



Statistisk sentralbyrå  
Statistics Norway



PBL Netherlands Environmental  
Assessment Agency

## Setting up a land use scenario and linking it with biodiversity

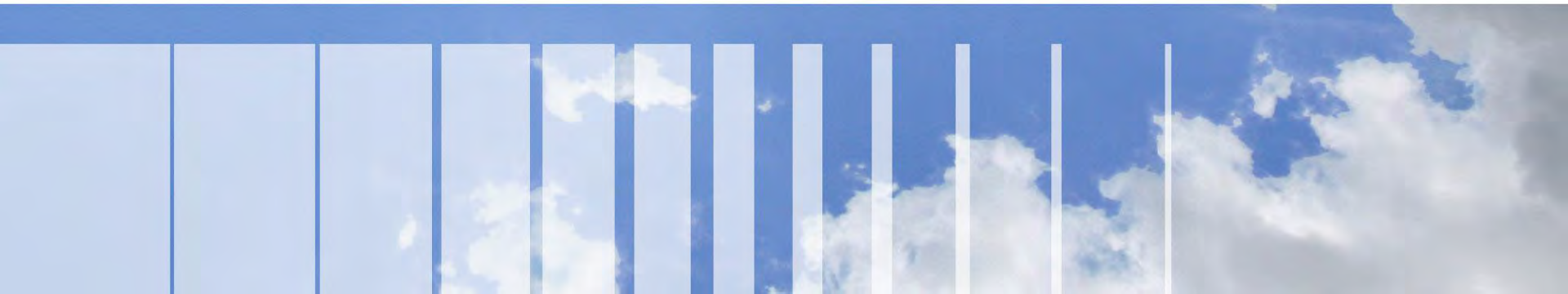
### Part I: Introduction to the GLOBIO and CLUE models

Scenario Planning Session  
The Arctic Biodiversity Congress:  
Trondheim, Norway, December 2-4, 2014

By Wilbert van Rooij

Plansup, The Netherlands

In collaboration with the Netherlands Environmental Assessment Agency and Statistics Norway



# Structure scenario planning session

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## Part I: Presentation 20 min

- ECONORIII project
- Intro to GLOBIO model
- Intro to CLUE model

## Part II: Presentation 20 min

- Intro to scenarios and land use scenario building

## Part III: Group exercise 35 min

- Land use scenario building exercise

## Part IV: Group exercise 15 min

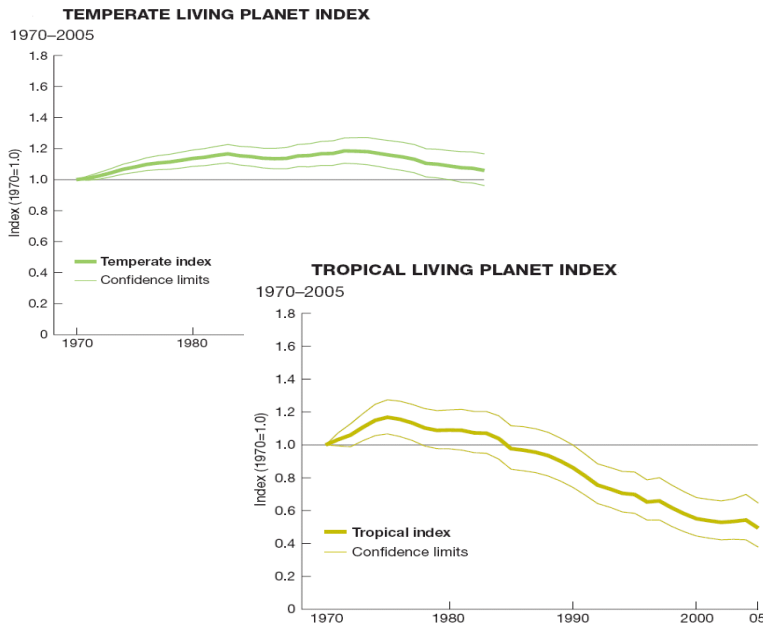
- Land use scenario training module

- Pilot biodiversity assessment study part of the ECONORIII project
- Focus on assessing the current anthropogenic impact factors on Arctic biodiversity
- Using the GLOBIO3 biodiversity model developed by the Netherlands Environmental Assessment Agency (PBL), downscaled for use at Arctic region level
- Pilot study is still in progress. Available data have been gathered and first analyses of this information has just started. Assessment of future biodiversity will be carried out for Norway with help of GLOBIO and CLUE land use model.
- A comparison of the model results will be made with those of the Norwegian Nature Index and (if possible) the Arctic Species Trend Index.

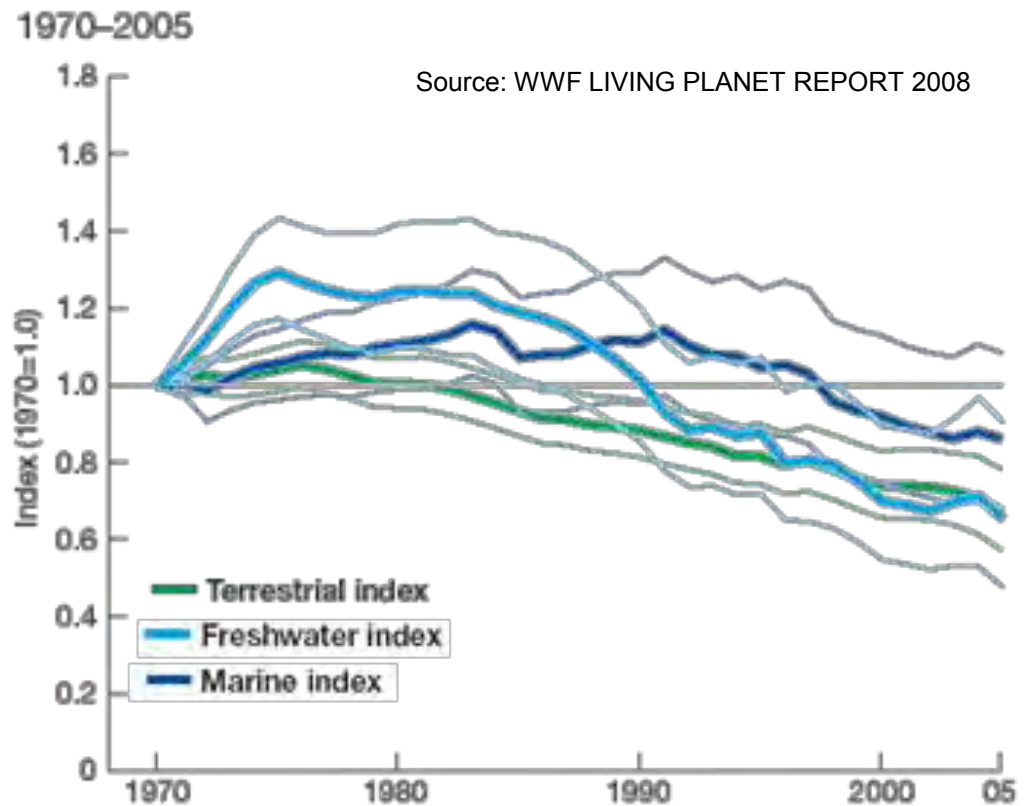
# Identification of key sustainability issues; Biodiversity loss

Populations of species are declining rapidly in all eco-systems, but not evenly distributed

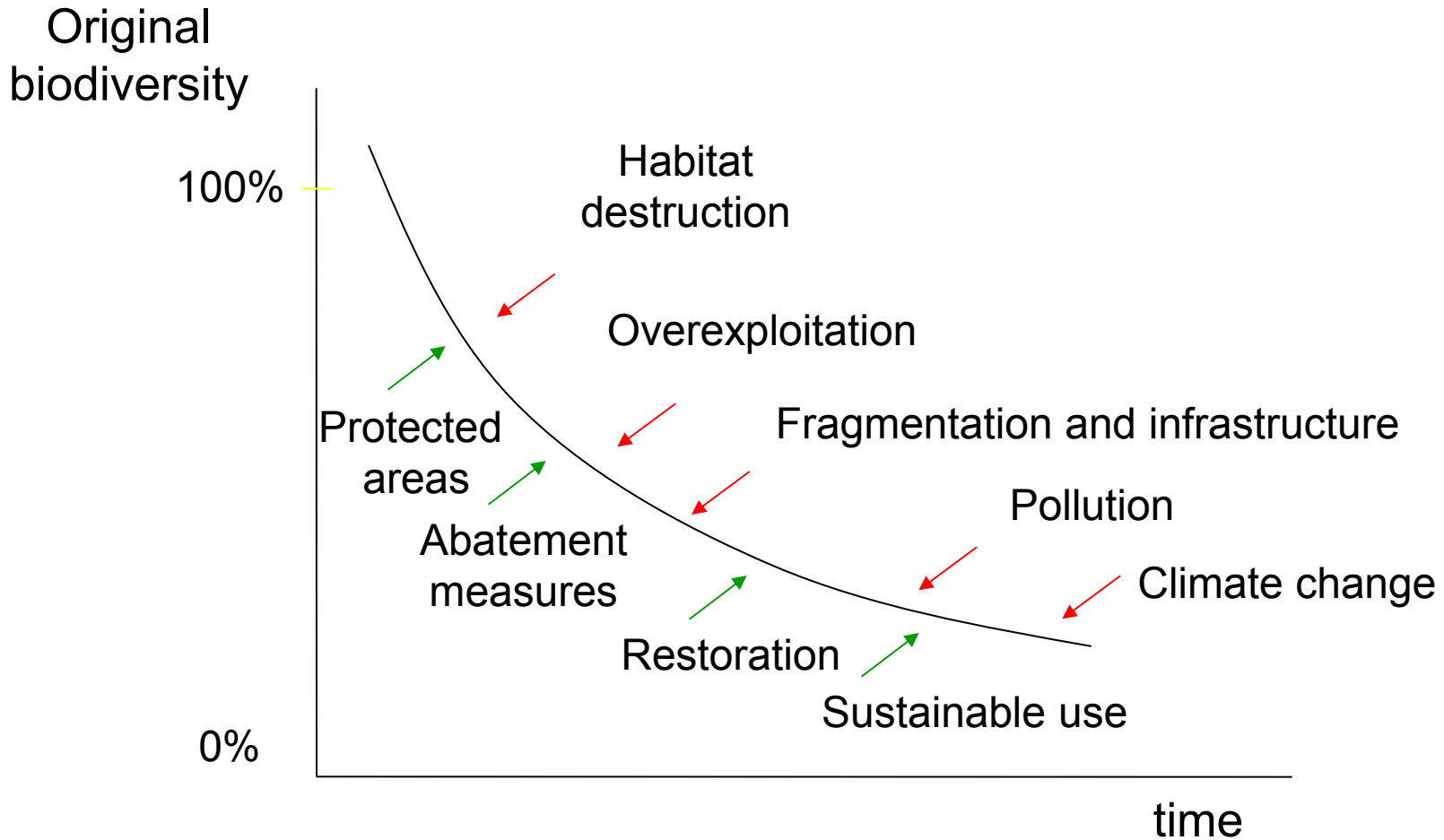
Decline of species and populations = Decline in Goods and Services



