoting sustainable development, but the tensions between environment and economic policies are biased towards social and economic considerations |
| **Correspondence with other scenarios** | GSG policy reforms, MA techno garden, OECD policy variants, WWV technology, WBSCD GEOpolity, |
| **Type of scenario** | explorative |
| **Policies specified** | policy limits market failure, climate change mitigation, air pollution, protect species diversity and ecosystem services |
| **Purpose** | UNEP GEO-4: Environment for Development shows how both current and possible future deterioration of the environment can limit people's development options and reduce their<br>quality of life. This assessment emphasises the importance of a healthy environment, both for development and for combating poverty. |
| **Authorizing environment** | UNEP: The scenarios were developed through a lengthy collaborative process that began with four of the GSG scenarios, which were then refined through a series of regional and global meetings (Raskin and Kemp-Benedict 2002), with input from the IPCC's Special Report on Emissions Scenarios. The emphasis of the process was on refining the narratives and giving them regional texture. A consortium of modelling teams elaborated on different aspects of the scenarios (Potting and Bakkes 2004). |
| **Stakeholders involved in the development** | Expert Group Meeting (Governments and relevant international organisations) |
| **Time horizon and resolution** | 2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population, economic activity, government (energy prices, taxes, environmental policies), lifestyle, technology, land use limitations |
| **Main actors** | governmental policies |
| **comments** | |

| **Scenario name** | **GEO-4: *Security First*** |
|---|---|
| **Description** | Security First focuses on the interests of a minority: rich, national and regional. It emphasizes sustainable development only in the context of maximizing access to and use of the environment by the powerful |
| **Correspondence with other scenarios** | GSG fortress world, SRES A2, MA order from strength |
| **Type of scenario** | explorative |
| **Policies specified** | trade barrier, strong national policy, no environmental policies except for air pollution |

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|---|---|
| **Purpose** | UNEP GEO-4: Environment for Development shows how both current and possible future deterioration of the environment can limit people's development options and reduce their quality of life. This assessment emphasises the importance of a healthy environment, both for development and for combating poverty. |
| **Authorizing environment** | UNEP: The scenarios were developed through a lengthy collaborative process that began with four of the GSG scenarios, which were then refined through a series of regional and global meetings (Raskin and Kemp-Benedict 2002), with input from the IPCC's Special Report on Emissions Scenarios. The emphasis of the process was on refining the narratives and giving them regional texture. A consortium of modelling teams elaborated on different aspects of the scenarios (Potting and Bakkes 2004). |
| **Stakeholders involved in the development** | Expert Group Meeting (Governments and relevant international organisations) |
| **Time horizon and resolution** | 2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population, economic activity, governemtn (energy prices, taxes, environmental policies), lifestyle, technology, land use limitations |
| **Main actors** | governmental policies, partly economic |
| **comments** | |

| **Scenario name** | **GEO-4: *Sustainability First*** |
|---|---|
| **Description** | Sustainability First gives equal weight to environmental and socio-economic policies, accountability, and it stresses transparency and legitimacy across all actors. It emphasizes the development of effective public-private sector partnerships not only in the context of projects but in the area of governance, ensuring that stakeholders across the environment-development discourse spectrum provide strategic input to policy making and implementation |
| **Correspondence with other scenarios** | GSG new sustainability, SRES B1, MA adapting mosaic, WWV values and lifestyles, WBCSD Jazz |
| **Type of scenario** | explorative |
| **Policies specified** | strong global management, climate mitigation, air pollution, protect species diversity and ecosystem services |
| **Purpose** | UNEP GEO-4: Environment for Development shows how both current and possible future deterioration of the environment can limit people's development options and reduce their quality of life. This assessment emphasises the importance of a healthy environment, both for development and for combating poverty. |
| **Authorizing environment** | UNEP: The scenarios were developed through a lengthy collaborative process that began with four of the GSG scenarios, which were then refined through a series of regional and global meetings (Raskin and Kemp-Benedict 2002), with input from the IPCC's Special Report on Emissions Scenarios. The emphasis of the process was on refining the narratives and giving them regional texture. A consortium of modeling teams elaborated on different aspects of the scenarios (Potting and Bakkes 2004). |
| **Stakeholders involved in the development** | Expert Group Meeting (Governments and relevant international organisations) |
| **Time horizon and resolution** | 2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | population, economic activity, government (energy prices, taxes, |

| | |
|---|---|
| | environmental policies), lifestyle, technology, land use limitations |
| **Main actors** | economy, government and individual behaviour |
| **comments** | |

| **Scenario name** | **OECD baseline scenario** |
|---|---|
| **Description** | |
| **Correspondence with other scenarios** | GSG market forces, SRES A1, MA global orchestration, GEO markets first, WWV business as usual, WBSCD FROG! |
| **Type of scenario** | trend |
| **Policies specified** | business-as-usual: no new policies |
| **Purpose** | The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope, aim is the exploration of options to reduce climate change and greenhouse gas emissions |
| **Authorizing environment** | OECD |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2005 to 2030 (policies) respectively 2050 (impacts) |
| **Spatial coverage and resolution** | global, for policies: OECD, BRIC and the rest of the world, spatial resolution of effects: 0.5º grid |
| **Domains mainly considered** | agricultural production and trade, energy sector (mitigation of climate change, control of urban air pollution), sewage treatment |
| **Main actors** | |
| **comments** | The Outlook examined drivers of environmental change, specific sectors that put the greatest pressure on the environment, and resulting environmental impacts. The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope. Global economic patterns were modelled using the OECD's JOBS model. These drivers were then used as inputs to the PoleStar System to assess potential environmental impacts in the scenarios. |

| **Scenario name** | **OECD- ppOECD** |
|---|---|
| **Description** | This policy variant implies a broad range of policies for a reduction of greenhouse gas emissions, including a carbon tax, are only implemented in the OECD countries starting in 2012. |
| **Correspondence with other scenarios** | GSG policy reform, MA techno garden, GEO policy first, WWV technology, WBSCD GEOpolity, |
| **Type of scenario** | trend (explorative) |
| **Policies specified** | broad policy package, including phased carbon tax in OECD countries (starting 2012 with US$ 25/tC), development towards maximum feasible reductions of air pollution, installing and updrading sewage treatment systems |
| **Purpose** | The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope, aim is the exploration of options to reduce climate changeand greenhouse gas emissions |
| **Authorizing environment** | OECD |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2005 to 2030 (policies) respectively 2050 (impacts) |
| **Spatial coverage and resolution** | global, for policies: OECD, BRIC and the rest of the world, spatial resolution of effects: 0.5º grid |
| **Domains mainly considered** | agricultural production and trade, energy sector (mitigation of climate change, control of urban air pollution), sewage treatment |

| | |
|---|---|
| **Main actors** | OECD policies |
| **comments** | The Outlook examined drivers of environmental change, specific sectors that put the greatest pressure on the environment, and resulting environmental impacts. The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope. Global economic patterns were modeled using the OECD's JOBS model. These drivers were then used as inputs to the PoleStar System to assess potential environmental impacts in the scenarios. |

| **Scenario name** | **OECD- 450ppm multigas** |
|---|---|
| **Description** | A policy variant with carbon taxes. The price for carbon is not fixed, but dependent on the greenhouse gas emissions with the goal to stabilize the $CO_2$ equivalent concentration at 450 ppm. |
| **Correspondence with other scenarios** | GSG policy reform, MA techno garden, GEO policy first, WWV technology, WBSCD GEOpolity, |
| **Type of scenario** | trend (normative) |
| **Policies specified** | Climate policy aimed at stabilizing the concentration of the six Kyoto gases at 450 ppm carbon dioxide equivalents |
| **Purpose** | The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope, aim is the exploration of options to reduce climate changeand greenhouse gas emissions |
| **Authorizing environment** | OECD |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2005 to 2030 (policies) respectively 2050 (impacts) |
| **Spatial coverage and resolution** | global, for policies: OECD, BRIC and the rest of the world, spatial resolution of effects: 0.5º grid |
| **Domains mainly considered** | agricultural production and trade, energy sector (mitigation of climate change, control of urban air pollution), sewage treatment |
| **Main actors** | global policies |
| **comments** | The Outlook examined drivers of environmental change, specific sectors that put the greatest pressure on the environment, and resulting environmental impacts. The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope. Global economic patterns were modeled using the OECD's JOBS model. These drivers were then used as inputs to the PoleStar System to assess potential environmental impacts in the scenarios. |

| **Scenario name** | **OECD-ccglobal2008** |
|---|---|
| **Description** | This policy variant implies an immediate implementation of carbon taxes worldwide. |
| **Correspondence with other scenarios** | GSG policy reform, MA techno garden, GEO policy first, WWV technology, WBSCD GEOpolity, |
| **Type of scenario** | trend (explorative) |
| **Policies specified** | uniform global carbon tax, starting in 2008 |
| **Purpose** | The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope, aim is the exploration of options to reduce climate changeand greenhouse gas emissions |

| | |
|---|---|
| **Authorizing environment** | OECD |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2005 to 2030 (policies) respectively 2050 (impacts) |
| **Spatial coverage and resolution** | global, for policies: OECD, BRIC and the rest of the world, spatial resolution of effects: 0.5º grid |
| **Domains mainly considered** | agricultural production and trade, energy sector (mitigation of climate change, control of urban air pollution), sewage treatment |
| **Main actors** | global policies |
| **comments** | The Outlook examined drivers of environmental change, specific sectors that put the greatest pressure on the environment, and resulting environmental impacts. The focus of the Outlook is the critical environmental concerns facing OECD countries, but the study is global in scope. Global economic patterns were modeled using the OECD's JOBS model. These drivers were then used as inputs to the PoleStar System to assess potential environmental impacts in the scenarios. |

| **Scenario name** | **IAASTD baseline scenario** |
|---|---|
| **Description** | |
| **Correspondence with other scenarios** | |
| **Type of scenario** | trend |
| **Policies specified** | no new policies (national and international agricultural policy) |
| **Purpose** | |
| **Authorizing environment** | IAASTD |
| **Stakeholders involved in the development** | Private and public sector participation in writing teams |
| **Time horizon and resolution** | 50 years backward and forward |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | food production, water supply, energy production and use, land use change, climate, trade policies and markets |
| **Main actors** | economy |
| **comments** | |

| **Scenario name** | **MIMES/GUMBO: baseline** |
|---|---|
| **Description** | |
| **Correspondence with other scenarios** | OECD baseline |
| **Type of scenario** | trend |
| **Policies specified** | no new policies |
| **Purpose** | |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **MIMES/GUMBO: star trek** |
|---|---|
| **Description** | higher rates of consumption and investment in built capital, lower investment in human, social and natural capital and the real state of the world corresponds to the optimistic parameter assumption set (new alternative energy comes on line, etc.) |
| **Correspondence with other scenarios** | |
| **Type of scenario** | explorative |
| **Policies specified** | higher rates of consumption and investment in built capital, lower investment in human, social and natural capital |
| **Purpose** | |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **MIMES/GUMBO: big government** |
|---|---|
| **Description** | set of technologically sceptical policies (lower rates of consumption and investment in built capital, higher rates of investment in human, social and natural capital) and the real state of the world corresponds to the optimistic parameter assumption set |
| **Correspondence with other scenarios** | |
| **Type of scenario** | explorative |
| **Policies specified** | technologically sceptical policies (lower rates of consumption and investment in built capital, higher rates of investment in human, social and natural capital) |
| **Purpose** | |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **MIMES/GUMBO: mad max** |
|---|---|
| **Description** | higher rates of consumption and investment in built capital, lower investment in human, social and natural capital) and the real state of the world corresponds to the sceptical parameter assumption set (no new energy forms come on line, etc.) |
| **Correspondence with other scenarios** | |
| **Type of scenario** | explorative |

