Scenarios and models for exploring future trends of biodiversity and ecosystem services changes

TASK 3

ASSESSMENT OF IMPACTS OF KEY ASSUMPTIONS

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AIMS of TASK 3

1. ***how changes in key assumptions affect the results of different models*** *with a* ***focus on either the impact on ecosystem services or on the economy more generally****".*

2. *evaluate* ***large-scale assessments*** *of the impacts of the loss of* ***biodiversity*** *and* ***ecosystem services worldwide****,*

3. ***how such models could be adapted to better assess policies***

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FEASIBILITY

Re 1: Assessment of key assumptions

It was recognised from the very beginning that it will not be possible to carry out an analysis of the sensitivity of models to policy impacts and other parameters *by running models and comparing results* (within the contract)

However, it was expected to be *possible to identify potential weaknesses and key assumptions* by an examination of the *descriptions of model structure and applications of models* in scenario-driven assessments.

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STEP 1: Selection Criteria

1. Suitability for TEEB scenario-studies:

- **Quantity and Quality of TERRESTRIAL and MARINE ecosystems services**
- **Economic value as output parameters or the possibility to link EG&S (directly) to economic parameters**
- **Global but regionalised output**

2. Earlier application within assessments

- The applications may be global, sectoral or regional

3. Availability to assessments within TEEB

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Integrated (TERRESTRIAL) assessment models

name	Ecosystem Service Provision				Biodiversity	Economic Value of Output	Scale of Output	Earlier applications in assessments
	Provisioning services	Supporting services	Cultural services	Regulating services				
IMAGE	Agricultural production, (grass/fodder and livestock/ milk, demand wood products, timber, fuelwood	Soil fertility	Not available	Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution, soil moisture	MSA through link with GLOBIO	Not available	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
GUMBO	Harvested organic matter, water supply, mined ores, and extracted fossil fuel	Soil formation (decomposition), nutrient (N) cycling	recreation, cultural	gas regulation (C flux), climate (temperature), waste assimilation, disturbance regulation (variation in total biomass)	Not available	valuation: marginal product of ecosystem services in production and welfare functions	global, 11 biomes globally aggregated, not spatially explicit	Not available
MIMES	Food production, production of raw materials	Soil formation, nutrient cycling	recreation, cultural	climate regulation, waste assimilation , disturbance regulation	Not available	valuation: marginal product of ecosystem services in both the model's production and welfare functions	global, 1º by 1° resolution	Not available
AIM	Water supply, food and timber production	Not available	Not available	greenhouse gas emissions, air pollution, carbon sequestration, human health (malaria distribution), flood damage	Vegetation distribution	Not available	Focused on Asian-Pacific region, but linked to a global model representing 9 regions; 5° x 5°	SRES

(Integrated) MARINE assessment models

Model name	Ecosystem Service Provision				biodiversity	Economic Value of Output	Scale of Output	Earlier application in assessments
	Provisioning services	Regulating services	Cultural services	Supporting services				
EwE, EcoSpace & EcoVal	Fisheries (inc. their ecosystem effects).	Biomass and fluxes	Economic valuation of resources (Ecoval).	Population dynamics (Top-down vs. Bottom-up controls)	?	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.
Cumulative Threat Model global ocean	Impacts on fisheries/aquaculture; abiility of ecosystems to provide non-living resources.	Impact ability of ecosystem to provide regulating services generally.	Impacts on recreation, aesthetic values and experience, spiritual enrichment etc.	Reduction in nutrient cycling ability (e.g. through dead zones/pollution); Impacts on habitats and their services.	?	benefits of highly impacted areas vs less impacted areas.Reduced goods and services vs negative impact on human health.	Global but can be applied at the local- and regional-scale; 1km^2 resolution grid.	Not applicable
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.	Recreational Value; ecotourism; sustaining livelihoods of local communities; aesthetic value; support of cultural, religious and spiritual values.	Mantainence of habitats, of biodiversity and genetic library;and of resilience; mobile links and export of organic production between ecosystems; protection of adjacent shorelines; generation of coral sand; build up of land.	?	Negatively impact economic benefits; Increase vulnerability of coastal habitats to natural hazards; Reduce food availability impacted on human health	Global coral reefs; 4km resolution	Not applicable