Arctic regions?



# Can we halt future biodiversity loss?



# So why aren't we halting biodiversity loss?

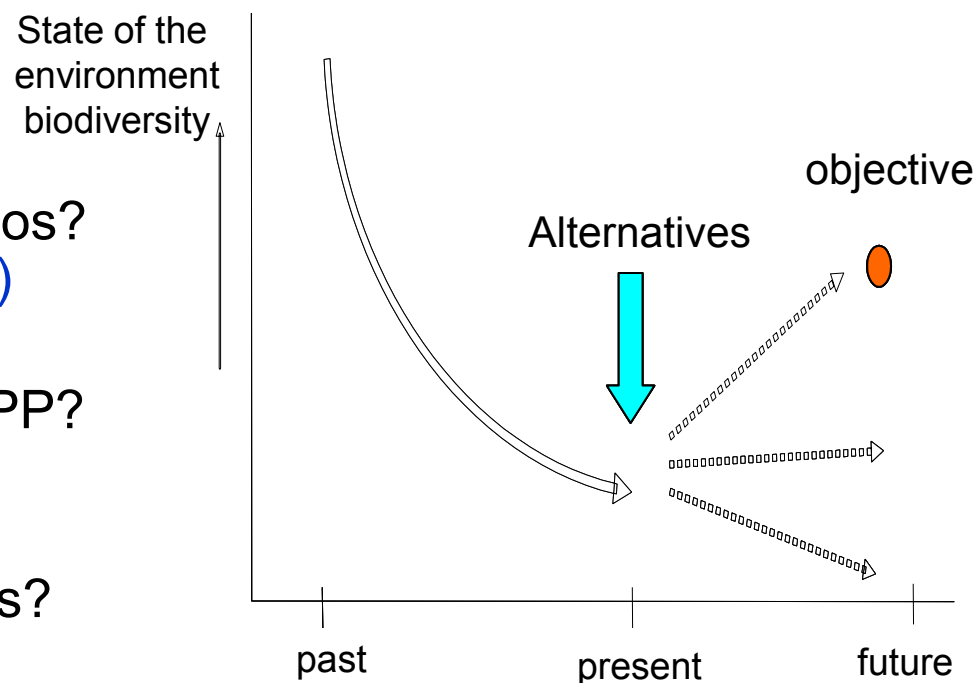
We do not meet the 2010 CBD target, in spite of several new environmental laws. There are several reasons for this:

- Natural lands used as source of land (population increase)
  - Economic development first priority, often at the cost of biodiversity
  - Short term benefits prevail over long term benefits
  - Poor governance leading to weak law enforcement
  - Climate change, especially in the Arctic
- Lack of understanding relation between biodiversity loss and driving factors. - → *biodiversity modelling can help here*

# What can a model do?

## Answering key questions:

- What is the present state?  
(→ [Iu/biodiversity status](#))
- What is the future state / scenarios?  
(→ [Iu/biodiversity status, trends](#))
- Causes of change + impacts of PP?  
(→ [pressures / impacts](#))
- Assess and compare alternatives?  
(→ [assess impacts of policies](#))



# What models are used?

## I 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 / ecosystem
- Combines ecosystem quality (*species abundance*) and quantity (*extent*)
- The MSA can be calculated to determine past, present or future state

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



x

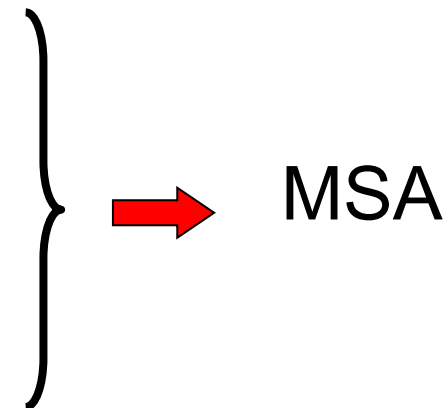


Quality

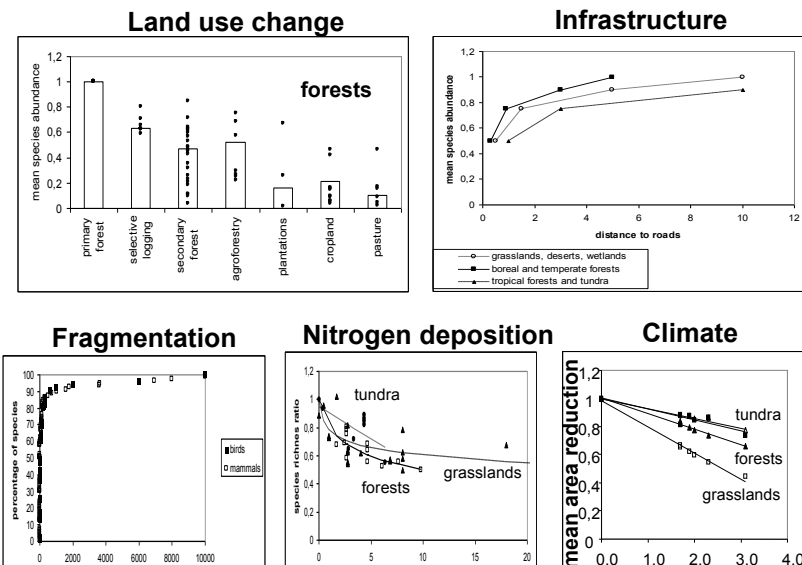
\* Quantity

# Environmental pressures included in GLOBIO3

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



*Cause – Effect relations for each pressure based on literature research in terms of quantity and quality*