| | |
|---|---|
| **Policies specified** | higher rates of consumption and investment in built capital, lower investment in human, social and natural capital |
| **Purpose** | |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **MIMES/GUMBO: ecotopia** |
|---|---|
| **Description** | technologically sceptical policies and the real state of the world corresponds to the sceptical parameter assumption set |
| **Correspondence with other scenarios** | |
| **Type of scenario** | explorative |
| **Policies specified** | technologically sceptical policies (lower rates of consumption and investment in built capital, higher rates of investment in human, social and natural capital) |
| **Purpose** | |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **WWV: business as usual** |
|---|---|
| **Description** | current water policies continue, high inequity |
| **Correspondence with other scenarios** | GSG market forces, SRES A1, OECD baseline, MA global orchestration, GEO markets first, WBSCD FROG! |
| **Type of scenario** | explorative |
| **Policies specified** | no, focus on demographic, technoloigcal and lifestyle development |
| **Purpose** | To increase awareness of a rising global water crisis. |
| **Authorizing environment** | Word Water Counsil |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2025 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | lifestyle choice, technology development, demographics, economics |
| **Main actors** | institution and economy |
| **comments** | (focus on water, agricultural use, storage, scarcety, distribution) |

| **Scenario name** | **WWV: technology, economic and the private sector** |
|---|---|

| | |
|---|---|
| **Description** | market-based mechanisms, better technology |
| **Correspondence with other scenarios** | GSG policy reforms, MA techno garden, GEO policy first, OECD policy variants, WBSCD GEOpolity, |
| **Type of scenario** | explorative |
| **Policies specified** | no, focus on demographic, technological and lifestyle development |
| **Purpose** | To increase awareness of a rising global water crisis. |
| **Authorizing environment** | Word Water Counsil |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2025 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | lifestyle choice, technology development, demographics, economics |
| **Main actors** | economy (private sector) |
| **comments** | (focus on water, agricultural use, storage, scarcety, distribution) |

| **Scenario name** | **WWV: values and lifestyles** |
|---|---|
| **Description** | less water intensive activities, ecological preservation |
| **Correspondence with other scenarios** | GSG new sustainability, SRES B1, MA adapting mosaic, GEO sustainability first, WBCSD Jazz |
| **Type of scenario** | explorative |
| **Policies specified** | no, focus on demographic, technological and lifestyle development |
| **Purpose** | To increase awareness of a rising global water crisis. |
| **Authorizing environment** | Word Water Counsil |
| **Stakeholders involved in the development** | |
| **Time horizon and resolution** | 2025 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | lifestyle choice, technology development, demographics, economics |
| **Main actors** | lifestyle choices (individual citizens, consumers) |
| **comments** | (focus on water, agricultural use, storage, scarcety, distribution) |

| **Scenario name** | **WBCSD: FROG!** |
|---|---|
| **Description** | market-driven growth, economic globalization |
| **Correspondence with other scenarios** | GSG market forces, SRES A1, OECD baseline, MA global orchestration, GEO markets first, WWV business as usual |
| **Type of scenario** | explorative |
| **Policies specified** | open markets |
| **Purpose** | to engage the business community in the debate on sustainable development |
| **Authorizing environment** | World Business Council for Sustainable Development; the scenarios were developed in an open process involving representatives from 35 organizations. |
| **Stakeholders involved in the development** | representatives from 35 organizations |
| **Time horizon and resolution** | 2000-2050 |
| **Spatial coverage and resolution** | global |
| **Domains mainly considered** | ecosystem sustainability, economy, technology |
| **Main actors** | economy |
| **comments** | |

| Scenario name | WBCSD: GEOpolity |
|---|---|
| Description | top-down approach to sustainability |
| Correspondence with other scenarios | GSG policy reforms, MA techno garden, GEO policy first, OECD policy variants, WWV technology |
| Type of scenario | explorative |
| Policies specified | global policies aiming at sustainable development |
| Purpose | to engage the business community in the debate on sustainable development |
| Authorizing environment | World Business Council for Sustainable Development; the scenarios were developed in an open process involving representatives from 35 organizations. |
| Stakeholders involved in the development | representatives from 35 organizations |
| Time horizon and resolution | 2000-2050 |
| Spatial coverage and resolution | global |
| Domains mainly considered | ecosystem sustainability, economy, technology |
| Main actors | global policies |
| comments | |

| Scenario name | WBCSD: JAZZ |
|---|---|
| Description | bottom-up approach to sustainability, ad hoc alliances, innovation |
| Correspondence with other scenarios | GSG new sustainability, SRES B1, MA adapting mosaic, GEO sustainability first, WWV values and lifestyles |
| Type of scenario | explorative |
| Policies specified | governmental activity limitd to local level |
| Purpose | to engage the business community in the debate on sustainable development |
| Authorizing environment | World Business Council for Sustainable Development; the scenarios were developed in an open process involving representatives from 35 organizations. |
| Stakeholders involved in the development | representatives from 35 organizations |
| Time horizon and resolution | 2000-2050 |
| Spatial coverage and resolution | global |
| Domains mainly considered | ecosystem sustainability, economy, technology |
| Main actors | Lifestyle (individual citizens, consumers) |
| comments | |

Table 4: General information on scenarios

| Scenario name | EURuralis: global economy |
|---|---|
| Description | Societies in the Global economy scenario are predominantly driven by market-based solutions. Trade barriers are gradually eliminated; CAP subsidies are phased out, and so are transfers of capital to support EU regions lagging behind economically. Government roles are limited to core responsibilities, like basic education, security and law enforcement (Westhoek *et al.*, 2006) |
| Correspondence with other scenarios | SRES A1 |
| Type of scenario | explorative with extra policy options |
| Policies specified | agricultural subsidies abolished, |

| | |
|---|---|
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | economy, multilateral cooperation, strong technology development |
| **comments** | |

| **Scenario name** | **EURuralis: global cooperation** |
|---|---|
| **Description** | The Global co-operation scenario assumes intensive multilateral international co-operation on many issues. Tariff barriers restricting market access are gradually removed but international food safety standards are raised and new mechanisms are introduced to ensure high social and environmental production standards of traded goods (Westhoek *et al*., 2006). |
| **Correspondence with other scenarios** | SRES A2 |
| **Type of scenario** | explorative with extra policy options |
| **Policies specified** | some agricultural subsidies, |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | economy, multilateral cooperation for sustainability, nature conservation and equity, strong technology development |
| **comments** | |

| **Scenario name** | **EURuralis: continental markets** |
|---|---|
| **Description** | The Continental markets scenario assumes a view that social and cultural values can best be preserved in regional political alliances, within which nation states should keep as much sovereignty as possible.Agricultural protection measures to shield this market remain in place to safeguard food security (Westhoek *et al*., 2006). |
| **Correspondence with other scenarios** | SRES B1 |
| **Type of scenario** | explorative with extra policy options |
| **Policies specified** | agricultural subsidies abolished, |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |

| | |
|---|---|
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | economy, regional cooperation for sustainability, nature conservation and equity |
| **comments** | |

| **Scenario name** | **EURuralis: regional communities** |
|---|---|
| **Description** | In the Regional communities scenario, a high value is attributed to the subsidiarity principle and, in fact, many issues are addressed at a level below that of the nation-state. Few benefits are attributed to market-based solutions; shielded markets are preferred so as to address the strong environmental and socio-cultural concerns that typify this scenario (Westhoek *et al*., 2006). |
| **Correspondence with other scenarios** | SRES B2 |
| **Type of scenario** | explorative with extra policy options |
| **Policies specified** | only agri-environmental payments, |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | government, regional cooperation for sustainability, nature conservation and equity |
| **comments** | |

| **Scenario name** | **EURuralis: CAP market support variants** |
|---|---|
| **Description** | These variants are implemented on top of one of the scenarios and related to market price supports in the EU which can be maintained or abolished. |
| **Correspondence with other scenarios** | |
| **Type of scenario** | policy variants |
| **Policies specified** | full market liberalization for agricultural products to constant price support |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |

| | |
|---|---|
| **Main actors** | |
| **comments** | |

| **Scenario name** | **EURuralis: CAP income support variants** |
|---|---|
| **Description** | In these policy variants income support can be abolished, maintained or increased. |
| **Correspondence with other scenarios** | |
| **Type of scenario** | policy variants |
| **Policies specified** | abolishment of income support to increasing income support for farmers |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **EURuralis: biofuel variants** |
|---|---|
| **Description** | Different biofuel variants exist from no or low obligations for biofuels to 11.5% share of biofuels in the energy sector. |
| **Correspondence with other scenarios** | |
| **Type of scenario** | policy variants |
| **Policies specified** | no targets (no taxes and subsidies) to 11.5% obligations in 2010 |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | |
| **comments** | |

| **Scenario name** | **EURuralis: less favoured area policy variants** |
|---|---|
| **Description** | Policy variants with abolishment of support for less favourite areas to increase/shift of areas. |
| **Correspondence with other scenarios** | |
| **Type of scenario** | policy variants |

| | |
|---|---|
| **Policies specified** | no special policy, current policy or new policies based on slope and altitude of land |
| **Purpose** | Support European governments on decisions about future |
| **Authorizing environment** | |
| **Stakeholders involved in the development** | Scientific advisory group and policy advisory group |
| **Time horizon and resolution** | 2030 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | macro-economy, demography, agro-technology, border support, income support, LFA, nature policy, spatial policy, erosion policy, energy policy |
| **Main actors** | |
| **comments** | |

Table 4: General information on scenarios

| **Scenario name** | **ATEAM A1** |
|---|---|
| **Description** | Rapid economic growth, little concern about environment, increase in mass-tourism |
| **Correspondence with other scenarios** | SRES A1 |
| **Type of scenario** | explorative |
| **Policies specified** | recreation focus in protected areas |
| **Purpose** | Main objective is to assess the vulnerability of human sectors relying on ecosystem services with respect to global change |
| **Authorizing environment** | ATEAM is a consortium consisting of 18 scientific institutes |
| **Stakeholders involved in the development** | Scenarios were developed in intensive cooperation with stakeholders, primarily ecosystem managers and policy advisors. |
| **Time horizon and resolution** | baseline: 2000; 2020, 2050, 2080 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | land use change based on economy (GDP), techological development, citizen participation, governmental policies, tourism, rural development, spatial planning |
| **Main actors** | global economy |
| **comments** | |

| **Scenario name** | **ATEAM A2** |
|---|---|
| **Description** | Moderate economic growth, strong EU, little concern about environment, decrease in tourism in general but increase in regional tourism |
| **Correspondence with other scenarios** | SRES A2 |
| **Type of scenario** | explorative |
| **Policies specified** | weak nature conservation policies, protection declines |
| **Purpose** | Main objective is to assess the vulnerability of human sectors relying on ecosystem services with respect to global change |
| **Authorizing environment** | ATEAM is a consortium consisting of 18 scientific institutes |
| **Stakeholders involved in the development** | Scenarios were developed in intensive cooperation with stakeholders, primarily ecosystem managers and policy advisors. |
| **Time horizon and resolution** | baseline: 2000; 2020, 2050, 2080 |
| **Spatial coverage and resolution** | Europe |

| | |
|---|---|
| **Domains mainly considered** | land use change based on economy (GDP), techological development, citizen participation, governmental policies, tourism, rural development, spatial planning |
| **Main actors** | regional economy |
| **comments** | |

| | |
|---|---|
| **Scenario name** | **ATEAM B1** |
| **Description** | Moderate economic growth, great concern about environment, styrong central government, increase in regional recreation, decrease in tourism |
| **Correspondence with other scenarios** | SRES B1 |
| **Type of scenario** | explorative |
| **Policies specified** | strict protection and expansion of selected areas |
| **Purpose** | Main objective is to assess the vulnerability of human sectors relying on ecosystem services with respect to global change |
| **Authorizing environment** | ATEAM is a consortium consisting of 18 scientific institutes |
| **Stakeholders involved in the development** | Scenarios were developed in intensive cooperation with stakeholders, primarily ecosystem managers and policy advisors. |
| **Time horizon and resolution** | baseline: 2000; 2020, 2050, 2080 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | land use change based on economy (GDP), techological development, citizen participation, governmental policies, tourism, rural development, spatial planning |
| **Main actors** | global government |
| **comments** | |

| | |
|---|---|
| **Scenario name** | **ATEAM B2** |
| **Description** | Low economic growth, great concern about environment, decrease in tourism, increase in eco-recreation, strong regional governments |
| **Correspondence with other scenarios** | SRES B2 |
| **Type of scenario** | explorative |
| **Policies specified** | local policies for nature conservation |
| **Purpose** | Main objective is to assess the vulnerability of human sectors relying on ecosystem services with respect to global change |
| **Authorizing environment** | ATEAM is a consortium consisting of 18 scientific institutes |
| **Stakeholders involved in the development** | Scenarios were developed in intensive cooperation with stakeholders, primarily ecosystem managers and policy advisors. |
| **Time horizon and resolution** | baseline: 2000; 2020, 2050, 2080 |
| **Spatial coverage and resolution** | Europe |
| **Domains mainly considered** | land use change based on economy (GDP), techological development, citizen participation, governmental policies, tourism, rural development, spatial planning |
| **Main actors** | regional government |
| **comments** | |

