Terrestrial modelling with GLOBI03

An introduction

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Content

- State of biodiversity; policy awareness
- Concept GLOBI03 model, MSA & pressures
- Calculation biodiversity with GLOBI03
- Integration with other models
Understand the link between ecosystems and development

People impact ecosystems

Ecosystems provide people benefits
Millennium Ecosystem Assessment (2005): drivers of change and ecosystem services
So why aren’t we halting biodiversity loss?

We did not meet the 2010 CBD target, in spite of several new environmental laws. There are several reasons for this:

- Land use conversion because of population increase, economic growth and changing consumption patterns
- Trade offs from economic development at the cost of environment and biodiversity
- Short term benefits prevail over long term benefits
- Poor governance leading to weak law enforcement
Why using a model for biodiversity assessment?

- When existing monitoring information about the past-present trends of biodiversity at country/region level are not available

- When monitoring is expensive and a cheap and quick assessment is needed based on existing data

- When individual or combined impact of the main pressures on biodiversity need to be assessed: Lack of understanding relation between biodiversity loss and driving factors

- When estimations of future biodiversity-loss trends are required

- When impact of policies (will) for biodiversity conservation in the future must be estimated/compared
The GLOBIO3 biodiversity model

The model uses the MSA indicator:

**Mean Species Abundance** of the species, relative to their abundance in primary vegetation:

Indicates the ‘naturalness’ or ‘intactness’ of an area or ecosystem

Combines ecosystem quality (**species abundance**) and quantity (**extent**)  

Model uses cause effect relations based on measured effects of pressures:

- Comparison between undisturbed and disturbed ecosystems
- Relative decrease of species abundance and richness at local level
Environmental pressures included in GLOBI3

1. Land-use change (agriculture expansion, forestry) (management; e.g. harvest system, rotation, etc.)
2. Infrastructure & settlement
3. Fragmentation
4. Climate change
5. N-deposition

Cause – effect relations for each pressure based on literature research in terms of quantity and quality
Methodology for cause-effect relationships

For each driver a meta analysis:
- Scan literature (Web of Science etc.)
- Select studies: comparison undisturbed - disturbed
- Extract data
- Calculate MSA values per pressure in each study

Combine all studies (in total about 250 datasets)
Calculate overall MSA values (Mixed effect model: GLMM)
Concept calculation of ‘naturalness’ of biota
~ Relative Biodiversity: ‘MSA’

[Abundance = nr. of individuals per species]

<table>
<thead>
<tr>
<th>Species no.</th>
<th>Abundance in Pristine state</th>
<th>Abundance in Disturbed state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec. 1</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Spec. 2</td>
<td>60</td>
<td>12</td>
</tr>
<tr>
<td>Spec. 3</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Spec. 4</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Spec. 5</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

Species 1: 80/100 = 0.8  
Species 2: 12/60 = 0.2  
Species 3: 0/27 = 0.0  
Species 4: 1.0 (maximum)  
Species 5: -- (not original)

Σ (ratio)/ # of native species  
= Relative Biodiversity = 0.5
MSA in pictures

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Recent baseline: fair comparison?

Biodiversity

Netherlands

Baseline: 2000

Brazil

0

100

2000

2050

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Historic baseline: fair comparison?

Biodiversity

Baseline: natural state

Brazil

Netherlands

100

1900 1950 2000 2050
GLOBIO3 Terrestrial: structure

![Diagram of GLOBIO3 Terrestrial structure]

- Ecosystem map
- Land use
- Road map
- Nitrogen deposition
- N-Critical loads

Input: Temp

Processes:
- Globio Climate
- Globio Land use classes
- Globio Patch size
- Globio Impact zones
- Globio Nitrogen exceedance

Cause-effect relationships:
- MSA Climate
- MSA Land use
- MSA Patch size
- MSA Infrastructure
- MSA Nitrogen

Output: MSA combined
Actual calculation of overall terrestrial MSA (per pixel)

\[ \text{MSA} = \text{MSA}_{\text{LUC}} \times \text{MSA}_{\text{CC}} \times \text{MSA}_N \times \text{MSA}_I \times \text{MSA}_F \]

\[ \text{MSA} = \text{Mean abundance of original species relative to pristine} \]

- \( \text{MSA}_{\text{LUC}} \) = Remaining MSA for land use change
- \( \text{MSA}_{\text{CC}} \) = Remaining MSA for climate change
- \( \text{MSA}_N \) = Remaining MSA for Nitrogen pollution
- \( \text{MSA}_I \) = Remaining MSA for Infrastructure
- \( \text{MSA}_F \) = Remaining MSA for Fragmentation

- Spatial aggregation:

\[ \sum_i M S_i A_i \]

\[ \sum A_i \]
Illustration MSA calculation: Biodiversity loss by land use

Country X

- Low impact logging forest
- Agricultural crops
- Forest plantation
- Pristine forest

Pressures on nature:
Land-cover / land use
- Forest
- Grassland
- Agriculture
MSA calculation: Biodiversity loss by Land Use

Country X

150 ha

450 ha

100 ha

50 ha

250 ha

Land-use intensities
- Unaltered forest
- Low impact logging
- Plantation forest
- Intensive grazing
- Intensive agriculture

The higher the land use intensity the lower the \( MSA_{LU} \) value

\( MSA_{LU} \)
MSA calculation: Biodiversity loss by Land Use

Light use: 0.7

Intensive agriculture: 0.1

Pristine forest: 1.0

150 ha

100 ha

450 ha

50 ha

250 ha

MSA_{LU} = (0.7 \times 150 + 0.2 \times 100 + 0.1 \times 450 + 0.1 \times 50 + 1.0 \times 250) / 1000 = 0.43