STEP 2: EVALUATION of MODEL QUALITY

Based on TASK 1 Database and Model Documentation

1. General quality

Calibration / validation
peer reviewed
sensitivity / uncertainty

2. Assumptions

Drivers,
model structural relationships,
model dynamics,
representativeness of indicators

3. Transparency

documentation of models (incl. assumptions)

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1. Quality & 3. transparency

Model name	**IMAGE**
Analytical technique	dynamic systems model
Calibration	IMAGE is calibrated against historical data from 1765-2000 (carbon and climate), 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 (Climatic Change 16, 331-356) 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

Model name	**AIM**
Analytical technique	Dynamic systems model
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)

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1. Quality & 3. transparency

Model name	**GUMBO**	
Analytical technique	dynamic systems model, meta-model (GUMBO relationships are base don outputs of more complex and computational intense models)	
Calibration	Historical calibration 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 (Ecol Econ 41, 529-560); Werners et al., 2004, Costanza et al. 2006	
Model name	**MIMES**	
Analytical technique	meta-model, dynamic system model	
Calibration	**Not available**	
Validation	**Not available**	
Uncertainty analysis	**Not available**	
Key reference	http://www.uvm.edu/giee/publications/Boumans_Costanza_GWSP%20Chapter_2007.pdf	

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EwE, Ecoval, Ecospace 1. Quality & 3. transparency

Calibration	Validation	Peer-review of model	Peer review results	Sensitivity	Robustness of Results
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 external validation is acheived.	Models are fitted to time series reference 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 (see comment).	The modelling approach is thoroughly documented in peer-reviewed scientific literature. Key papers include: Ecopath - 1992, Ecological modelling 61: 169-185; Ecosim - 1997, Fish Biol. Fisheries 7: 139-172; Ecosim II - 2000, Ecosystems 3: 70-83; Ecospace - 1999, Ecosystems, 2: 539-554; EwE overview - 2000, ICES J. Of Marine Science; EwE - 2000, 'EwE: A User's Guide'; among others.	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.	EwE can produce misleading predictions about even the direction of impacts of policy proposals. However, erroneous predictions ususally result from bad estimates or errors of ommission for a few key parameters, rather than 'diffuse' effects of uncertainties in all input information.	When EwE is used for policy comparisons, incorrect comparisons (EwE leading the user to favor a wrong policy option) are due to **errors in the specific input data** to which a particular policy comparison is sensitive. Therefore, EwE can give correct answers for some policy comparisons but some wildly incorrect ones for others based upon the inputs used.

2. Assumptions

1. **Independent reviews of the models are not available**

2. **estimated impact of changes in driver-assumptions (scenarios) by applications of the models in a variety of circumstances only available now for IMAGE+, AIM and EwE, but not feasible within the timeframe**

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STEP 3: ADAPTABILITY

ARE THE INTEGRATED ASSESSMENT MODELS ADAPTABLE ?

➔ *MOST OF THEM ARE MODULAR SO ADDITION OF NEW MODULES APPEARS TO BE NO PROBLEM*

ARE THERE MODELS WHICH FILL “HOLES” IN THE SELECTED INTEGRATED ASSESSMENT MODELS ?

➔ *YES, SEE NEXT TABLES*

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Model name	Ecosystem Service Provision				biodiversity	Economic Value of Output	Scale of Output	Earlier application
Biogeochemical								
IBIS	water runoff	NPP, SOC, N balance	Not available	carbon balance, water regulation	Vegetation composition (functional types)	Not available	0.5 - 4°	Not available
LPJmL	runoff volumes, crop production	annual NPP	Not available	CO2 exchange, water balance	vegetation cover (fraction of different plant functional types per grid cell); Vegetation composition	Not available	global, 0.5° grid cells	Not available
SAVANA	livestock production, grass/timber production, water supply (runoff, deep drainage)	NPP, nutrient cycling	Not available	water balance	Species distribution and abundance community composition	Not available	regional, resolution depending on input data and studied ecosystem	Not available
Hydrological								
Water GAP	water supply	Not available	Not available	Not available	Not available	Not available	global, country, river basin, grid cells 0.5 by 0.5	OECD, GEO, MA, with IMAGE, IMPACT, EcoSim and AIM