## 1.5 Scenario summary with information relevant for TEEB

| **Scenario name** | **type** | **International acknowledgement** | **Width of spectrum of drivers** | **Richness of detail including sectoral detail** | **Models that have been used with scenario** |
|---|---|---|---|---|---|
| IPCC-SRES | explorative | very high | wide set of quantitative indicators | Limited | AIM, IMAGE |
| MA | explorative | high | wide set of quantitative indicators | High | IMPACT, IMAGE, WaterGAP, EwE, SAR |
| GEO-4 | explorative | high | wide set of quantitative indicators | High | AIM, IMAGE, PoleStar, WaterGAP, EcoOcean (EwE) |
| GSG | normative | high, SRES, MA and GEO-scenarios are based on GSG scenarios, however, GSG scenarios are normative instead of explorative | narrative | limited | PoleStar |
| OECD baseline | trend with policy options | high | wide set of quantitative indicators | High | WaterGAP, IMAGE, GLOBIO |
| IAASTD baseline | trend with policy options | moderate | wide set of quantitative indicators | High | IMAGE, IMPACT-WATER, GLOBIO, EcoOcean (EwE) |
| MIMES/GUMBO | explorative | limited | wide set of quantitative indicators | Moderate | MIMES, GUMBO |
| EURuralis | explorative with policy options | Moderate (high within Europe) | moderate | Moderate | GTAP, IMAGE, CLUE |
| WWV | explorative | Limited to water management community | moderate | Moderate | |
| WBCSD | explorative | limited | moderate | Moderate | |
| ATEAM | explorative with policy options | moderate | moderate | Moderate | |

## 1.6 Summary of models with respect to drivers, pressures and impacts

### *1.6.1 Integrated Assessment Models*

| **Model name** | **AIM** | **GUMBO** | **IFs** | **IGSM** | **IIASA** | **IMAGE** | **MIMES** |
|---|---|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | Climate change (as affected by emissions and policy) | climate | climate | Climate change (as affected by emissions and policy) | Climate change (as affected by emissions and policy) | Climate change (as affected by emissions and policy) | climate |
| **human drivers and pressures** | energy demand (land use change) | Human population, knowledge and social institutions (rules and norms) drive the rate of the material and energy flux. | demography, economic, agricultural, energy, socio-political, international political | capital, labour | demography, economy, energy demand | Demography, macro-ecomomy, agricultural demand and trade (from GTAP) | Human population, knowledge and social institutions (rules and norms) drive the rate of the material and energy flux. |
| **policies** | scenario-inputs | scenario inputs | international politics | scenario-inputs | scenario-inputs | Policy decision support model FAIR, scenario inputs | scenario inputs |
| **land use** | land use change model included, spatially explicit | 11 biomes globally aggregated (open ocean, coastal ocean, forests, grasslands, wetlands, lakes/rivers, deserts, tundra, ice/rock, | not spatially explicit | spatially explicit | spatially explicit | geographically explicit modelling of land use/cover | spatially explicit, different types: forest, wetland, grass, urban, desert |

| Model name | AIM | GUMBO | IFs | IGSM | IIASA | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|
| | | croplands, urban): areal land use, not spacially explicit | | | | | |
| **biodiversity** | Vegetation distribution | Not available | Not available | Not available | Not available | MSA via GLOBIO | Not available |
| **ecosystem function** | Water balance | carbon, water and nutrient cycles, decomposition | | water and carbon cycling, NPP | carbon cycle (MAGICC, DIMA) | C, N cycle, LAI, vegetation distribution | Soil formation, nutrient cycling |
| **ecosystem services** | water supply, food and timber production, greenhouse gas emissions, air pollution, carbon sequestration, human health (malaria distribution), flood damage/sea level rise | soil formation, gas regulation, climate regulation, nutrient cycling, disturbance regulation, recreation and culture, and waste assimilation, water, harvested organic matter, mined ores, and extracted fossil fuel | Agricultural production, including marine fishing and aquaculture, Human health, $CO_2$ emissions | agriculture, air pollution, sea level, carbon sequestration, human health impacts, air pollution, carbon stocks | timber production, agricultural food production, renewable water resources | food production, forestry module, water (forthcoming), Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution | Food production, production of raw materials, climate regulation, waste assimilation , disturbance regulation, cultural and recreational |
| **economic value/human well-being** | human health | valuation: marginal product of ecosystem services in both the model's production and | Human health | Health impacts, policy costs | | | valuation: marginal product of ecosystem services in both the model's production and welfare functions |

| Model name | AIM | GUMBO | IFs | IGSM | IIASA | IMAGE | MIMES |
|---|---|---|---|---|---|---|---|
| | | welfare functions (food, energy, GWP and welfare per capita) | | | | | |

### *1.6.2 Economic models, scenario-building tools, IMPACT-WATER and CLUE*

| Model name | PoleStar | Threshold 21 | GTAP | ENV-Linkages | IMPACT-WATER | CLUE |
|---|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | resources, pollution | Not available | Not available | Climate change (as affected by emissions and policy) | water availability, soil conditions, climate | climate, land suitability for crops, effects of past land use, impact of pests, weeds and diseases |
| **human drivers and pressures** | GDP and population development, more specified socio-economic drivers, pollution | socio-economic factors, resources, technology | production functions including capital, labour and land prices | socio-economic factors, policy instruments (carbon taxes, tradable emission permits, regulatory policies) | population development, economy, technology development | population size and density, technology level, political structure, economy |
| **policies** | policy options | policy options | policy options | policy options | policy options | Scenario inputs |
| **land use** | yes | spatially explicit | explicit different land use types (land price and suitability for crops) | spatially explicit | spatially explicit, river basin scale | geographically explicit modeling of land use/cover |
| **biodiversity** | Not available | Not available | Not available | Not available | Not available | Not available |

| Model name | PoleStar | Threshold 21 | GTAP | ENV-Linkages | IMPACT-WATER | CLUE |
|---|---|---|---|---|---|---|
| **ecosystem function** | Not available | Not available | Not available | Not available | N, P and S balance, water cycle | Not available |
| **ecosystem services** | water resources, raw materials and agriculture, solid waste management, environmental loadings | agriculture, consumption of natural resources (renewable and non-renewable), resource depletion (e.g. forests), soil erosion, land degradation, greenhouse gas emissions, air and water quality (pollution) | agricultural food production | timber production | agricultural food production (crops and livestock), water supply | not available, except for land sused for agriculture, forestry and grazing |
| **economic value/human well-being** | income distribution and poverty | GDP | | | Percentage and number of malnourished preschool children, Per-capita calorie availability from Foods, prices | |

### *1.6.3 Biogeochemical models*

| Model name | PICUS | LPJmL | CENTURY | Agro-IBIS | IBIS | SAVANNA |
|---|---|---|---|---|---|---|
| **Natural drivers and environmental** | climate | climate | climate | climate | climate | Climate, fire |

| Model name | PICUS | LPJmL | CENTURY | Agro-IBIS | IBIS | SAVANNA |
|---|---|---|---|---|---|---|
| **pressures** | | | | | | |
| **human drivers and pressures** | forestry management | land use change | land use | land use, agricultural management practices (fertilization, irrigation) | Land use | land management (stocking density, fire) |
| **policies** | Via management input | Not directly, via land use only | Not directly, via land use only | Not directly, via land use only | Not possible | Yes, via land management, socio-economic factors |
| **land use** | spatially explicit | spatially explicit | not spatially explicit, detailed land management options (new ones can be defined) | spatially explicit | spatially explicit | spatially explicit (fractional cover of grid cells by different plant types) |
| **biodiversity** | forest species composition (diversity, naturalness indicators) | Vegetation composition (functional types) | No included | Vegetation composition (functional types) | Vegetation composition (functional types) | flora and fauna abundance (for defined functional groups) |
| **ecosystem function** | carbon sequestration, soil moisture (water cycling), N cycling, NPP | $CO_2$ exchange, water balance, annual NPP, | C, N, P, S and water balance, decomposition | Water cycling, energy balance, carbon flux, N balance, NPP, LAI, phenology | NPP, LAI, phenology, water cycle, energy balance | primary production, plant competition for water, light and nutrients, herbivory, predation, nutrient cycling |
| **ecosystem services** | timber production | Annual NPP, crop production | grass, tree and crop production, water supply | water balance, crop production | NPP, water runoff | livestock production, water budget (runoff) |
| **economic value/human well-being** | Costs and benefits of management practices | Not available | Not available | Not available | Not available | Costs and benefits of management practices |

### *1.6.4 Hydrological models*

| **Model name** | **WaterGAP** | **(E-) SWAT** | **WBM** |
|---|---|---|---|
| **natural drivers and environmental pressures** | Climate, including climate change , disturbances (fire) | climate, topology | climate, topology |
| **human drivers and pressures** | Socio-economic factors (population growth, GDP): energy production, livestock numbers, area irrigated, population size | Land use/management (pollution) | demography |
| **policies** | Via scenario input | Via land use | Not available |
| **land use** | Geographically explicit modeling of land use/cover | spatially explicit | spatially explicit |
| **biodiversity** | no | no | no |
| **ecosystem function** | water cycle (runoff, discharge) | water cycle | water cycle |
| **ecosystem services** | Water supply | water supply, erision control | water supply, livestock production |
| **economic value/human well-being** | Water scarcity | Not available | Not available |

### *1.6.5 Biodiversity models*

| **Model name** | **GLOBIO** | **MIRABEL** | **Biodiversity intactness index** | **Species area relationship (SAR)** | **GARP-based species distribution models** | **EUROMOVE** |
|---|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | climate change, N deposition | climate change, N deposition | none | climate change | climate change | climate change |
| **human drivers and pressures** | land use change, N deposition, infrastructure, fragmentation | land use change, N deposition, infrastructure, fragmentation | land use | habitat loss and fragmentation (land use change), N deposition | None (via greenhouse gans emissions) | Land use |
| **policies** | Via IMAGE | Via land use, pollution | Via land use | Via land use | Via climate change | Via climate change and land use |
| **land use** | spacially explicit (input variable) | EUNIS land use classification | spatially explicit, classification: from protected to moderate use, degraded, cultivated, urban and plantation | not spatially explicit (aggregated at biogeographical units) | spatially explicit | spatially explicit |
| **biodiversity** | MSA (mean species abundance of original species) | habitats at risk | biodiversity intactness index | number of species | number of species, species distribution | number of species, species distribution |
| **ecosystem function** | Not available | habitats at risk | Not available | Not available | Not available | Not available |
| **ecosystem services** | Not available | Not available | Not available | Not available | Not available | Not available |
| **economic value/human well-being** | Not available | Not available | Not available | Not available | Not available | Not available |