43% remaining biodiversity compared to original state

57% of biodiversity loss is caused by land use
MSA calculation: Biodiversity loss by Nitrogen deposition and Climate Change

Pressures on nature:
- N-deposition
- Climate change

MSA_N = (0.9*150 + 0.9*100 + 1*450 + 1*50 + 0.9*250) / 1000
= 0.95

MSA_CC = (0.8*150 + 0.8*100 + 1*450 + 0.9*50 + 0.8*250) / 1000
= 0.895
MSA calculation: Biodiversity loss by Infrastructure and Fragmentation

Infrastructure and Fragmentation pressure only impact on natural areas (impact on agricultural area already included in Lu_impact)

**MSA_I = (15*0.5+135*1) + (20*0.5+80*1) + 1*450 + 1*50 + 1*250) / 1000 = 0.9825**

**MSA_F = (0.8*150 +1*100 + 1*450 + 1*50 + 0.9*250) / 1000 = 0.945**

**Infrastructure and Fragmentation**

**Infrastructure:**
Influence area (buffer) \( \times \) impact factor

**Fragmentation:**
Factor patch size \( \times \) area
MSA calculation: Overall biodiversity

Total MSA

\[
\text{MSA}_{\text{tot}} = \sum (\text{MSA pressures}) = \text{MSA}_{\text{LUC}} \ast \text{MSA}_{\text{CC}} \ast \text{MSA}_{\text{N}} \ast \text{MSA}_{\text{I}} \ast \text{MSA}_{\text{F}}
\]

\[
0.43 \ast 0.95 \ast 0.895 \ast 0.9825 \ast 0.945
\]

\[
= 0.34
\]

\[\rightarrow 34\% \text{ of original biodiversity is left}\]

But also interesting to know e.g. remaining biodiversity in parks:

MSA_{primary \text{ forest}} =

\[
1 \ast 0.9 \ast 0.8 \ast 1 \ast 0.9 = 0.65
\]

\[\rightarrow 35\% \text{ biodiversity loss in parks}\]
Application of the GLOBIO3 model

- Global
  UNEP’s Global Biodiversity Outlook 2, UNEP Geographic Environmental Outlook 4, OECD, FAO’s Agricultural Assessment

- Regional
  Global deserts, The fall of the water (*Himalaya*), Environmental Performance Assessment in the Greater Mekong Sub-region, EU-Ruralis, Central America*

- National
  Colombia, Ecuador, Peru, Nicaragua, Guatemala, Honduras, El Salvador, Belize, Panama, Mexico, Nicaragua, Kenya, Mozambique, Zambia, Cambodia, Laos, Myanmar, Thailand, Vietnam

- Provincial
  Yunan (China), Quang Nam (Vietnam)
Scale: model resolution

- Model calculations carried out with raster map calculation in raster GIS software. Mathematical relations between pressures and biodiversity are processed with standard raster analysis tools. Model itself is shareware, independent of GIS package.

- The global application of Globio3 is calculated based on a grid cell size of 0.5 * 0.5 degrees (~ 50*50 km)

- Grid cell size national application of Globio3 is 1 * 1 km. Higher resolution not realistic because of lack of data on this scale (scenario and other input data)

- Model output quality dependent of used input data: Garbage in = Garbage out

Resolution of model should correspond with detail level input maps
Input from other models

The IMAGE 2.4 model:

Integrated Model for the Assessment of Global Environmental change

Globio3 uses output of IMAGE: Land use + scenario, Nitrogen and Climate output

National application of Globio3 uses only the Nitrogen and Climate data. Rest based on National data and Clue land use model.
Questions that can be resolved with IMAGE

- How can future food demand be satisfied?
- Where and how can irrigated area be expanded?
- What will be the relative contribution of intensification and expansion of agriculture?
- How much biomass can be produced under which sustainability criteria?
- Additional LU emission of bio-energy production (N2O, CO2 from land use change)
- How does climate change affect crop yields and thereby land use?
- How does land use change affect climate change?
Integration of GLOBIO with IMAGE model

Globcov map

Land use

Nitrogen deposition

Climate change

(rail-) roads

Land-use effect

Nitrogen effect

Climate effect

Fragmentation effect

Infrastructure effect

Biodiversity (MSA) of land ecosystems

GLOBIO

Land use and climate Model (IMAGE)
Input data for IMAGE

Baseline scenario
- Population
- Economic growth
- Technology
- Lifestyle

Options:
1. Closing yield gap
2. Post harvest loss
3. Diet change (meat)
4. Improved forestry
5. Reduced deforest
6. CCM, bio-fuels
7. Protected areas
8. Aqua-culture
9. Liberalisation trade

Indirect drivers
- Food demand
- Wood demand
- Energy demand
- Energy mix
- Trade

Pressures
- Agriculture
- Forestry / fisheries
- Infrastr / urbani
- Fragmentation
- Climate change
- Eutrophication

Economic valuation

Biodiversity
- natural area
- Wilderness
- MSA (quality*quantity)

EG&S
- inland water quality
- C-seq
- Climate change T
- Food / fish
- Timber
- Biofuel

Economic
- food consumption
- land price
Impact per pressure and combined

Baseline development - South and East Asia

mean species abundance (%)

Climate
Fragmentation
Infrastructure/settlement
Nitrogen
Forestry
Agriculture

2000
2050
Example of output on global scale: biodiversity loss

Biodiversity in 2000 (MSA)

Source: MNP/OECD 2008