# Species richness vs. naturalness

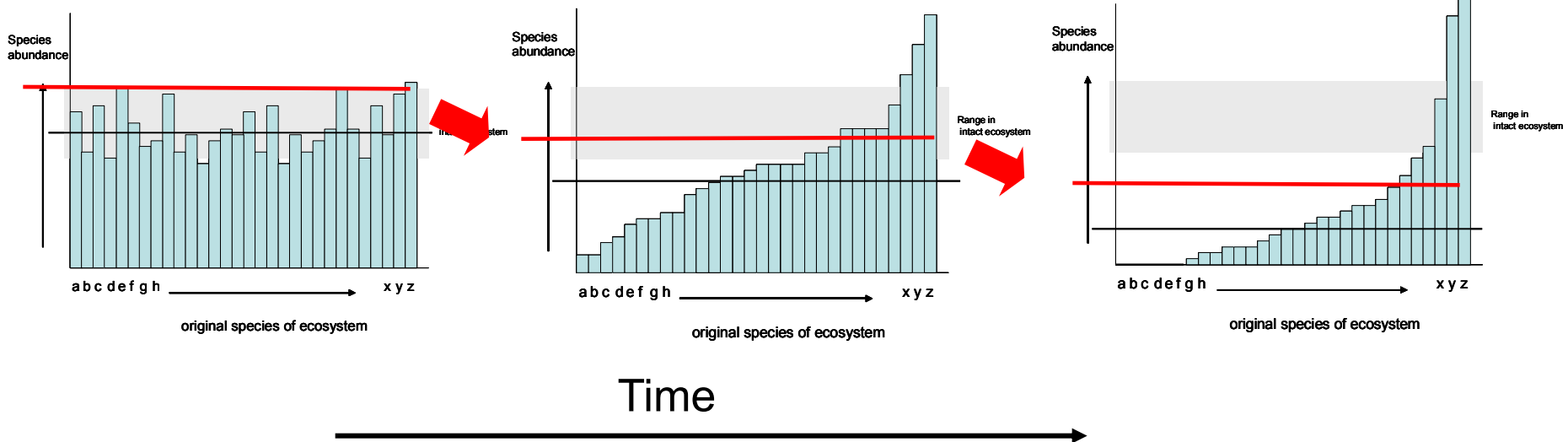


# MSA: Quantity \* Quality

1. Quantity  $\approx$  Total area of each ecosystem
2. Quality  $\approx$  Species Abundance

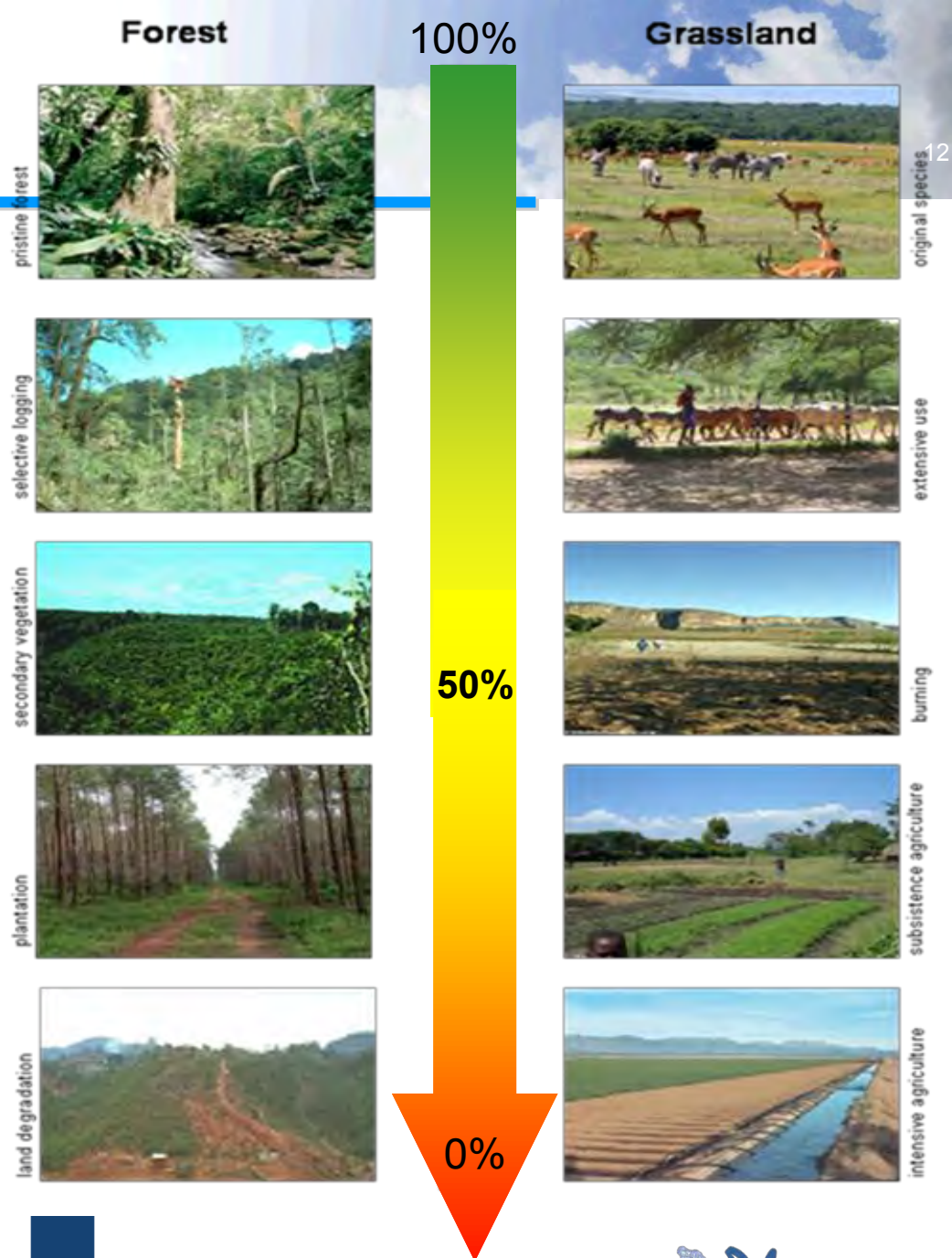
$$MSA^i = \frac{\sum MSA^i}{\sum A^i}$$

Current or future species abundance compared with original  
 Natural distribution of representative set of species  
 New or invasive species excluded



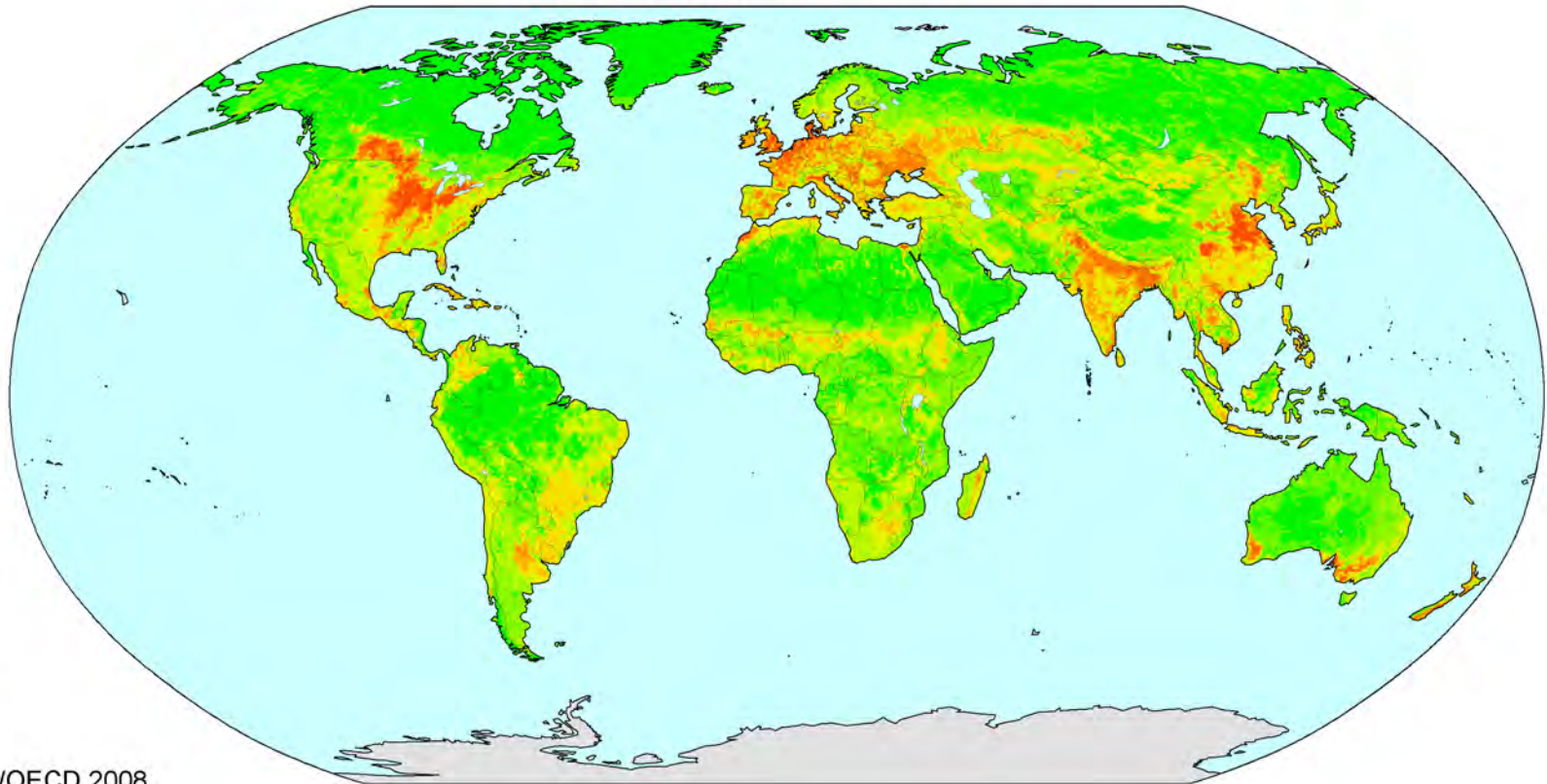
# MSA in pictures

- Mean abundance of original species relative to the pristine situation
- Degradation of original ecosystems leads to a decrease of the MSA
- To be used in addition to other indicators. Together they give a representative indication of actual biodiversity