### *1.6.6 Ocean models I*

| **Model name** | **ASSETS** | **Atlantis** | **Aus-ConnIe** | **Cumulative Threat Model for the global ocean** | **EwE, EcoSpace & EcoOcean** | **GEEM - General Equilibrium Ecosystem Model** |
|---|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | Capacity of a system to flush/dilute nutrient loads | Biological, chemical, ecological and physical drivers related to the ecosystem | Sea level; Wind fields; Particle trajectories; Geostrophic currents; Wind forced components; Ocean currents; | Vulnerability/sensitivity of ecosystems | Population dynamics; Habitat preferences; Trophic interactions. | Population dynamics; trophic interactions; biomass fluxes. |
| **human drivers and pressures** | Input of Nitrogen and Phosphorous; Poor management of watersheds. | Fisheries | Not applicable | 17 different anthropogenic drivers covering pelagic and demersal,fishing, climate change, pollution, transport, and invasive species. | Fisheries | Human impacts on the energy/biomass flows within a food web, e.g. culling fish species through fisheries or habitat modification. |
| **policies** | Related policies are: Clean Water Act of 1972 (US); Air Pollution Prevention and Control Act of 1977 (US); Coastal Zone Management of 1972 (US); Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (US); EU Water Framework | Relating most closely to fisheries and environmental protection policies. | None specified | None considered but this model could be used to advise on a wide range of marine protection/use policies. | Relating most closely to fisheries and environmental protection policies. | Aim nof model is to influence more effective policy-making through providing a link between the ecosystem and its economic valuation. |

| **Model name** | **ASSETS** | **Atlantis** | **Aus-ConnIe** | **Cumulative Threat Model for the global ocean** | **EwE, EcoSpace & EcoOcean** | **GEEM - General Equilibrium Ecosystem Model** |
|---|---|---|---|---|---|---|
| | Directive (EU); Urban Wastewater Treatment Directive (EU); Nitrates Directive (EU); Shellfish Directive (EU); Bivalve Transport Directive (EU); OSPAR Convention; HELCOM Convention; and Barcelona Convention. | | | | | |
| **land use** | Land-based nutrient run-off | Not applicable | Not applicable | Land-based pollution | Not applicable. | Model can be used to assess the impacts of land modification/use on the energy relationships in food webs. |
| **biodiversity** | Macroalgae, diatoms, flagellates, pelagic and benthic alage, harmful algae. | Dynamics of functional groups within a given food web (with Nitrogen as the common currency between these groups) | Larvae (dispersal and recruitment); other species influenced by ocean currents; connectivity of genetic resources. | Implicit through the focus on ecosystems. | Biodiversity impacts of fisheries, *e.g.* direct loss of biodiversity through Depeletion Index. | Impacts of human interactions on the trophic dynamics of species food-webs within an ecosystem with the view to linking economic valuation information to this. |
| **ecosystem function** | Loss of SAV; Dissolved Oxygen; Nuisance and Toxic | Fisheries impacts on ecosystem function and | Connectivity of ecosystems inc. Larval and | Implication that increased cumulative threat index would lead | Fisheries impacts on ecosystem function, e.g. Loss of functional | Negative impacts on food webs can lead to loss of functional |

| Model name | ASSETS | Atlantis | Aus-ConnIe | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM - General Equilibrium Ecosystem Model |
|---|---|---|---|---|---|---|
| | Algal Blooms; Eutrophication leading to dead zones, thus loss of ecosystem function. | structure. | contaminant dispersal. | to loss of ecosystem function. | groups, disaggregation of communities, change in community controls (i.e. Bottom-up/top-down). | groups, trophic cascades, and a reduction of ecosystem functionality in general. |
| **ecosystem services** | Negative impact on water quality, thus affecting fisheries/aquaculture; ecosystem health; and human uses. | Unsustainable use of provisioning services; Disruption to trophic structure; Loss of connectivity/genetic resources. | Connectivity affects larval recruitment for fisheries; increases genetic diversity leading to increased redundancy and higher ecosystem resilience and functioning; Dispersal of contaminants and understanding their potentially negative effects on ecosystem services. | Approach provides a structured framework for quantifying the ecological tradeoffs associated with different human uses of marine ecosystems and for identifying locations and strategies to minimize ecological impact and maintain sustainable use | Unsustainable use of provisioning services; Destruction of supporting habitats; Loss of connectivity/genetic resources; | Trophic controls of fisheries; carbon and nutrient cycling; ecosystem reactions to impacts including loss of functionality leads to potential impact on ecosystem services; |
| **economic value/human well-being** | Negatively impact fisheries/aquaculture; revenue from recreation; Toxic algal blooms can be harmful to human health. | Food security; economic/fisheries resource value of ecosystem goods and services under different management scenarios. | Understanding sustainability of fisheries, understanding dispersal of contaminants possibly harmful to marine | Model implies that areas that are more highly impacted will not be able to provide the quality and range of ecosystem services as less impacted areas. Reduced goods and | Bioaccumulation effects; food security; economic value of ecosystem goods and services under different management scenarios; | Negatively impact fisheries; possible threats to food security; negative impacts on livelihoods if ecosystem functionaility/services |

| Model name | ASSETS | Atlantis | Aus-ConnIe | Cumulative Threat Model for the global ocean | EwE, EcoSpace & EcoOcean | GEEM - General Equilibrium Ecosystem Model |
|---|---|---|---|---|---|---|
| | | | resources and humans thus reducing ecosystem services, general understanding of the sustaiability and connectivity of ecosystem services. | services will have a general negative impact on human health. | | are lost potentially impacting vulnerable coastal communities. |

### *1.6.7 Ocean model II*

| Model name | Impact of Climate Change on Global Biodiversity | RamCo (Versions 1.0 and 2.0) | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | Population dynamics; Species habitat preferences; Oceanographic variables (e.g. Bathymetry). | Micro-scale drivers of Sea Use Functions (seagrass and coral reefs); Land Use functions (Mangrove; Nature/forest); Land use features (Sea; Inland water); and Macro-scale drivers based around water and ecology. | Relative slope, land cover class, and precipitation are used for the Inland pollution and erosion model. Otherwise, natural drivers, such as disease and bleaching, are not considered. | Carbon dynamics; nutrient dynamics; trophodynamics; physical drivers such as climate and weather ( when linked with physical models). | Biological: age (day), length (mm), stage (egg, yolk-sac larva, or feeding larva), location (longitude/latitude) and depth (m), and status (alive or dead). Physical: current velocities (m s-1), temperature (*C), and salinity. The physical inputs are |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo (Versions 1.0 and 2.0) | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | | | | | archived from oceanic simulations of the "Regional Oceanic Modelling System" (ROMS) or the "Model for Applications at Regional Scale" (MARS). |
| **human drivers and pressures** | Anthropogenic climate change | Micro-scale functions of Land Use functions (Agriculture; Rice culture; Shrimp culture; Industry; Tourism; Urban residential; Rural residential); and Land use features (Airport; Harbour; Beach); and Macro-scale drivers based around land use and the economy. | Coastal development; Marine pollution; Overexploitation and Destructive fishing; Inland Pollution and Erosion. | Not available | Not available |
| **policies** | Not specified, however, model outputs are relevant to fisheries policies and marine | Future policy choices under the influence of climate changes, demographic | Outputs can be and have been used to inform policy making and have been | Production of accurate scenarios by the ERSEM can be used to inform | None specified |

| **Model name** | **Impact of Climate Change on Global Biodiversity** | **RamCo (Versions 1.0 and 2.0)** | **Reefs at Risk** | **ERSEM II** | **ICTHYOP** |
|---|---|---|---|---|---|
| | protection policies (through identification of hotspots). | growth or changing economic demand can be tested. | used to set regional and local priorities - such as in Sabah, where the Reefs at Risk analysis aided the development of legislation restricting coastal development | policy-makers on decisions relating to sectors such as fisheries management and climate change. | |
| **land use** | Not applicable | Land Use functions (Agriculture; Rice culture; Shrimp culture; Industry; Tourism; Urban residential; Rural residential; Mangrove; Nature/forest); and Land use features (Sea; Inland water; Airport; Harbour; Beach). | Land cover type and inland sources of pollution. | Not applicable | Not applicable |
| **biodiversity** | Current and future distributions of 1066 commercial fish species are modelled. | Impacts of policies and future demographic and socio-economic | Coral reef degradation is considered in terms of major changes in | Lower trophic levels of pelagic and benthic marine systems. | Larvae (dispersal and recruitment); connectivity of genetic resources. |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo (Versions 1.0 and 2.0) | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | | change on coastal zone biodiversity, in particular, pollution impacts on rivers and the coast, destruction of habitats for food production increasing erosion and sedimentation. | species composition and relative species abundance. | | |
| **ecosystem function** | Disassociation of communities within an ecosystem leading to functional loss or change. | Pollution and sedimentation lead to species die-offs and alteration of current ecosystem function. Destruction of land-based habitats negatively effect ecosystem buffering functionality, increasing flooding. | Coral reef degradation is considered in terms of major change sto the productivity of coral reef communities. | Carbon and nutrient cycling; lower trophodynamic influences regarding bottom-up control. | Connectivity of ecosystems inc. Larval dispersal. |
| **ecosystem services** | Impacts on fisheries (commercial and artisanal); Potential services loss through | Increased pressures on the coastal zone will negatively impact | Considers impacts on all ecosystem services provided | Bottom-up control of fisheries; carbon and nutrient | Connectivity affects larval recruitment for fisheries; increases |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo (Versions 1.0 and 2.0) | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | teh diassociation of functioning ecosystem communities. | biodiversity and ecosystem function, thus generally degarding teh wide variety of ecosystem services provided by coastal zone systems. | by coral reefs. | cycling; ecosystem reactions to impacts and thus potential impact to ecosystem services; Regulation of marine bacteria and viruses. | genetic diversity leading to increased redundancy and higher ecosystem resilience and functioning. |
| **economic value/human well-being** | Negatively impact fisheries economics, particularly the vulnerable coastal communities that rely on small, artisanal fisheries | Polluted water has negative impacts on human health, potential for risks to food security if coastal system functionality is lost, increased or modified flood patterns can cause direct risks to coastal communities. | Negatively impact economic benefits of coral reefs (fisheries, medicinal products, curio/jewellry, aquarium trade); Increase vulnerability of coastal communities and habitats to natural hazards; Reduce food availability impacted on human health; Negatively impact livelihood associated with coral reefs; negatively impact | Bottom-up control of fisheries; Marine bacteria and virus dynamics; Influence of weather and climate on marine ecosystem services (e.g. Food security). | Understanding sustainability of fisheries; general understanding of the sustaiability and connectivity of ecosystem services. |

| Model name | Impact of Climate Change on Global Biodiversity | RamCo (Versions 1.0 and 2.0) | Reefs at Risk | ERSEM II | ICTHYOP |
|---|---|---|---|---|---|
| | | | spiritural, cultural, and aesthetic values associated with coral reefs. | | |

### 1.6.8 *Regional models/asssessments*

| Model name | ATEAM | InVEST | Naidoo et al., 2008 | Swallow et al., 2009 | Patuxent landscape model (PLM) Costanza et al. 2002 |
|---|---|---|---|---|---|
| **natural drivers and environmental pressures** | climate | not yet (possible: climate change) | none (mapping only) | None (mapping only) | Climate |
| **human drivers and pressures** | socioeconomic factors and land use | management practices, infrastructure, governance | none (mapping only, potentially: land use) | land use change | land use |
| **policies** | Via scenario inputs | governance, stakeholder-defined scenarios | examined: habitat conservation policies: synergies with ecosystem services | Via land use change | Via economics |
| **land use** | 14 land use types, spatially explicit | spatially explicit | spatially explicit | spatially explicit | spatially explicit, land use types: water, forest, agricultural, rural |

| Model name | ATEAM | InVEST | Naidoo et al., 2008 | Swallow et al., 2009 | Patuxent landscape model (PLM) Costanza et al. 2002 |
|---|---|---|---|---|---|
| | | | | | residential, urban |
| **biodiversity** | yes (species richness and turnover of plants, mammals, birds, reptiles and amphibians), shifts in suitable habitats | yes (Species richness (species area realtionship), habitat area and quality) | yes (species distribution for mammals, birds, reptiles and amphibians) | Not available | Not available |
| **ecosystem function** | Water and carbon cycling, soil fertility | carbon and water cycling | carbon and water cycling | Not available | primary production, soil nutrient cycling |
| **ecosystem services** | food and timber production, water and carbon regulation, soil fertility, recreation | water quality, supply and regulation, timber and food production, carbon stocks and sequestration, recreation, species richness | carbon sequestration and storage, water supply, livestock production | Food and water supply, erosion control, water quality | water supply, aesthetic value (house prices) |
| **economic value/human well-being** | Not available | economic valuation of ecosystem services (per hectare market values) | Not available | Not available | aesthetic value (house prices) |