Integrated REGIONAL assessment models

Model name	Ecosystem Service Provision				Biodiversity	Economic Value of Output	Scale of Output	Earlier applications in assessments
	Provisioning services	Supporting services	Cultural services	Regulating services				
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	Not available	Europe 15 + Norway and Switzerland, 10' by 10' grid	Not available
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 requirements of 37 terrestrial vertebrate species, dispersal ability)	Not available	regional, resolution flexible; case study: USA (30 m x 30 m grid, for results: 500 ha units)	Not available
CLUE	None (but land used for agriculture, grazing, forestry)	Not available	Not available	Not available	Land cover diversity explicit	Not available	Europe (EU-27), also case studies between 30m and 32km	EURURALIS (at Alterra. Wageningen)

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BIODIVERSITY models

Model name	Ecosystem Service Provision				Biodiversity	Economic Value of Output	Scale of Output	Earlier applications in assessments
	Provisioning services	Supporting services	Cultural services	Regulating services				
GLOBIO	FROM link with IMAGE: Agricultural production, demand for wood products, timber, fuelwood	FROM link with IMAGE: Soil fertility	Not available	FROM link with IMAGE: Carbon flux, carbon plantations, ocean carbon model, water-erosion sensitivity, air pollution, soil moisture	mean species abundance (MSA)	Not available	global, (0.5° by 0.5° for climatic data, 1km by 1km for land use data)	OECD, GBO
BII	Not available	Not available	Not available	Not available	biodiversity intactness index	Not available	global, scale of aggregation : 104 to 106 km2	Not available
SAR	Not available	Not available	Not available	Not available	number of species; Vegetation composition/ species distribution	Not available	global, for different biogeographical units (biomes, ecoregions), not spatially explicit	MA

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CONCLUSIONS (1)

1. **A limited number of models and scenarios** have so far been (and can again) be used for large-scale / global assessments and policy impact assessments; **no single model comprehensively assesses all aspects** of biodiversity and ecosystem services and links to the economy (ToR)

2. modeling paradigms / approaches are (still) quite different in the terrestrial and marine domains. Interfaces (coastal zone) are crucial in a total global assessment

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CONCLUSIONS (2)

3. There is ***no competitor available (yet)*** at the global scale for **GLOBIO-MSA** for biodiversity assessment. Biodiversity measures of relevance to the TEEB / CBD processes need to be added

4. There is ***no competitor available (yet)*** for the **EwE model group** of UBC for global marine ecosystem modelling. Biodiversity measures of relevance to the TEEB / CBD processes need to be added.

5. The models of the GUMBO – MIMES family are promising in that they feature ecosystem services across the whole spectrum and they have internal feedbacks of changes in ess to social and economic indicators of wealth. Need explicit testing in scenario-assessments

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Immediate needs, but future work

-indicators/measures of ecosystem services (being developed, WRI)

- collection and collation of real data on biodiversity to validate and ground truth model outputs

- need comparative analysis of models and of application in scenario-assessments *(similar to what climate-modellers are already doing in IPCC reports)*

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Methodological questions

•how to define ‘undisturbed’ (see discussion on baseline below)
•how to deal with biological, ecological and environmental differences in the 'dose-response curves' for different species (Note: MSA does not use species specific dose response models)
•why exclude cases where the populations do well in disturbed habitats (the ratio>1)(In MSA these are not excluded, but truncated at 1, otherwise increasing and decreasing species will compensate and nothing will be detected).
•how to add up or average different studies – dealing with both biological variance and error variance, as well as with the fact that non-linear responses may be both common and significant.
•How can the MSA be verified independently ? Is it possible to obtain access to the underlying data (apparently derived from published studies) ? (Data are available, but it takes work to make them accessible)

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MSA as a measure of biodiversity (statements of limitations)

- MSA does not seem to measure diversity at all.
- The same MSA value can result from very different situations.
- It cannot distinguish different levels of species richness – either before or after ‘disturbance’.
- It cannot deal with changing species composition (extinction, invasion etc.).
- It does not differentiate between different levels of biomass.
- It seems to be largely a measure of driver intensity

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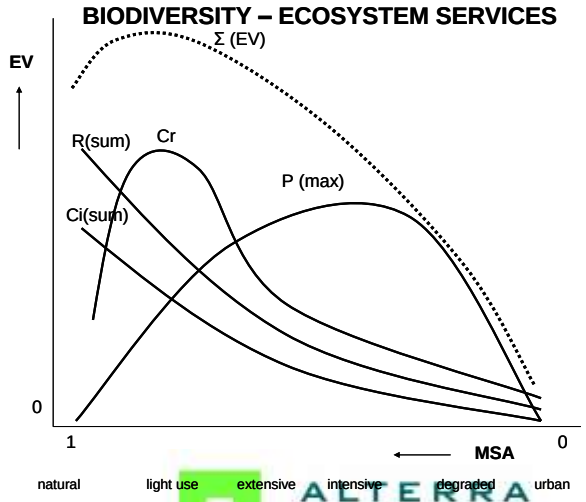
MSA and ecosystem functions and services