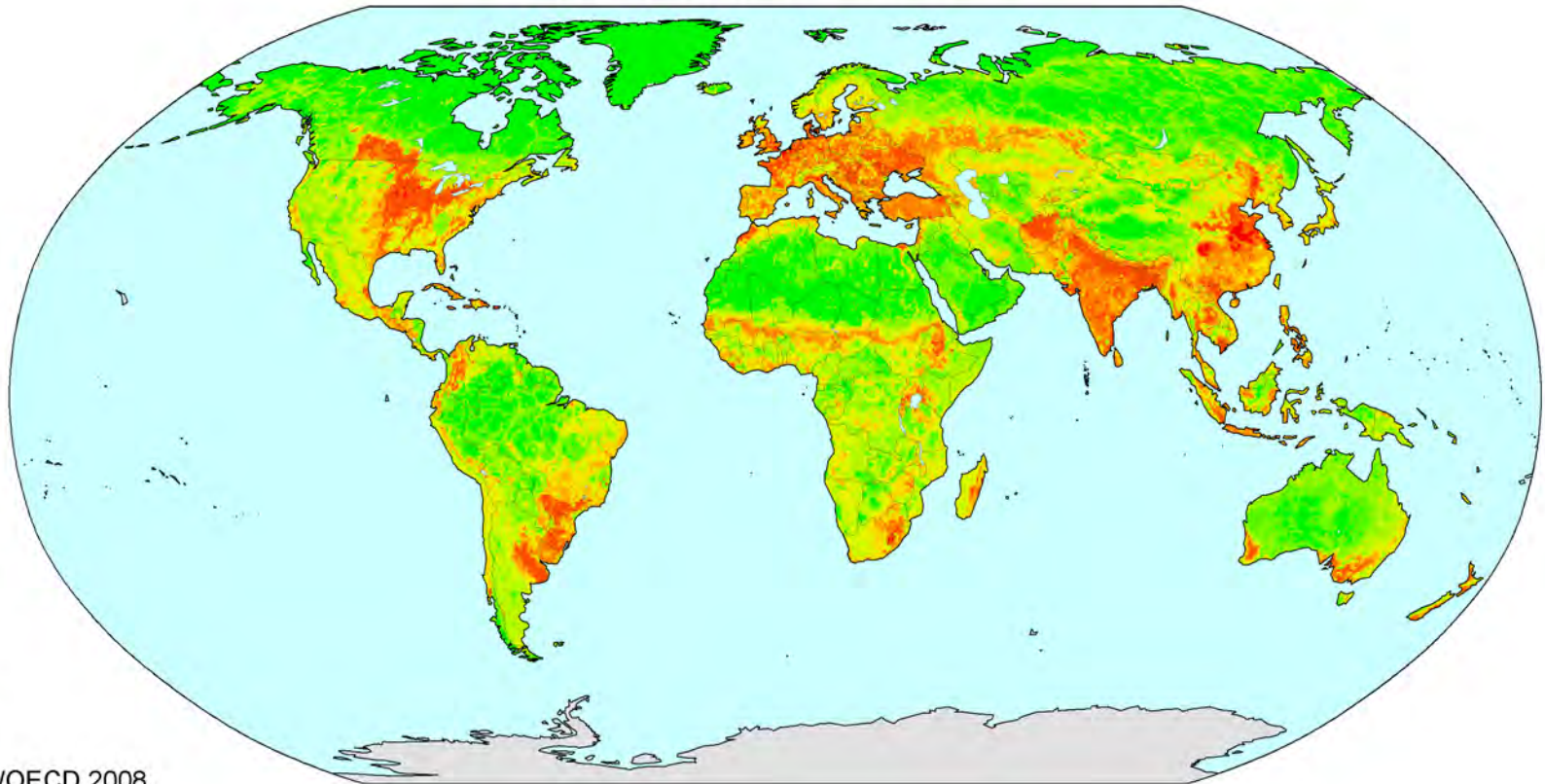
# Biodiversity loss

## Biodiversity in 2000 (MSA)

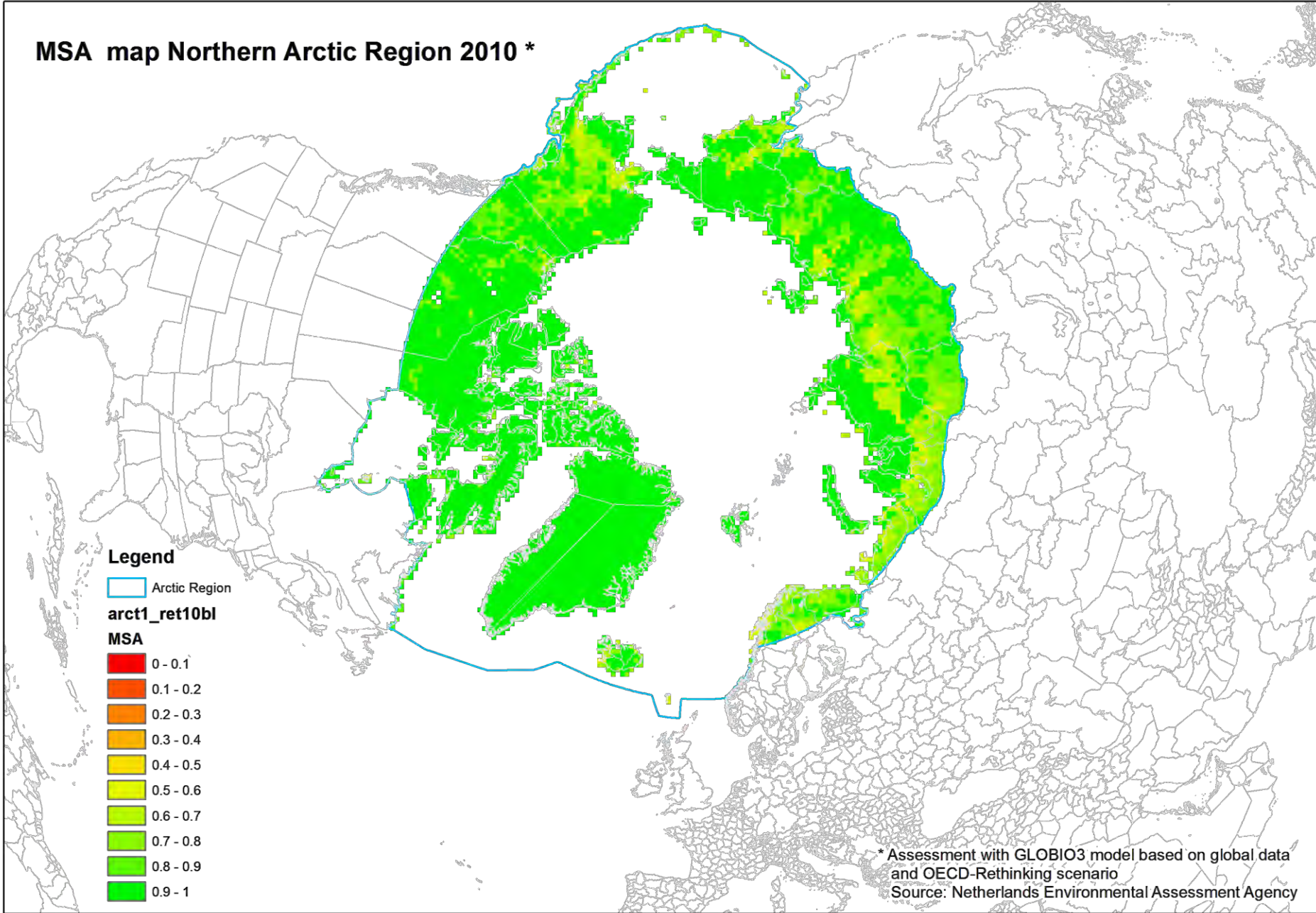


# Biodiversity loss in the future

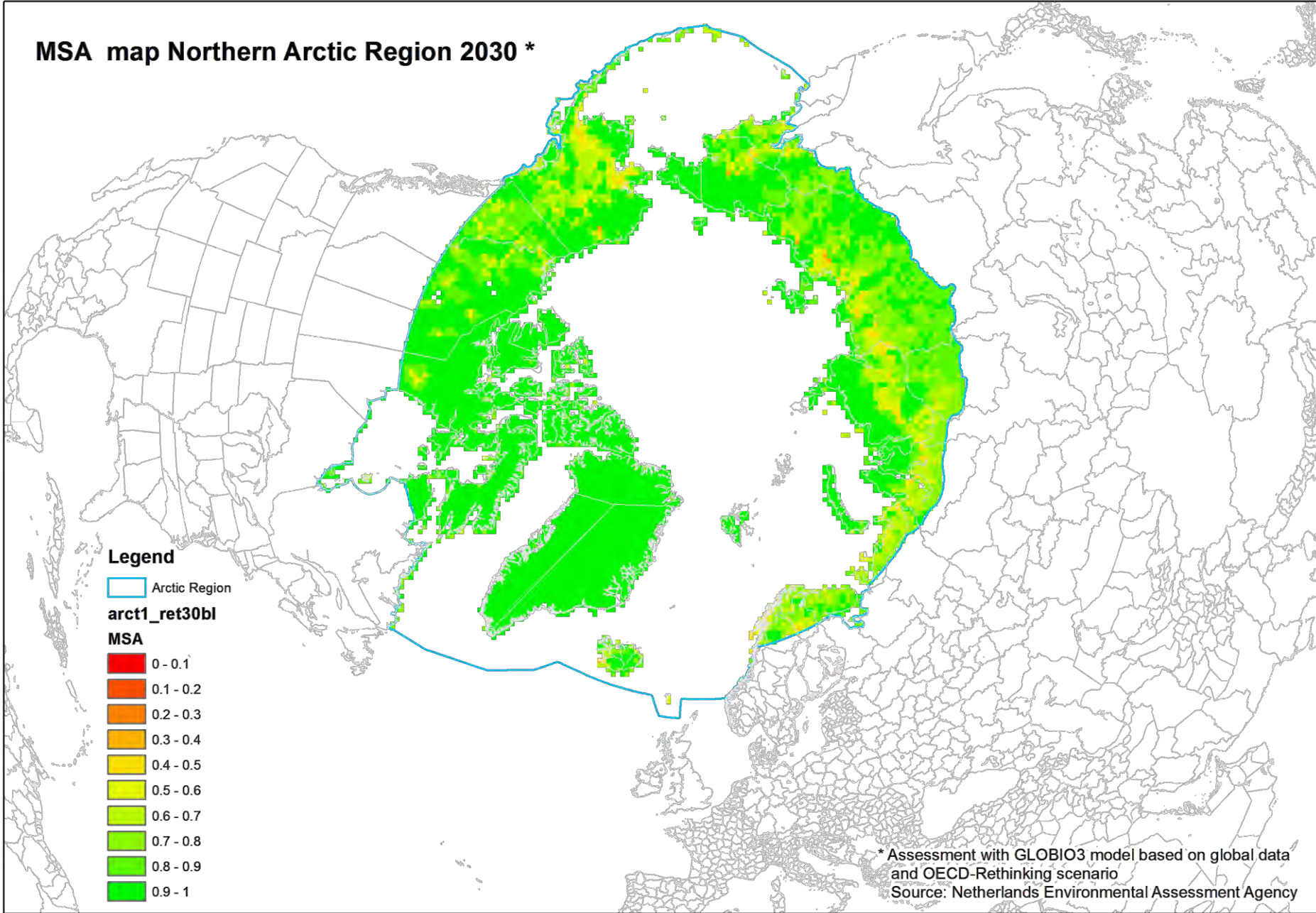
## Biodiversity in 2030 (MSA)