# 2 APPENDICES OF CHAPTER 3: OVERVIEW OF RESULTS FROM MODELS FOR THE LOSS OF BIODIVERSITY AND ECOSYSTEMS AND THEIR SERVICES

## 2.1 List of relevant projections and model results made in the assessment

| **Biodiversity / ecosystem service** | **Assessment** | **Scenarios** | **Indicator** | **Model** | **Details examined?** |
|---|---|---|---|---|---|
| Terrestrial biodiversity | OECD Environmental Outlook to 2030 | 1 | Mean Species Abundance | IMAGE | Yes |
| Terrestrial Biodiversity | GEO 4 | 4 | Forest cover | IMAGE | Yes |
| Terrestrial biodiversity | MA | 4 | Forest cover | IMAGE 2.2 | Yes |
| Terrestrial biodiversity | MA | 4 | Global loss of vascular plant species | IMAGE 2.2 | Yes |
| Terrestrial biodiversity | GEO 4 | 4 | Mean Species Abundance | GLOBIO | Yes |
| Terrestrial biodiversity | CBD 2006 | 7 | Mean Species Abundance | IMAGE GLOBIO 2 | Yes |
| Terrestrial Biodiversity | MA | 4 | Global loss of vascular plant species through nitrogen deposition | IMAGE 2.2 | No |
| Terrestrial biodiversity | MA | 4 | Global loss of vascular plant species through habitat loss | IMAGE 2.2 | No |
| Food availability | IAASTD | 1 | kilocalories/day | IRPRI IMPACT | Yes |

| **Biodiversity / ecosystem service** | **Assessment** | **Scenarios** | **Indicator** | **Model** | **Details examined?** |
|---|---|---|---|---|---|
| Food availability | GEO 4 | 4 | kilocalories/day | IMAGE | Yes |
| Food production | MA | 4 | Cereal yield (megatonnes/year) | IMPACT | Yes |
| Food production | IAASTD | 2 | Fish landings | ECO-OCEAN | Yes |
| Food production | IAASTD | 1 | cereal yield | IFPRI IMPACT | Yes |
| Marine biodiversity | MA | 4 | Biomass Diversity Index | Ecopath with Ecosim | Yes |
| Marine biodiversity | GEO 4 | 4 | Change in total biomass of select fish groups | EwE | Yes |
| Marine biodiversity | Ecosystem based global fishing policy scenarios | 4 | MTI (Marine Trophic Index) | EcoOcean | Yes |
| Marine: Biomass Diversity Index | IAASTD | 2 | Biomass Diversity Index | EcoOcean | Yes |
| Terrestrial biodiversity | Ag Assessment | 1 | Mean Species Abundance | GLoBio3 | Yes |
| Erosion control | MA | 4 | million km2 | IMAGE 2.2 | Yes |
| Erosion control | GEO 4 | 4 | million km2 | IMAGE | No |
| Food production | MEA | 4 | fish landings | Ecopath/Ecosim | No |
| Food production | GEO 4 | 4 | cereal yield (tonnes/ha) | IMAGE | No |

| **Biodiversity / ecosystem service** | **Assessment** | **Scenarios** | **Indicator** | **Model** | **Details examined?** |
|---|---|---|---|---|---|
| Food production | GEO 4 | 4 | Total landings from marine fisheries (billion tonnes) | EcoPath with EcoSim | No |
| Food production | Ecosystem based global fishing policy scenarios | 4 | Total landings from marine fisheries (billion tonnes) | EcoOcean | No |

## 2.2 Projections of biodiversity and ecosystems services under different assessment scenarios.

All projections from 2000 to 2050 unless stated

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| CBD - Global Biodiversity Outlook | Baseline | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global losses of 7.5%. Sub-Saharan Africa, Europe show declines of greater than 11%. | Infrastructure, increasing climate change, agriculture, increasing climate change development and settlement also become increasingly important. |
| | Full trade liberalisation in agriculture | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global losses of 8.8%; 1.3% below the baseline. | Shift of agricultural production to Southern Africa and Latin America. Agricultural areas no longer required in developed countries potentially restored for biodiversity. |
| | Alleviation of extreme poverty in Sub-Saharan Africa | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global losses of 9.2%; 1.7% below the baseline. Reduces by 5.7% from the baseline in Sub-Saharan Africa. | Increased food consumption in Africa, produced predominately in the region. Potential long term benefits from reductions in demographic pressure and economic improvements. |
| | Climate Change mitigation policy | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global losses 8.5%; 1% below the baseline. | Biodiversity gain (+1%) from avoiding climate change and reduced nitrogen deposition. Loss (-2%) from additional land use for biofuels. |
| | Sustainable wood production | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 7.4%; +0.1% above the baseline. | Initial biodiversity loss through landuse. Later, reduced climate change and pressure on natural forests. Semi natural forests previously exploited left to recover. |
| | Sustainable meat production | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 7.2%. +0.3% above the baseline. | Increase in the cost of meat means lower demand and less area being needed for agriculture and lower nitrogen deposition. |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | Doubling terrestrial biomes under protection | Terrestrial Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 6.4%. +1.1% above baseline. Latin America and Africa see smallest improvements. | Nitrogen deposition, fragmentation and climate change and increased pressure on adjacent land. Partly offset by reduced land conversion and greater connectivity. |
| OECD Environmental Outlook to 2030 | OECD baseline scenario | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 11%. Deterioration faster than 20th century. | Infrastructure, climate change, expansion of agricultural land. |
| | OECD policy package | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 11%. Deterioration faster than 20th century. | Infrastructure becomes an increasing source of pressure on MSA between now and 2050, from -6% to -11%. Climate change also becomes more significant. The expansion of crops and pasture accounts for the biggest loss of MSA. |
| | OECD 450ppm | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 10%. Biggest improvement from baseline. | Infrastructure, climate change, woody fuel, crops. Partly offset by reduced impacts of climate change. |
| | OECD global policy package | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 11%.Deterioration faster than 20th century. | Infrastructure, climate change, crops. |
| IAASTD | Baseline | Terrestrial: Mean Species Abundance | GLoBio3 | Global loss of 10%. The rate of loss is faster than between 1970 - 2000. | Infrastructure, climate change and agricultural expansion. |
| GEO 4 | *Markets first* | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 12%. 16% and 15% loss in Africa and Latin American & the Caribbean respectively. | Infrastructure to access natural resources, climate change. Agriculture exerts negative pressure in Africa and Latin America & the Caribbean. Positive impact elsewhere. |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | *Policy first* | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 7%. 10% and 8% loss in Africa and Latin American & the Caribbean respectively. | Climate change, agriculture expansion. Protected areas protect some of the most endangered species. |
| | *Security first* | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 10%. 16% and 12% loss in Africa and Latin American & the Caribbean respectively. | Infrastructure and climate change, exacerbated by large population growth and increased conflict. |
| | *Sustainability first* | Terrestrial: Mean Species Abundance | IMAGE GLOBIO 3 | Global loss of 7.5%. 10.5% and 9% loss in Africa and Latin American & the Caribbean respectively. | Climate change and expanded demand of agricultural land for biofuels. Protected areas protect some of the most endangered species. |
| GEO 4 | *Markets first* | Forest cover | IMAGE GLOBIO 3 | Global forest cover projected to reduce from circa 45 million $km^2$ in the year 2000 to circa 40 million $km^2$ by 2050. N. America and Europe projected to see a slight growth in forest cover whereas Africa, Latin America and the Caribbean are all projected to have a decrease. | Loss of forest cover is not as pronounced as under the Policy First and Sustainability First scenarios since the increasing demand for land is partly compensated by developments in technology under this scenario. |
| | *Policy first* | Forest cover | IMAGE GLOBIO 3 | Global forest cover projected to reduce from circa 45 million $km^2$ in the year 2000 to circa 35 million $km^2$ by 2050. Africa is projected to lose nearly the entirety of its forest cover. | Population growth, strong targets for mitigating the effects of GHG emissions under this scenario leads to added pressure to increase the area of land used for biofuel crop production. |
| | *Security first* | Forest cover | IMAGE GLOBIO 3 | Global forest cover projected to reduce to circa 42 million $km^2$ by 2050 (from 45 million $km^2$ in 2000). From 2030, an increase in forest cover is projected in Asia and the Pacific, Europe and N. America. In Latin America and the Caribbean forest cover is projected to stabilise at circa 8 million $km^2$ between 2020 and 2050. | Under this scenario, low economic growth means agricultural land expansion is smallest out of all the scenarios. In Latin America and the Caribbean where forest is a key natural resource, key forest areas are kept well protected due to the interests of the elite in this region. |
| | *Sustainability first* | Forest cover | IMAGE GLOBIO 3 | Global forest cover projected to decrease by circa 7 million $km^2$ (from the year 2000) to circa 38 million $km^2$ in 2050. Slight increase in forest cover in Latin America and the Caribbean projected between 2030 and 2050. | Strong targets for mitigating the effects of GHG emissions under this scenario, added pressure to increase the area of land used for biofuel crop production. Improvements in technology made under this scenario counterbalanced by an increased concern for food availability. In Latin America and the Caribbean, |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | | | | | mechanisms put in place in order to rehabilitate affected forest ecosystems. |
| | *Global Orchestration* | Forest cover | IMAGE 2.2 | Rate of loss of "original forest"* unchanged. Cover increases in Industrial regions and declines in Developing regions | Rapid income growth and preference for meat. Partly offset by increased crop yields due to technological innovation. Circa 50% of Sub-Saharan forest disappears. |
| | *Order from Strength* | Forest cover | IMAGE 2.2 | Rate of loss of "original forest"* globally increases from 0.4% to 0.6%. Significant reductions in Developing regions. | Increasing population and slow improvements in crop yield in low-income countries. Two thirds of Central African forest in 1995 gone. |
| | *Adapting Mosaic* | Forest cover | IMAGE 2.2 | Rate of loss of "original forest"* unchanged. Cover increases in Industrial regions and declines in Developing regions | Locally successful experiments mitigate expansion of agricultural land after 2040. Lowest deforestation rates in Africa but virtual depletion of forest areas in South Asia by 2100 due to low crop yields. |
| MA | *Techno Garden* | Forest cover | IMAGE 2.2 | Net increase in forest cover. Rate of loss of "original forest"* slightly below current rate. Significant depletion in Africa and Southeast Asia. | Assumed lower meat consumption reducing pastureland. Partly offset by increase in crops and land for biofuels to combat climate change. |
| | *Global Orchestration* | Global loss of vascular plant species | IMAGE 2.2 | 16.5% loss between 1970 and 2050. | Climate change main driver on savanna and cool conifers. Agricultural expansion, particularly in temperate, tropical and warm mixed forests. N deposition important driver on temperate deciduous forest. |
| | *Order from Strength* | Global loss of vascular plant species | IMAGE 2.2 | 18.5% loss between 1970 and 2050. | Climate change, agricultural expansion, N deposition. Expanding population and slow crop yields main driver. |
| MA | *Adapting Mosaic* | Global loss of vascular plant species | IMAGE 2.2 | 15% loss between 1970 and 2050. | Climate change, agricultural expansion. Slower development rates in developing countries slowing the increases in food demand. |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | *Techno Garden* | Global loss of vascular plant species | IMAGE 2.2 | 13.5% loss between 1970 and 2050. | Agricultural expansion, climate change. Higher yields and stabilising population reduce land expansion impact. |
| GEO 4 | *Markets first* | Food availability (kilocalories/day) | IMAGE GLOBIO 3 | Large increases in all regions. Consistent gaps between rich and poor. | Increased demand, greater investments in technology. |
| | *Policy first* | Food availability (kilocalories/day) | IMAGE GLOBIO 3 | Large increases in all regions. Consistent gaps between rich and poor. | Increased demand, greater investments in technology, environmental stewardship. |
| | *Security first* | Food availability (kilocalories/day) | IMAGE GLOBIO 3 | Food production barely keeps up with population increase after 2020 and there is a small decline after 2040. | Growing population, lack of investment in technology. |
| | *Sustainability first* | Food availability (kilocalories/day) | IMAGE GLOBIO 3 | Largest increases in all regions. Significant reduction in gap between rich and poor countries. | Lower overall population growth, reduced land degradation, regional integration. |
| IAASTD | *Reference scenario* | Food availability (kilocalories/day) | IFPRI IMPACT | Slow improvement. Lowest in Sub-Saharan Africa and South Asia at circa 2, 7400 compared to over 3,000 elsewhere. Child malnutrition grows 11% in Sub-Saharan Africa. | Increasing food prices, inability of poor countries to increase production to match population growth. |
| | *Reference scenario* | Food production (cereal yield) | IFPRI IMPACT | Grows at a slower annual rate than 1980-2000 of 1.96% to 1.02%. Latin America and Caribbean and Sub-Saharan Africa grow 1.61% and 1.68% respectively. | Moderate technological investment. Slowed by increasing water scarcity, drought from climate change. |
| MA | *Global Orchestration* | Food production (cereal yield) | IMPACT | World output increases 72% , almost four-fold in Sub-Saharan Africa. | Large investments in agricultural research and supporting infrastructure. Land under irrigation increases rapidly. |