•MSA is not designed to indicate ecosystem services. A relationship between MSA and EGS might exist

•Most reviews of biodiversity to ecosystem function relationships conclude that either composition (i.e. exactly what species or types of species are there) or functional diversity (i.e. the range of species traits present) will be important, and for many ecosystem services, the total biomass may be critical.



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BIODIVERSITY

Pressure index
indirect
sensitive
models
cheap

Hot spots
static
indirect
cheap

Natural area
direct
measurable
models
no quality

Wilderness areas
indirect
sensitive
models
cheap
only a part

Red list
direct
difficult measurable
no models
unsensitive
too late

Species richness
static
unsensitive
wrong message
unmeasurable
no models
expensive

Living Planet Index
species trend index
direct
sensitive, measurable
models,cheap

Natural Capital Index
direct
sensitive, measurable
models, cheap

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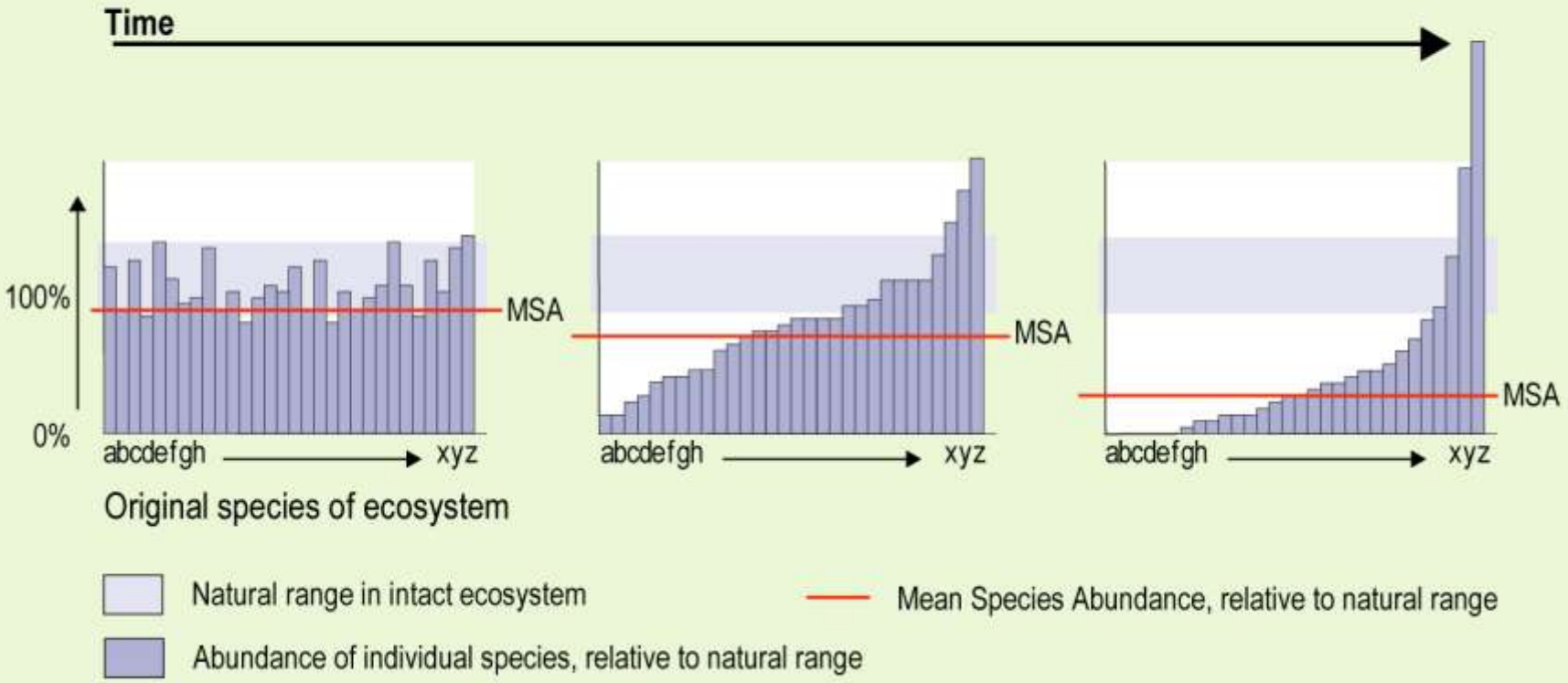
Process of biodiversity homogenization expressed by the MSA indicator