# MSA map Northern Arctic Region 2010 \*



# MSA map Northern Arctic Region 2030 \*



## **Spatial data** (global vs national) needed on:

- Land use, (e.g. agriculture, pastures, urban areas, forestry, mines, natural areas)
- Infrastructure, (roads, railways, pipelines, electricity lines)
- Protected areas,
- Nitrogen deposition (available from global models)
- Temperature increase (available from global models)

## **Non-spatial data:**

Qualitative information on local land use: type of grazing, forest mgmt, etc  
Census data on land use per administrative units  
Local knowledge on intactness of present ecosystems

Assessment of future biodiversity (pilot Norway): Scenarios and maps that have a relation with the locality of land use (soil suitability, rainfall, slope, population density, distance to towns and roads, etc). Future land use maps to be generated with land use model (e.g. Clue).

# 1: Land use: Data availability Arctic Regions

In general less maps available for areas with low population

Arctic regions: Lack of maps on land use intensity

- Large areas of forest and open semi natural lands, but how to measure the difference in land use intensity within these areas?

Example (Northern-) Norway:

- Agriculture is mapped and statistically recorded, but extensive agriculture area not mapped (only area size known)
- No differentiation in land use of semi natural 'Open land'
- What forest areas are logged intensively and which areas are used less?

# 1: Land use: Adjusting generic MSA values to local conditions

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**Globally population pressure is the main driver behind land use change.**

Often this is at the cost of biodiversity:  
Conversion of nature for agriculture, forestry and urban development

**Arctic Region: Low population pressure!**

Important land use related pressures:

- Forestry (in arctic forest areas)
- Grazing in (semi-) natural areas
- Hunting
- Local: Mining

Local expertise needed to adjust global MSA values to local conditions

Global MSA\_lu table

Biodiv class name	MSA value
Primary forests	1.0
Forest plantations	0.2-0.3
Secondary forests	0.5
Light used primary forests	0.7
Agro forestry	0.5
Extensive agriculture	0.3
Irrigated intensive agriculture	0.05
Intensive agriculture	0.1
Perennials & woody bio fuels	0.2
Natural grass & shrub lands	1.0
Man made pastures	0.1
<b>Livestock grazing</b>	<b>0.7</b>
Natural Bare, rock & snow	1.0
Natural inland water	null
Artificial water	null
River/stream	null
Built up areas	0.05

# 1: Land use: Adjusting generic MSA values to local conditions: Example grazing areas

## Example grazing areas

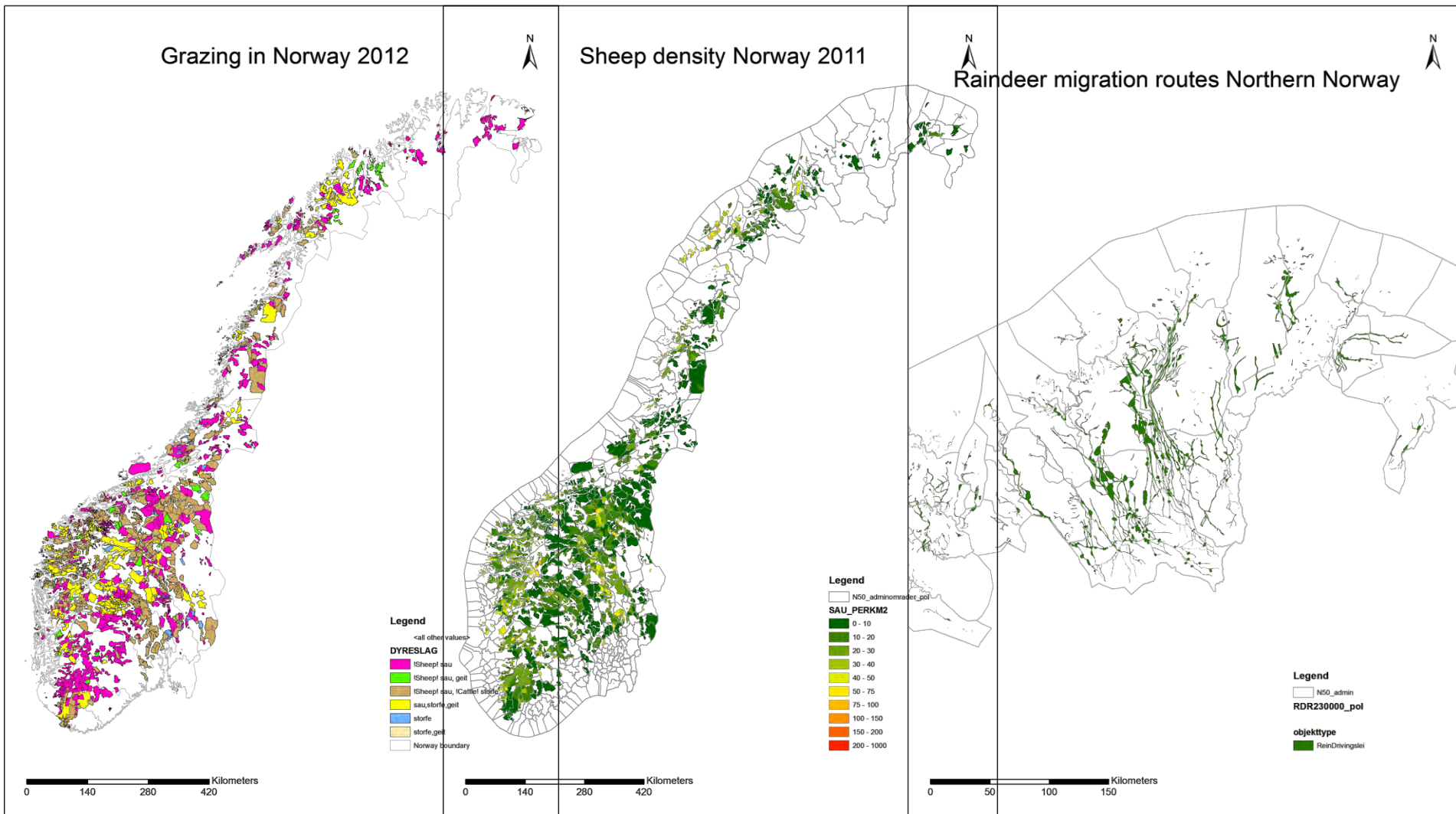
### Step 1: Differentiation by grazing intensity

Rangelands (Global)		Average MSA values for different grazing intensities, resulting from the meta analysis
Type of rangeland	Short description	MSA Global
Natural rangelands	Rangeland ecosystems determined by climatic and geographical circumstances and grazed by wildlife or domestic animals at rates similar to those of free-roaming wildlife	1
Moderately used rangelands	Rangelands with higher stocking rates: grazing has different seasonal patterns or vegetation structure is different compared with natural rangelands	0.6
Intensively used rangelands	Rangelands with very high stocking rates: grazing has different seasonal patterns and vegetation structure is different compared with natural rangelands	0.5
Man-made grasslands	Rangeland with high degree of human management, including converted forests	0.3
Ungrazed abandoned rangelands	Original grasslands no longer in use, lacking wildlife grazing and no forests developed	0.7