| | **Scenario** | **Biodiversity / ecosystem service** | **Model** | **Projections** | **Pressures and trends** |
|---|---|---|---|---|---|
| | *Order from Strength* | Food production (cereal yield) | IMPACT | World output increases 55%. | Significant crop area expansion as investments insufficient to match demand. Subsidies and barriers increase cost of procuring food, particularly for the poor. |
| | *Adapting Mosaic* | Food production (cereal yield) | IMPACT | World output increases 53%. | Food produced locally on expanded crop areas insufficient for demand. Results in pressures on food prices and increase in demand for imports. |
| | *Techno Garden* | Food production (cereal yield) | IMPACT | World output increases 57%. | Substantial improvements in crop yields and lower meat consumption diet reducing demand for crop area expansion. Medium population growth. |
| | *Markets first* | Change in total biomass of select fish groups | Ecopath with Ecosim | Large demersals decrease by circa 6% and large pelagics decrease by circa 14%. | Increase in global income and improved technology. Increased fishing effort. |
| | *Policy first* | Change in total biomass of select fish groups | Ecopath with Ecosim | Large demersals increase to circa 8% while large pelagics decrease by circa 7%. | Increased fishing effort. |
| | *Security first* | Change in total biomass of select fish groups | Ecopath with Ecosim | Large demersals increase by circa 4% while large pelagics decrease by circa 11%. | Large projected population |
| GEO 4 | *Sustainability first* | Change in total biomass of select fish groups | Ecopath with Ecosim | Large demersals increase to 30% while large pelagics decrease by circa 8%. | Attempt to fish lower on the food chain, shifting diets and smaller increases in population. |
| MA | *Global Orchestration* | Marine: Biomass Diversity Index | Ecopath with Ecosim | **Gulf of Thailand** responds well to ecosystem rebuilding, but drops dramatically when focus changes to provide fishmeal for aquaculture. **Bay of Benguella** responds to ecosystem recovery after 2030. **Central North Pacific** is not much affected. | Decline in fisheries addressed once economic importance becomes apparent. High global coordination a positive. |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | *Order from Strength* | Marine: Biomass Diversity Index | Ecopath with Ecosim | Risk of fisheries collapse high worldwide. **Gulf of Thailand** decreases consistently. **Bay of Benguella** initially does well as focus on jobs results in ecosystem management. **Central North Pacific** loses biomass diversity. | Unchecked exploitation and lack of co-ordination. |
| | *Adapting Mosaic* | Marine: Biomass Diversity Index | Ecopath with Ecosim | **Gulf of Thailand** decreases consistently. **Bay of Benguella** increased due to management policy to maintain jobs. **Central North Pacific** increases slightly in response to protection but decreases in 2030 when focus returns to high-value fisheries. | Informed local management does well but is hampered by lack of co-ordination at the global level. |
| | *Techno Garden* | Marine: Biomass Diversity Index | Ecopath with Ecosim | **Gulf of Thailand** responds very well to ecosystem rebuilding, but drops dramatically when focus changes to provide fishmeal for aquaculture. **Bay of Benguella** drops initially but increases after 2030 when managed to provide fishmeal due to the favourable mix of species present. **Central North Pacific** decreases as technology improves catch rate. Not affected by development of aquaculture. | Decline in fisheries is addressed through environmental technologies and rapid development of aquaculture. |
| Ecosystem based global fishing policy scenarios | *Markets first* | MTI (Marine Trophic Index) | EcoOcean | General decrease in Marine Trophic Index in all oceans studied. Increased landings usually at lower trophic levels. | As most large bodied demersal fish already overexploited in 2003, landings were increased by augmenting secondary demersal fish groups and invertebrates (e.g. lobster, crab, shrimp). |
| | *Policy first* | MTI (Marine Trophic Index) | EcoOcean | General decrease in Marine Trophic Index in all oceans studied. Increased landings usually at lower trophic levels. | As most large bodied demersal fish already overexploited in 2003, landings were increased by augmenting secondary demersal fish groups and invertebrates (e.g. lobster, crab, shrimp). |

| | Scenario | Biodiversity / ecosystem service | Model | Projections | Pressures and trends |
|---|---|---|---|---|---|
| | *Security first* | MTI (Marine Trophic Index) | EcoOcean | General decrease in Marine Trophic Index in all oceans studied. Increased landings usually at lower trophic levels. | As most large bodied demersal fish already overexploited in 2003, landings were increased by augmenting secondary demersal fish groups and invertebrates (e.g. lobster, crab, shrimp). |
| | *Sustainability first* | MTI (Marine Trophic Index) | EcoOcean | Least increase in landings. Slightly higher MTI in most oceans studied than the other scenarios but a general decrease still projected in all oceans studied. Increased landings usually at lower trophic levels. In some areas under this scenario a decreased demersal fleet effort is projected. | As most large bodied demersal fish already overexploited in 2003, landings were increased by augmenting secondary demersal fish groups and invertebrates (e.g. lobster, crab, shrimp). |
| GEO-4 | *Markets first* | Marine Trophic Index of catch | Ecopath with Ecosim | General decrease in MTI | Increased fishing effort and improved technology |
| | *Policy first* | Marine Trophic Index of catch | Ecopath with Ecosim | General decrease in MTI | |
| | *Security first* | Marine Trophic Index of catch | Ecopath with Ecosim | General decrease in MTI. Highest MTI of catch as effort is maintained on more valuable species. | Lower catches but efforts maintain on higher value fish. |
| | *Sustainability first* | Marine Trophic Index of catch | Ecopath with Ecosim | Biggest decrease in MTI | Attempt to fish lower on the food chain to maintain marine ecosystems. Lower overall catch increases due to smaller population increases and changing diets. |
| IAASTD | Reference Scenario | Marine Trophic Index of catch | EcoOcean | **Atlantic Ocean:** decreased trophic level of catches by 2-2.5%. **Pacific Ocean:** Unchanged. **Indian Ocean:** Unchanged. **Mediterranean:** 3% decline. All between 2003-2048. | Value of landings optimised with fishing effort as the driver, until 2010, after which only small pelagic fleet allowed to change. |

| | **Scenario** | **Biodiversity / ecosystem service** | **Model** | **Projections** | **Pressures and trends** |
|---|---|---|---|---|---|
| | Increase in small pelagic fleet | Marine Trophic Index of catch | EcoOcean | **Atlantic Ocean:** decreased trophic level of catches of 2-2.5%. **Pacific Ocean:** declines 1.3%. **Indian Ocean:** Consistent decline. **Mediterranean:** consistent decline. All between 2003-2048. | 2% increase in pelagic fishing effort per year after 2010. Sustainability of Indian Ocean & Mediterranean uncertain due to constant fall in trophic level. Atlantic observes declines in large demersal and bentho-pelagic fish. |
| | Reference Scenario | Food Production (fish landings) | EcoOcean | **Atlantic Ocean**: decrease 5.4%. **Pacific Ocean**: declines 5%. **Indian Ocean**: initial decline, eventual 1% increase. **Mediterranean:** 7% increase. All between 2003-2048. | Value of landings optimised with fishing effort as the driver, until 2010, after which only small pelagic fleet allowed to change. |
| | Increase in small pelagic fleet | Food Production (fish landings) | EcoOcean | **Atlantic Ocean:** increase 7%. **Pacific Ocean:** large increase. **Indian Ocean:** less than 5% increase. **Mediterranean:** 50% increase, then level. All between 2003-2048. | 2% increase in pelagic fishing effort per year after 2010. Increases in small pelagic. |
| MA | *Global Orchestration* | Water induced Soil Erosion | IMAGE 2.2 | Significant increasing pressure, global area of soil with high water erosion risk increases from circa 22 $Mkm^2$ in 2000 to circa 28 $Mkm^2$ in 2050. | Large pressure as a result of precipitation increase, and to a lesser extent from land use change. |
| | *Order from Strength* | Water induced Soil Erosion | IMAGE 2.2 | Significant increasing pressure, most of all the scenarios. Approximately 50% increase in the global area of soil with high water erosion risk by 2100 (from circa 22 $Mkm^2$ in 2000 to 32 $Mkm^2$ in 2050 and 40 $Mkm^2$ in 2100). | Large pressure as a result of land use change to a lesser extent from increased precipitation and agricultural practices. |
| | *Adapting Mosaic* | Water induced Soil Erosion | IMAGE 2.2 | Significant increasing pressure, global area of soil with high water erosion risk increases from circa 22 $Mkm^2$ in 2000 to circa 28 $Mkm^2$ in 2050. | Pressure due to increased precipitation and land use. Agricultural practices have a positive impact owing to localised objectives to prevent soil erosion which slows the degradation of active agricultural land and significantly restores previously degraded land. |
| | *Techno-Garden* | Water induced Soil Erosion | IMAGE 2.2 | Significant increasing pressure but less than other scenarios. Global area of soil with high water erosion risk increases from circa 22 $Mkm^2$ in 2000 to circa 28 $Mkm^2$ in 2050 and increases to circa 31 $Mkm^2$ by 2100 (lowest of all scenarios). | Pressure due to increased precipitation and land use. Agricultural practices have a positive impact since they are more ecologically proactive. |

**NOTES**

All projections from 2000 to 2050 unless stated

* "Original forests" here means forests that were present in 1970 and have not changed their attributes through agricultural expansion, timber production or climate change. Historic rate refers to rate between 1970 - 2000 rate.