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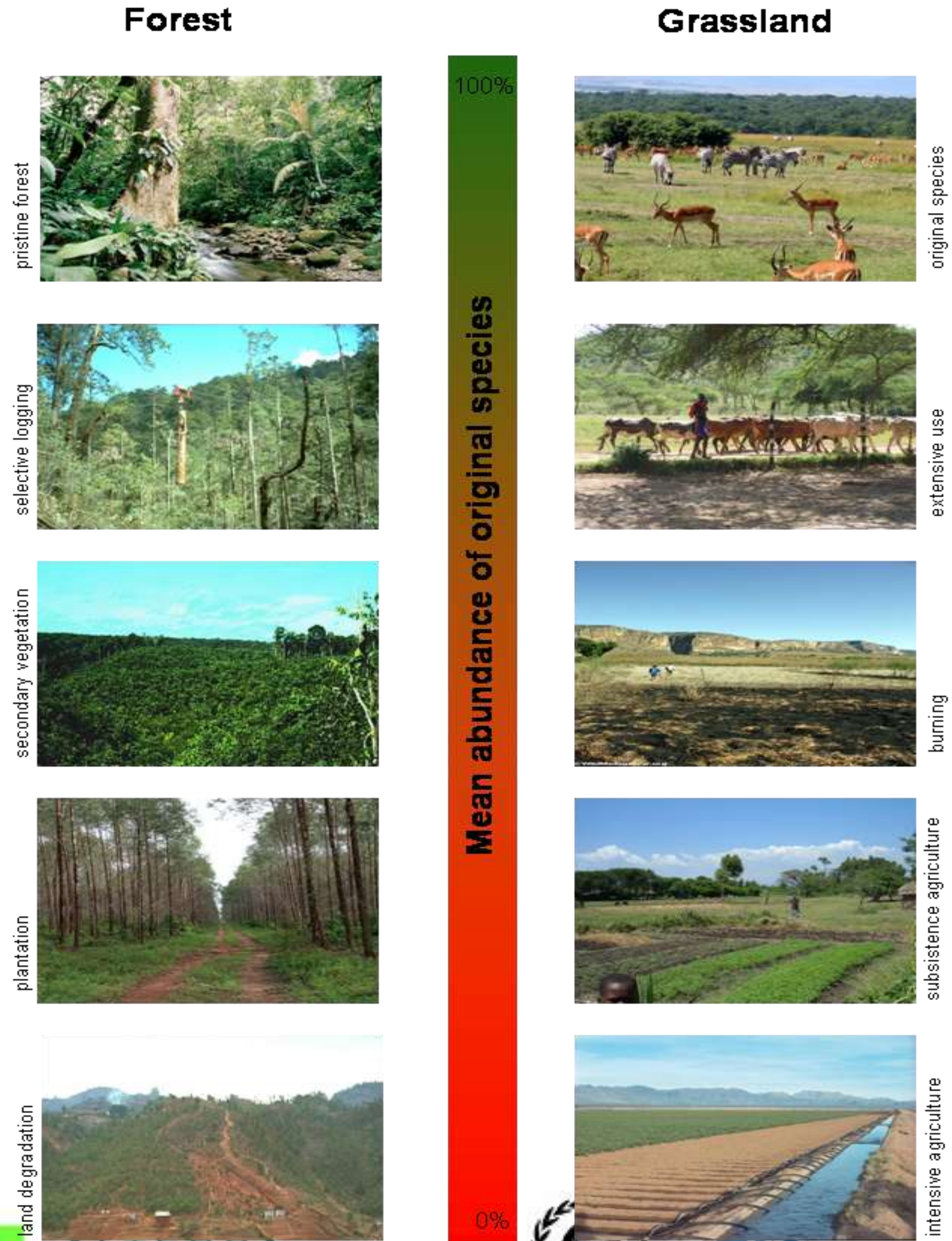

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