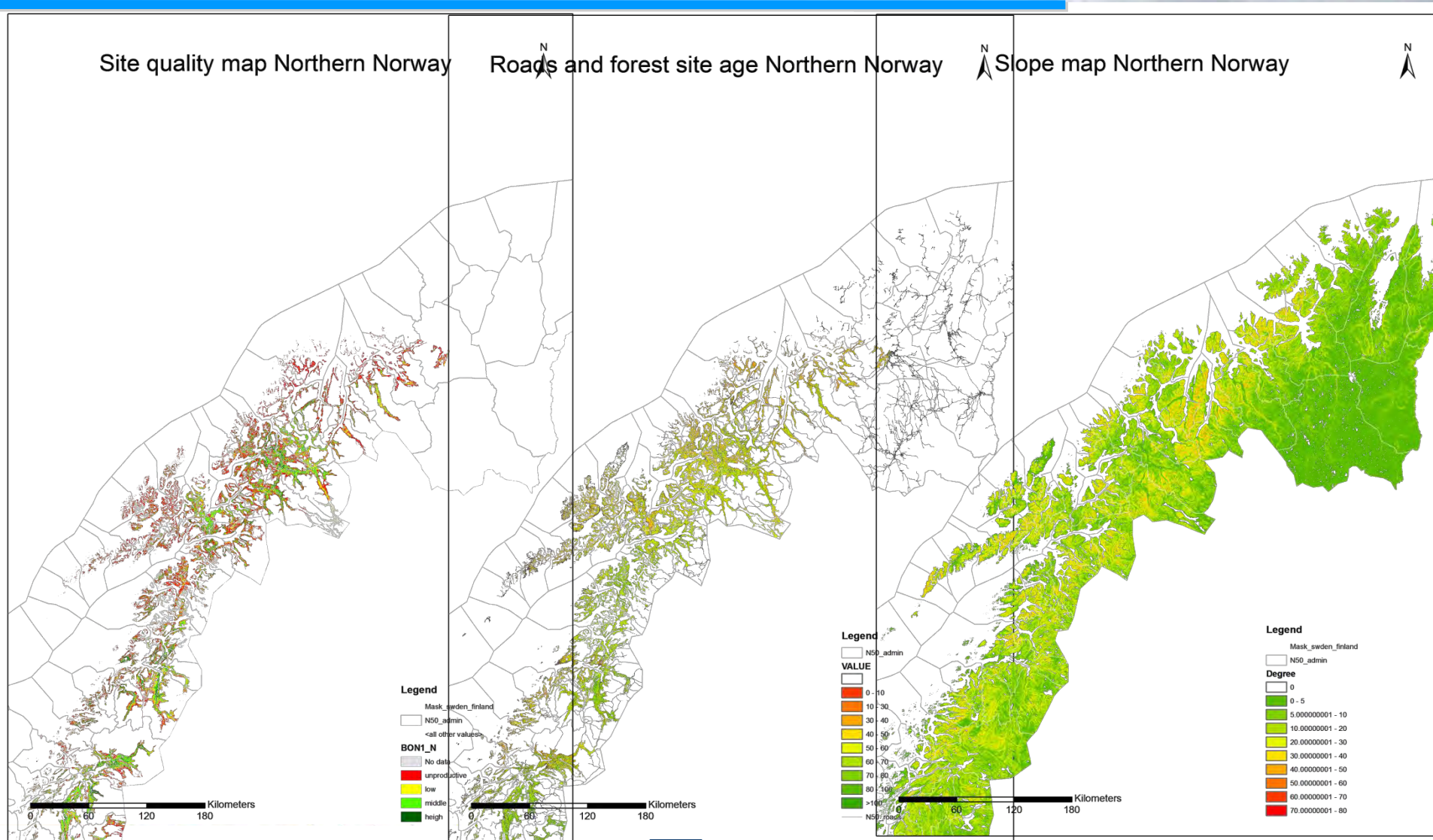
### Step 2: Interpretation of Intactness by local grazing specialists:

Interpolation of above MSA\_rangeland values

# 1: Land use: Adjusting generic MSA values to local conditions: Example grazing areas (Cont.)



# 1: Land use: Adjusting generic MSA values to local conditions: Example Forest areas

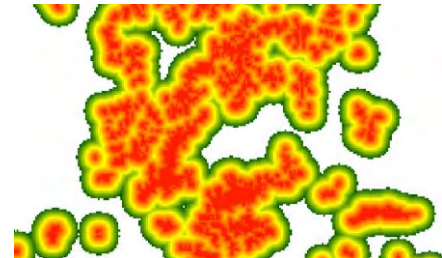
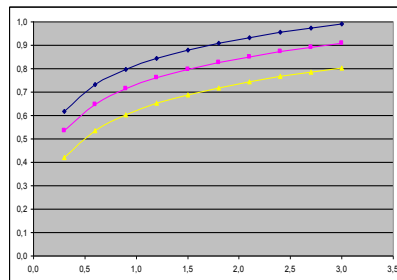


## 2 Infrastructure & settlements

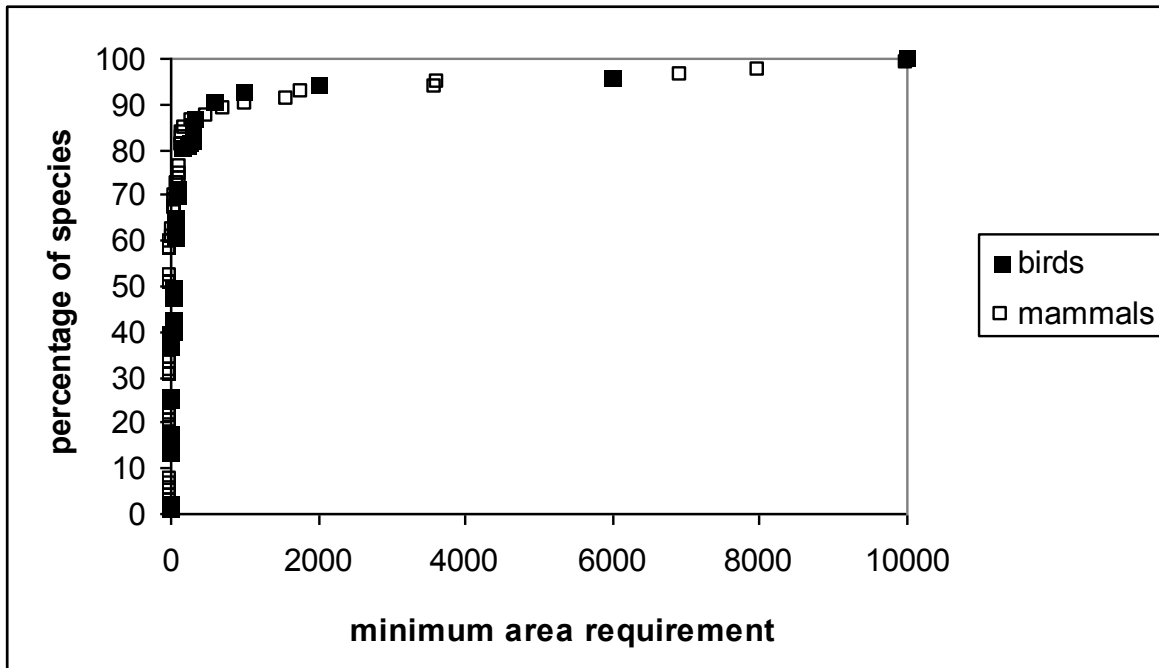
Along roads and around urban, mining and agricultural areas:

Construction	temporary (direct)
Habitat loss	length * width (direct)
Increased access	presence / quality (indirect)
Settlement	presence / quality (indirect)
Disturbance	intensity (direct)
Fragmentation	intensity (direct)

- Roads: 5km impact zone around roads, based on two species groups
- Buffer zone of 10 km around urban, mining and agricultural areas with gradual biodiversity loss with 15% loss at border, reducing to 0% at 10km distance



# 3: Fragmentation



Fragmentation	MSA
<b>Cluster size</b>	<b>MSA</b>
0-1	0.35
1-10	0.45
10-100	0.65
100-1000	0.9
1000-10000	0.98
>=10000	1

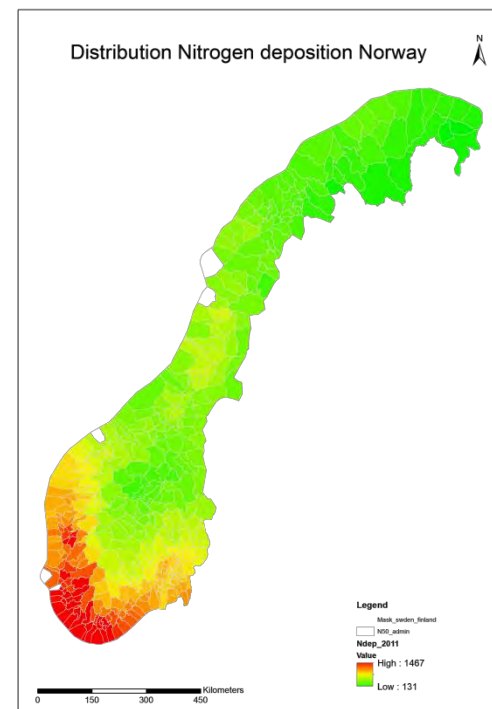
## 4: Nitrogen Deposition change

Regression equations for the relationship between atmospheric N deposition exceedance (NE)\* and  $MSA_N$  for three ecosystems.

Ecosystem	Equation	Land use class
Arctic-Alpine ecosystem	$MSA_N = 0.9 - 0.05 NE$	Snow and ice
Boreal coniferous forest	$MSA_N = 0.8 - 0.14 \ln(NE)$	Forests
Grassland	$MSA_N = 0.8 - 0.08 \ln(NE)$	Grassland and shrub

\* *NE is calculated as Ndep minus Crit. Load.*

Because of the absence of larger towns and high livestock densities in the upwind areas, Nitrogen deposition in the Arctic is in general lower than the critical load level.