## 2.3 The most important assumptions and examples of different categories of scenarios used in the assessments

| | | Population | Overall GDP Increase | Energy Use | Agricultural production & consumption | Primary Goals | Environmental protection | Trade | Technology development |
|---|---|---|---|---|---|---|---|---|---|
| Business as usual | OECD Baseline | 9.1 bn in 2050 (40% increase);<br><br>8.2 bn in 2030 (27% increase) | Annual global GDP increase of 2.8%.<br><br>Overall world GDP increases 87%; India and China increase over 300%. (2005 - 2030) | 280 EJ to 470 between 2000 and 2030. | Consumption increases 50% globally by 2030; 70% in developing countries. stable in OECD countries. | Not defined | Both reactive and proactive | Weak globalisation | Average |
| | IAASTD Baseline | 8.2 bn in 2050 | Developed regions will see relatively low and stable to declining growth rates between 1 and 4% per year out to 2050.<br><br>East and SE Asia growth rate of between 4-7% per year to 2050.<br>LAC region 3.5-4.5% growth per year to 2050 | 280 EJ (year 2000) increases to 500 EJ by 2030 and to over 700 EJ in 2050. Biggest rises in developing countries; but higher energy consumption per capita in developed countries. | Number of malnourished children will decline from150 million (2000) to 130 million in 2025 and to 100 million in 2050.<br><br>Total area of agricultural land worldwide increased by 10% in 2050. | Not defined | Both reactive and proactive | Current trade conditions continue to 2050 – no trade liberalisation or reduction in sectoral protection. | |
| Convent ional | GEO 4 *Markets First* | 9.2 bn by 2050 | Approximately 500% increase in global GDP by 2050. | Increases from 400 EJ in 2000 to over 1000EJ | | Maximum economic growth | Reactive | Significant increase in global trade (from | Rapid |

| | | Population | Overall GDP Increase | Energy Use | Agricultural production & consumption | Primary Goals | Environmental protection | Trade | Technology development |
|---|---|---|---|---|---|---|---|---|---|
| | | | | in 2050 | | | | approx 10 trillion US$ in 2000 to approx 75 trillion US$ in 2050) | |
| Reformed Markets | ~~MEA~~ MA Global Orchestration | 7.2 bn by 2020 increasing to 8.1 bn in 2050. Population projected to be 6.8 bn in 2100. | Annual growth rates of GDP per capita (% per year) is 3% between 2020 and 2050 and 2.3% between 2050 and 2100. | Increases from 400 EJ in 2000 to 1200 EJ by 2050 | | Globally connected society with a focus on global trade and economic liberalisation | Reactive | Trade liberalisation | Rapid |
| | GEO 4 *Policy First* | 8.6 bn by 2050 | Approximately 500% increase in global GDP by 2050 | 400 EJ in 2000 to 600-700 EJ in 2030 and around 800-900 EJ in 2050 | | Centralised approach in order to balance strong economic growth with reduced potential environmental and social impacts | Both reactive and proactive | Increase in global trade (from approx 10 trillion US$ in 2000 to approx 60 trillion US$ in 2050) | Rapid |
| Competition Between | GEO 4 *Security First* | 9.7 bn by 2050 | Nearly 300% increase in global GDP by 2050 | 400 EJ in 2000 to 600-700 EJ in 2030 and around 800-900 EJ in | | Security | Reactive | Trade increases from approx 10 trillion US$ in 2000 to 20 trillion | Slow |

| | | Population | Overall GDP Increase | Energy Use | Agricultural production & consumption | Primary Goals | Environmental protection | Trade | Technology development |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2050 | | | | US$ in 2050, the smallest increase of all four GEO4 scenarios | |
| | ~~MEA~~ MA Order from Strength | 7.7 bn by 2020 increasing to 9.5 bn in 2050, reaching 10.5 bn in 2100. | Annual growth rates of GDP per capita (% per year) is 1.0% between 2020 and 2050 and 1.3% between 2050 and 2100. | 400 EJ in 2000 to 800 EJ in 2050 | | Security and protection, emphasis on regional markets | Reactive | Trade barriers, regional markets | Overall technological development is low (medium in industrial countries) |

# 3 APPENDICES FOR CHAPTER 4: ASSESSMENT OF IMPACT OF KEY ASSUMPTIONS

## 3.1 Terrestrial Models

## (Score # indicates number of criteria (columns) for which the model does not provide information)

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Supporting services** | **Cultural services** | **Regulating services** | | | | | |
| *Integrated assessment models* | | | | | | | | | |
| GUMBO | Harvested organic matter, water supply, mined ores, and extracted fossil fuel | Soil formation (decomposition), nutrient (N) cycling | recreation, cultural (positively related to total biomass and density of social network, negatively related to human population size) | gas regualtion (C flux), climate regulation (temperature), waste assimilation, disturbance regulation (variation in total biomass) | x | valuation: marginal product of ecosystem services in both the model's production and welfare functions | global, 11 biomes globally aggregated, not spatially explicit | x | 2 |
| IMAGE | Agricultural production, including grass/fodder production and livestock/milk production, demand for wood products, timber, fuelwood | Soil fertility | x | Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution, soil moisture | MSA through link with GLOBIO | x | Global (with details for 24 world regions (energy, trade emissions) or or 0.5º x 0.5º grid (land cover, land use) | SRES, MA, GEO, OECD, IAASTD, EURURALIS | 2 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| MIMES | Food production, production of raw materials | Soil formation, nutrient cycling | recreation, cultural | climate regulation, waste assimilation , disturbance regulation | x | valuation: marginal product of ecosystem services in both the model's production and welfare functions | global, 1° by 1° resolution | x | 2 |
| AIM | Water supply, food and timber production | x | x | greenhouse gas emissions, air pollution, carbon sequestration, human health (malaria distribution), flood damage | Vegetation distribution | x | Focused on Asian-Pacific region, but linked to a global model representing 9 regions; 5°x 5° | SRES | 3 |
| IGSM | Agricultural production (can be separated into crops, livestock and forestry) | SOC | x | human health impacts, sea level, air pollution, carbon emissions and stocks | x | GDP growth | global, 16 regions with special studies on European countries, 0.5° to 4°by5° grid, depending on submodel for the biogeochemical part | x | 3 |
| IIASA | timber production, agricultural food production, | x | x | carbon sequestration | x | x | global, 0.5° grid | SRES | 4 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Supporting services** | **Cultural services** | **Regulating services** | | | | | |
| | renewable water resources | | | | | | | | |
| Ifs | Agricultural production, including marine fishing and aquaculture | x | x | Human health, CO2 emissions | x | x | Global (with details for 182 regions/countries), not spatially explicit | x | 5 |
| *Scenario building tools* | | | | | | | | | |
| PoleStar | water resources, raw materials and agriculture | x | x | solid waste management, environmental loadings | x | income distribution and poverty | x | SRES | 4 |
| Threshold 21 | agriculture, consumption of natural resources (renewable and nonrenewable), resource depletion (e.g. forests) | land degradation | x | soil erosion, greenhouse gas emissions, air and water quality (pollution) | x | x | focussed on the national level, globally applicable | x | 4 |
| *Economic models* | | | | | | | | | |
| ENV-Linkages | timber production, agricultural production (crops and | x | x | x | x | x | Global, aggregated in 34 countries/regions | x | 6 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| | livestock, intensive and extensive production) | | | | | | | | |
| GTAP | agricultural food production | x | x | x | x | x | Country level, not spatially explicit | Used in combination with IMAGE in a number of assessments | 5 |
| *Land-use models* | | | | | | | | | |
| CLUE | None (but land used for agriculture, grazing, forestry) | x | x | x | Land cover diversity explicit | x | Europe (EU-27), also case studies in a.o. Costa Rica, Ecuador, Honduras, the Netherlands, China, Java, Phillippines, Malaysia, Vietnam, Kenya, USA, 1x1km, case studies between 30m and 32km | EURURALIS | 4 |
| *Biogeochemical models* | | | | | | | | | |
| IBIS | water runoff | NPP, SOC, N balance | x | carbon balance, water regulation | Vegetation composition (functional types) | x | 0.5 - 4° | x | 3 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| LPJmL | runoff volumes, crop production | annual NPP | x | $CO_2$ exchange, water balance | vegetation cover (fraction of different plant functional types per grid cell); Vegetation composition | x | global, 0.5º grid cells | x | 3 |
| SAVANA | livestock production, grass and timber production, water supply (runoff, deep drainage) | NPP, nutrient cycling | x | water balance | Species distribution and abundance (plants + animals); community composition | x | regional, resolution depending on input data and studied ecosystem | x | 3 |
| Agro-IBIS | water supply, crop production | NPP, SOC, N balance | x | carbon flux, N leaching, water regulation | Vegetation composition (functional types) | x | currently only run for North America, global application planned, 0.5º grid | x | 3 |
| PICUS | timber production | nitrogen cycling in forests | x | carbon sequestration, soil moisture (water cycling) | forest species composition (diversity, naturalness indicators) | x | temperate forests, Europe, $100m^2$ patches | x | 3 |
| CENTURY | grass, tree and crop production, water supply (stream | N, P and S balance, SOC | x | Water balance, decomposition, $CO_2$ flux, erosion | x | x | any resolution (depending on input?) | x | 4 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| | discharge) | | | | | | | | |
| IMPACT-WATER | Agricultural food production (crops and livestock) | x | x | x | x | x | global: 115 regions and countries, intersected with 126 river basins (281 spatial units), uncluding EU-15 and eastern Europe | x | 6 |
| *Hydrological models* | | | | | | | | | |
| (E)-SWAT | water supply | x | x | erosion control | x | x | calculations are done on the scale of sub-watersheds | x | 5 |
| WaterGAP | water supply | x | x | x | x | x | global, country, river basin, grid cells 0.5° by 0.5° | OECD, GEO, MA, in combination with IMAGE, IMPACT, EcoSim and AIM | 5 |
| WBM (+) | water supply, livestock production | x | x | soil water content | x | x | 0.5° by 0.5° grid (30'grid) | x | 5 |
| *Biodiversity models* | | | | | | | | | |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| GLOBIO | FROM link with IMAGE: Agricultural production, including grass/fodder production and livestock/milk production, demand for wood products, timber, fuelwood | FROM link with IMAGE: Soil fertility | x | FROM link with IMAGE: Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution, soil moisture | mean species abundance (MSA) | x | global, (0.5º by 0.5º for climatic data, 1km by 1km for land use data) | OECD, GBO | 2 |
| BII | x | x | x | x | biodiversity intactness index | x | global, scale of aggregation: 104 to 106 km2 | x | 6 |
| EUROMOVE | x | x | x | x | number of species | x | Europe, 2500km2 grid cells | x | 6 |
| MIRABEL | x | x | x | x | habitats at risk Not available | x | 28 European countries, 13 ecological regions | x | 6 |
| SAR | x | x | x | x | number of species; Vegetation composition/ species distribution | x | global, calculated for different biogeographical units (biomes, ecoregions), not spatially explicit | x | 6 |
| GARP | x | x | x | x | Vegetation composition/ species distribution | x | x | x | 7 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| *Regional models / Assessments* | | | | | | | | | |
| ATEAM | food production, wood production, energy production, water supply | soil fertility maintenance (soil organic carbon), pollination | recreation, sense of place, beauty | carbon storage (LPJ model), drought and flood prevention, water quality | statistical niche modelling | x | Europe 15 + Norway and Switzerland, 10' by 10' grid | x | 2 |
| InVEST | drinking water, irrigation water, food production, timber production, non-timber forest products | pollination (contribution to yield) | recreation and tourism, cultural and aethetic values, real estate prices as indicator of valuation of nature | flood mitigation, carbon sequestration, erosion control, water quality | species richness (feeding and breeding habitat regquirements of 37 terrestrial vertebrate species, dispersal ability) | x | regional, resolution flexible; case study: Willamette Basin, Oregon, USA (30 m x 30 m grid, for results: 500 ha units) | x | 2 |
| PLM, Costanza et al 2002 | water supply, primary production of natural vegetation, plantations, grasslands, agriculture | soil nutrients | land prices based on surroundings | water quality | x | x | Patuxent River watershed, Maryland, USA; variable resolution, maximum resolution: 200 by 200m | x | 3 |
| Naidoo et al 2008 | grassland production of livestock, | x | x | carbon sequestration and carbon | mammal, bird, reptile, and | x | global, maximum resolution 0.5° | x | 4 |

| Model name | Ecosystem Service Provision | | | | Biodiversity | Economic Value of Output | Scale of Output | Earlier applications in assessments | Score |
|---|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Supporting services | Cultural services | Regulating services | | | | | |
| | water supply | | | storage | amphibian species distribution | | | | |
| Swallow et al, 2009 | food production, (water supply) | x | x | erosion control, (flood mitigation, water quality) | x | x | Lake Victory basin; multiple spatial scales, smallest: 5km by 2.5km (arial photograph), sub-basin, country division, river basin | x | 5 |