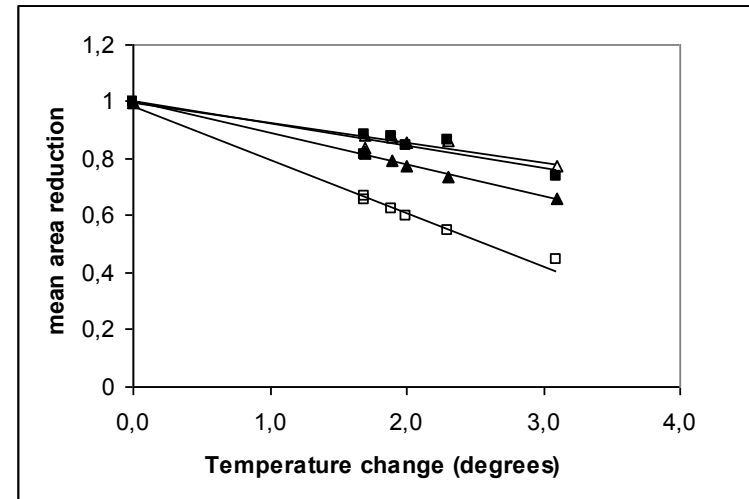
# 5: Climate change

Temp change: OECD  
Update 4 februari  
2014

GBO4 BL

Year	Degrees C *
1970	0.241
1975	0.267
1980	0.353
1985	0.448
1990	0.558
1995	0.670
2000	0.777
2005	0.888
2010	1.005
2015	1.152
2020	1.325
2025	1.499
2030	1.680
2035	1.865
2040	2.053
2045	2.242
2050	2.433

Biome	Slope Values
Ice	3.56
Tundra	4.26
Wooded tundra	4.26
Boreal forest	3.67
Cool conifer forest	11.27
Temperate mixed forest	4.87
Temperate deciduous forest	7.1
Warm mixed forest	14.57
Grassland and steppe	12.01
Hot desert / desert	12.01
Scrubland	6.6
Savanna	7.75
Tropical woodland	10.75
Tropical forest	10.75
Mediterranean shrub	6.61

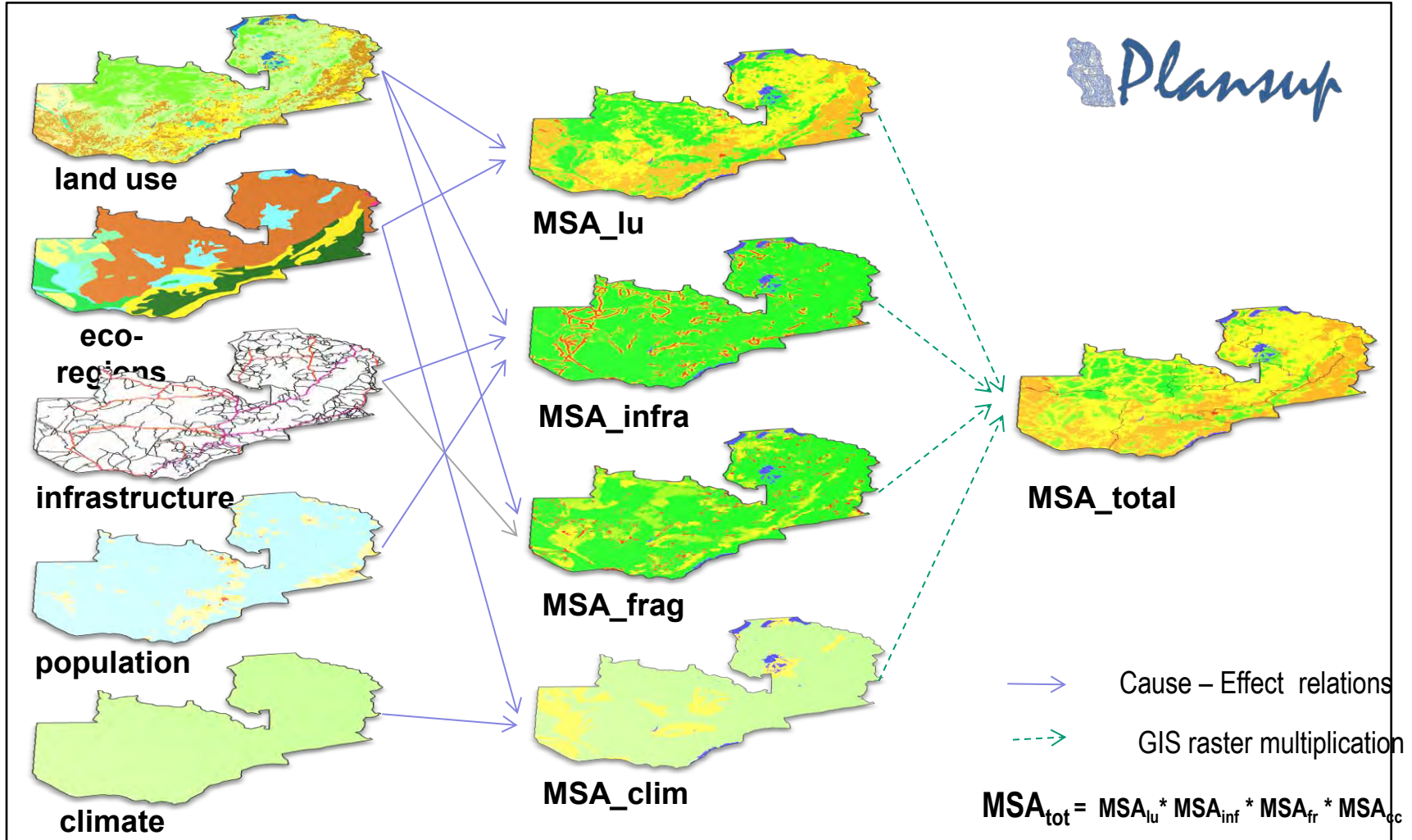


**\* Correction needed for Arctic region**

Slopes are used in the GLOBIO 3 model to calculate the correction factor for calculating the impact of climate change :MSACC, according to:  $MSACC = 1 - (\text{Slope} * \Delta\text{Temp.}) / 100$

# How is the biodiversity status calculated?

Illustration GIS calculation current biodiversity Zambia



**Input layers**  
(drivers / pressures)

**Intermediate output**  
Pressure impact

**Output**  
Overall impact pressures

# Why do we need land use scenario information for biodiversity modeling?

- Land use change plays an important role in the change of biodiversity
- Information on land use change needed to define the size and location of land use change
- Scenario information needs to be quantified per land use type -> demand table per scenario
- The demand table shows the area change of each land use type for each year
- CLUE uses the demand table together with regression information and other spatial settings to calculate future land use maps. These are needed for future biodiversity loss calculations in GLOBIO3

# GLOBIO: current and future biodiversity status

Model calculations in two parts:

1. Current biodiversity status calculation

The share of biodiversity loss per pressure type per administrative unit

-> National: current MSA per district or province

2. Future biodiversity status calculation

Based on the future change in: land use, infrastructure, fragmentation, nitrogen deposition, and climate.

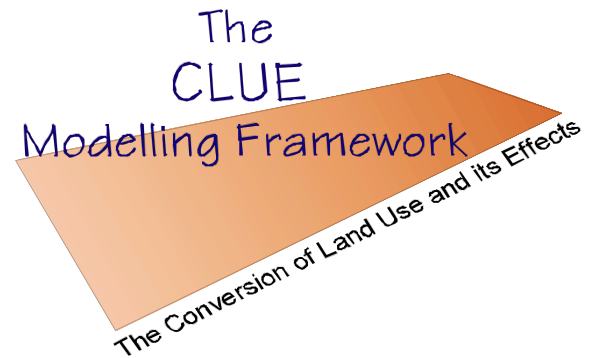
**Result: Relative trend and spatial distribution of future biodiversity per scenario**