## 3.2 Marine Models

**(Score # indicates number of criteria (columns) for which the model does not provide information)**

| **Model name** | **Ecosystem Service Provision** | | | | **Economic Value of Output** | **Scale of Output** | **Earlier application in assessments** | **Score** |
|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Regulating services** | **Supporting services** | **Cultural services** | | | | |
| ASSETS | Estuarine fisheries/aquaculture; water quality | Not applicable | Primary production, nutrient cycling | Recreation | Negatively impact fisheries/aquaculture; revenue from recreation; Toxic algal blooms can be harmful to human health. | Estuarine/Watershed level. Currently, there are 157 assessed estuarine systems in ASSETS primarily based in the U.S. But there are a number of international records. Resolution of output is based the the bathymetry grid used, however the details are not specified in the peer-reviewed methodology. | Not applicable | 2 |
| Aus-Connie | Larval recruitment to fisheries | Ecosystem connectivity (inc. genetic and nutrient flows), larval dispersal and recruitment | Nutrient cycling | Not applicable | Understanding sustainability of fisheries, dispersal of contaminants possibly harmful to marine resources and humans thus reducing ecosystem services, general understanding of the sustainability and connectivity of ecosystem services. | Australia; 0.5 degree geographical grid; All statistics were based on currents and trajectories computed at a fixed depth of Z = 20m, which was taken to be representative of surface waters where larval concentrations tend to be highest. | Not applicable | 2 |

| Model name | Ecosystem Service Provision | | | | Economic Value of Output | Scale of Output | Earlier application in assessments | Score |
|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Regulating services | Supporting services | Cultural services | | | | |
| Cumulative Threat Model for the global ocean | Impacts on fisheries/aquaculture; abiility of ecosystems to provide non-living resources. | Impact ability of ecosystem to provide regulating services generally. | Reduction in nutrient cycling ability (e.g. through dead zones/pollution); Impacts on habitats and their services. | Impacts on recreation, aesthetic values and experience, spiritual enrichment etc. | Model implies that areas that are more highly impacted will not be able to provide the quality and range of ecosystem services as less impacted areas.Reduced goods and services will have a general negative impact on human health. | Global but can be applied at the local- and regional-scale; 1km2 resolution grid. | Not applicable | 1 |
| EwE, EcoSpace & EcoVal | Fisheries (inc. their ecosystem effects). | Biomass and fluxes | Population dynamics (Top-down vs. Bottom-up controls) | Economic valuation of resources (Ecoval). | Bioaccumulation effects; food security; economic value of ecosystem goods and services under different management scenarios; | Multi-scale, ecosystem models. Ecospace is the only component that provides spatial representation and uses user-defined grid cells. | Millennium Ecosystem Assessment scenarios and the GEO-3 and -4 projections. | 0 |

| Model name | Ecosystem Service Provision | | | | Economic Value of Output | Scale of Output | Earlier application in assessments | Score |
|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Regulating services | Supporting services | Cultural services | | | | |
| GEEM | Fisheries (inc. their ecosystem effects). | Biomass and fluxes | Population dynamics (trophic controls); biological maintenance of resilience; changes to ecosystem community structure may impact on other ecosystem services; | Not applicable | Negatively impact fisheries; possible threats to food security; negative impacts on livelihoods if ecosystem functionaility/services are lost potentially impacting vulnerable coastal communities. | Multi-scale, ecosystem model based around food webs. Resolution measures are not applicable as spatial representation of outputs is not available. | Not applicable | 3 |
| Impact of Climate Change on Global Biodiversity | Fisheries (commercial and artisanal). | Not applicable | Changes to ecosystem community structure may impact on other ecosystem services. | Artisanal fishing practices | Negatively impact fisheries economics, particularly the vulnerable coastal communities that rely on small, artisanal fisheries | Global; 30' X 30' grid cell size. Can be scaled to local and regional levels. | Not applicable | 3 |

| Model name | Ecosystem Service Provision | | | | Economic Value of Output | Scale of Output | Earlier application in assessments | Score |
|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Regulating services** | **Supporting services** | **Cultural services** | | | | |
| RamCo | Food security of coastal systems; Water provisioning/water quality; commercial products provided by coastal zones. | Ability of coastal zone to provide regulating services generally. | Supporting services related to coastal zones generally, e.g. Primary production, nutrient cycling, maintenance of habitats, population dynamics etc. | Ability of coastal zone to provide cultural and spiritual services generally. | Polluted water has negative impacts on human health, potential for risks to food security if coastal system functionality is lost, increased or modified flood patterns can cause direct risks to coastal communities. | RAMCO can handle cellular models with dimensions up to 500 by 500 cells. Useful on grids which resolution varies from 50 to 500 meters. RamCo can to deal with spatial dynamics at different levels & will generally have two coupled components: one for macro-level, long range and large scale processes and a second one for processes operating on the micro-level, short range and micro-scale. Sub-models will in general operate at one level, but may exchange information with sub-models at the other level. | Not applicable | 3 |

| **Model name** | **Ecosystem Service Provision** | | | | **Economic Value of Output** | **Scale of Output** | **Earlier application in assessments** | **Score** |
|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Regulating services** | **Supporting services** | **Cultural services** | | | | |
| Reefs at Risk | Coral reef fisheries; Raw materials fro medicines; Other raw materials (seaweed and algae for agar, manure etc.); Curio and jewellry; Live fish and coral collected for aquarium trade. | Nitrogen fixation; CO2/Ca budget control; Waste assimilation. | Mantainence of habitats; maintenance of biodiversity and genetic library; biological maintenance of resilience; mobile links between ecosystems; export of organic production between ecosystems; protection of adjacent shorelines - in doing so supporting wetlands, seagrass beds, mangrove fisheries, population centres etc.; generation of coral sand; build up of land. | Recreational Value; ecotourism; sustaining livelihoods of local communities; aesthetic value; support of cultural, religious and spiritual values. | Negatively impact economic benefits of coral reefs (fisheries, medicinal products, curio/jewellry, aquarium trade); Increase vulnerability of coastal communities and habitats to natural hazards; Reduce food availability impacted on human health; Negatively impact livelihood associated with coral reefs; negatively impact spiritual, cultural, and aesthetic values associated with coral reefs. | Global coral reefs; 4km resolution | Not applicable | 1 |

| **Model name** | **Ecosystem Service Provision** | | | | **Economic Value of Output** | **Scale of Output** | **Earlier application in assessments** | **Score** |
|---|---|---|---|---|---|---|---|---|
| | **Provisioning services** | **Regulating services** | **Supporting services** | **Cultural services** | | | | |
| ERSEM II | Fisheries (understanding environmental drivers and bottom-up processes impacting fish populations; impacts of fisheries). | Ecological fluxes; nutrient limitations. | Lower trophic level habitat modelling for pelagic and benthic systems; | Not applicable | Bottom-up control of fisheries; Marine bacteria and virus dynamics; Influence of weather and climate on marine ecosystem services (e.g. Food security). | Dependent on resolution of the model that it is coupled to. ERSEM's upper boxes extend from the surface to 30 m, the lower boxes from 30 m to the bottom. coupled to high resolution hydrodynamic models, large geographical scales. Basin scale and open ocean applications in 1, 2 and 3 dimensions | Not applicable | 3 |

| Model name | Ecosystem Service Provision | | | | Economic Value of Output | Scale of Output | Earlier application in assessments | Score |
|---|---|---|---|---|---|---|---|---|
| | Provisioning services | Regulating services | Supporting services | Cultural services | | | | |
| ICTHYOP | Larval recruitment to fisheries | Ecosystem connectivity (inc. genetic and nutrient flows), larval dispersal and recruitment | Bottom-up support of food webs. | Not applicable | Understanding sustainability of fisheries; general understanding of the sustaiability and connectivity of ecosystem services. | The environmental state variables are provided on a discrete three-dimensional grid by archived simulations of the ROMS or MARS oceanic models. The Icthyop model sees the Eulerian velocity field at the same spatial scale as the Eulerian primitive equation models. Subgridscale parameterisations can be added in the IBM to address scales unresolved by the primitive equation models. The fields of salinity, current velocities, and temperature are interpolated in space to provide values at any individual location in Icthyop. | Not applicable | 2 |

# 4 APPENDICES TO CHAPTER 5: WORKSHOP

## 4.1 Workshop Programe

| | |
|---|---|
| **Wednesday, 13 May 2009 – Where we are and where we want to go** | |
| 10:00 | **Opening and Introduction: What this study aims to do?**<br>*Robin Miège*, DG Environment |
| 10:15 | **The role of the scenarios and models project in the TEEB context**<br>*Patrick ten Brink, IEEP* |
| **Session 1: Review of available models and scenarios: "State of the Art"**<br>Chair: *Leon Braat, Alterra* | |
| 10:30 | **Key findings of the project**<br>*Tom Kram, PBL* |
| 10:45 | **Discussion** |
| 11:45 | **Coffee Break** |
| **Session 2: Assessment of key assumptions in the available quantitative tools**<br>*Chair: Matt Walpole, UNEP-WCMC* | |
| 12: 00 | **Key findings of the project**,<br>*Leon Braat, Alterra* |
| 12: 15 | **Discussion** |
| 13:15 | **Lunch Break** |
| **Session 3: Policy recommendations: How to use the quantitative tools for policy development within TEEB**<br>*Chair: Patrick ten Brink, IEEP* | |
| 14:00 | **Short presentations (10 minutes) on recommendations for TEEB by five key-experts** |
| 14:50 | **Discussion** |
| 15:50 | Closing of the conference<br>*Alexandra Vakrou, DG Environment* |
| 16:00 | **End of the Workshop** |

## 4.2 Attendance List

| Name | First Name | Organisation |
|---|---|---|
| Alkemade | Rob | Wageningen University and Research Centre |
| Andre | Viviane | European Commission |
| Bidoglio | Giovanni | European Commission, Joint Research Centre |
| Braat | Leon | Alterra |
| Braeuer | Ingo | Ecologic Institute, Berlin |
| Christensen | Villy | University of British Columbia |
| Eppink | Florian | Helmholtz Zentrum für Umweltforschung (UFZ) |
| Gerdes | Holger | Ecologic Institute, Berlin |
| Heuermann | Nicol | Netherlands Environmental Assessment Agency (PBL) |
| Kram | Tom | Netherlands Environmental Assessment Agency (PBL) |
| McConville | Andrew | Institute for European Environmental Policy (IEEP) |
| Miège | Robin | European Commission |
| Neuville | Aude | European Commission |
| Pereira | Henrique Miguel | Universidade de Lisboa |
| Pirc-Velkavrh | Anita | European Environment Agency (EEA) |
| Poggi | Patrizia | European Commission |
| Richard | Dominique | European Topic Centre on Nature Protection and Biodiversity |
| Romanowicz | Agnieszka | European Commission |
| Rosenstock | Manfred | European Commission |
| Saether | Bent Arne | Ministry of the Environment, Norway |
| Scharlemann | Jorn | United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) |
| Spangenberg | Joachim | Sustainable Europe Research Institute (SERI) |
| Tallis | Heather | Stanford University |
| ten Brink | Patrick | Institute for European Environmental Policy (IEEP) |
| Torta | Giuliana | European Commission |
| Tucker | Graham | Institute for European Environmental Policy (IEEP) |
| Vakrou | Alexandra | European Commission |
| van Vuuren | Detlef | Netherlands Environmental Assessment Agency (PBL) |
| Walpole | Matt | United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) |