# What models are used?

## II: CLUE land use model

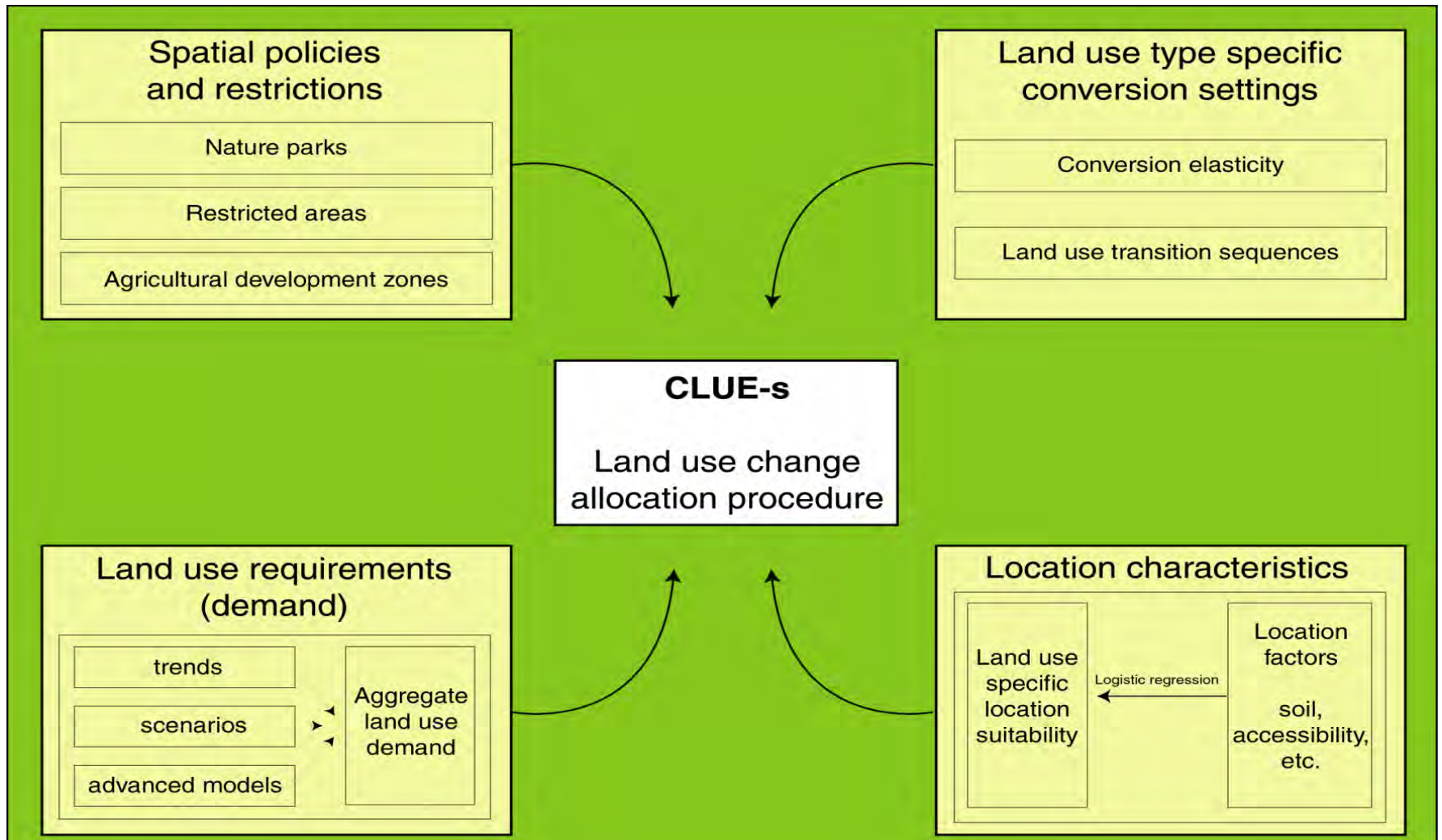
The **C**onversion of  
Land **U**se and its **E**ffects

[www.ivm.vu.nl/CLUE](http://www.ivm.vu.nl/CLUE)



- Dynamic, multi-scale land use and land cover change model
- Clue model will provide most important layer that is needed to calculate future MSA with GLOBIO (out of 5 pressures)
- Freeware

# Framework CLUE-s model



# Characterization of local suitability


- Land use is changed preferably at the location with the highest 'suitability'
- 'Suitability' depends on the preferences of the decision maker
- 'Suitability' cannot be expressed in monetary value or solely by biophysical attributes

# Exercise: land use matrix

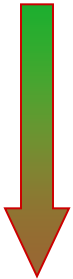
	A	B	C	D	E	F	G	H	I	J	K
1	<b>LU CLASS</b>	Primary forest	Light used forest	Secondary forest	Agroforestry	Highly degraded forest	Extensive agriculture	Intensive agriculture	Urban	Other	Rubber Plantation
2	Primary forest										
3	Light used forest										
4	Secondary forest										
5	Agroforestry										
6	Highly degraded forest										
7	Extensive agriculture										
8	Intensive agriculture										
9	Urban										
10	Other										
11	Rubber Plantation										

1 = Possible to change  
 0 = Not possible to change  
 130 = Takes at least 30 yrs

# Land use type specific conversion setting

 Future LU

Land Use Conversion Matrix

 Present LU

	Prim. For	Plant	Sec. For.	Ext. Agr.	Int. Agr.	Nature	Bare	Other
Prim. For	1	1	1	1	1	0	1	0
Plantation	0	1	110	1	0	0	1	0
Sec. For.	130	1	1	1	1	0	1	0
Ext. Agr.	0	1	1	1	1	0	1	0
Int. Agr.	0	0	0	1	1	0	1	0
Nature	0	0	0	0	0	1	0	0
Bare	0	1	110	1	1	0	1	0
Other	0	0	0	0	0	0	0	1

# location factors

location factors	source	original resolution	description of 3 km resolution location factors
<u>Local factors</u>			
mean annual rainfall	GAEZ	10 km	
length of dry period	IIASA	0.5°	number of consecutive “dry” months
altitude	HYDRO1K	1 km	
slope	HYDRO1K	1 km	median of 1km resolution slopes
geology	SOTER Lac	1:5 million	metamorphic or igneous rock
soil depth	GAEZ	10 km	
soil drainage	GAEZ	10 km	
soil fertility	GAEZ	10 km	
protected area, or: <i>national/indigenous park</i>	CIAT - UNEP-WCMC <i>idem</i>	various	
<i>other park/reserve</i>	<i>idem</i>		
population density	CIAT - UNEP - WRI	2.5'	
population growth	CIAT - UNEP - WRI	2.5'	1990-2000 extrapolated
<u>Contextual factor</u>			
topographical index	HYDRO1K	1 km	function of local gradient and contributive area
flat area size	HYDRO1K	1 km	surface of area with slope <3°
landscape fragmentation	GLC2000 / CCAD/WB	1 km	Euclidean distance to border of natural vegetation
cost of access from road	various	<1 km	cost distance from nearest paved road
cost of access to market	various	<1 km	cost distance to nearest city with over 100,000 inh.
proximity to fire	JRC	1 km	proximity to fire (15 and 45km neighbourhood)
population density			15 and 45km neighbourhood average
population growth			15 and 45km neighbourhood average

# Intermediate output of CLUE-s model

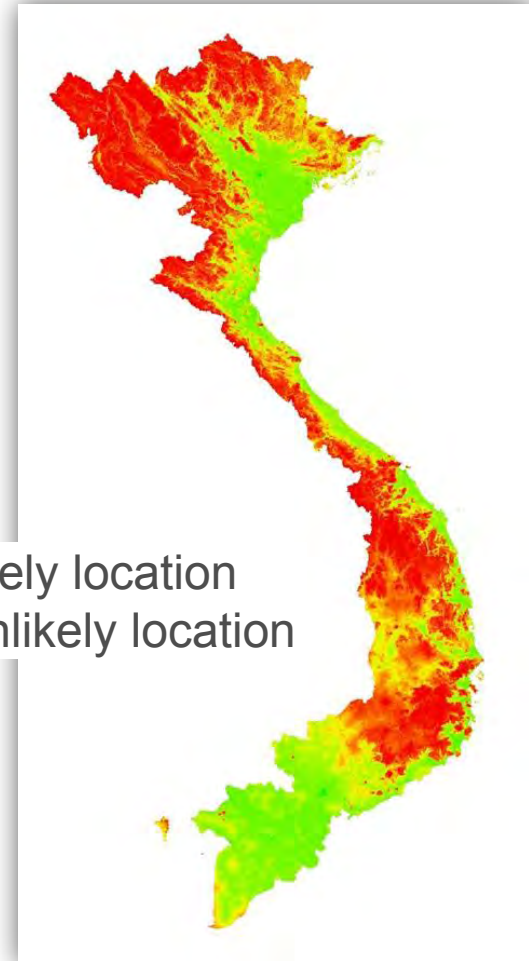
Probability / suitability map  
for each land use type

Vietnam:

Suitability based on following  
available location factors/maps:

- i). Precipitation (rainfall)
- ii). Travel time to town
- iii). DEM (Elevation)
- iv). Slope
- v). Population Density
- vi). Soil texture, fertility, depth

Probability / Suitability map  
Intensive Agriculture



**Green**

Most likely location

**Red**

Most unlikely location

# Scenarios: Example Vietnam

## 1. Baseline scenario:

- Cropland demand: OECD baseline scenario + 25% for 2030
- Cropland diversification: extensive (80%) and intensive (20%)
- Plantation demand: increment of 500 km<sup>2</sup>/year
- Primary forest assumed to remain constant

## 2. Biodiversity conservation scenario (policy option):

- Primary forest: total forest cover (plantation + primary class) will reach 40% of country land area in 2030
- Protected areas increase from 7% to 10% of the land
- Strict law enforcement

# Quantifying forest scenario Vietnam

## Creation of demand table in CLUE

		Primary forest	Slightly disturbed forest	Heavily disturbed forest	Regrowth shrub and bushes	Plantation	Shifting cultivation (ext.agr)	Degraded lands	Intensive agriculture	Residential and urban land	Nature	Others	Area
2000	0	26020	20763	36142	19691	13963	17846	47162	87488	11634	18229	28525	32,7463
2005	5	26581	25227	46052	25247	23300	9418	32269	80863	11751	18229	28525	32,7463
2010	10	27265	30682	53495	29225	29367	4970	22224	71612	11869	18229	28525	32,7463
2015	15	28089	36242	47594	30931	35433	2623	14452	73357	11988	18229	28525	32,7463
2020	20	29044	40970	42394	30878	41500	1384	8438	73993	12108	18229	28525	32,7463

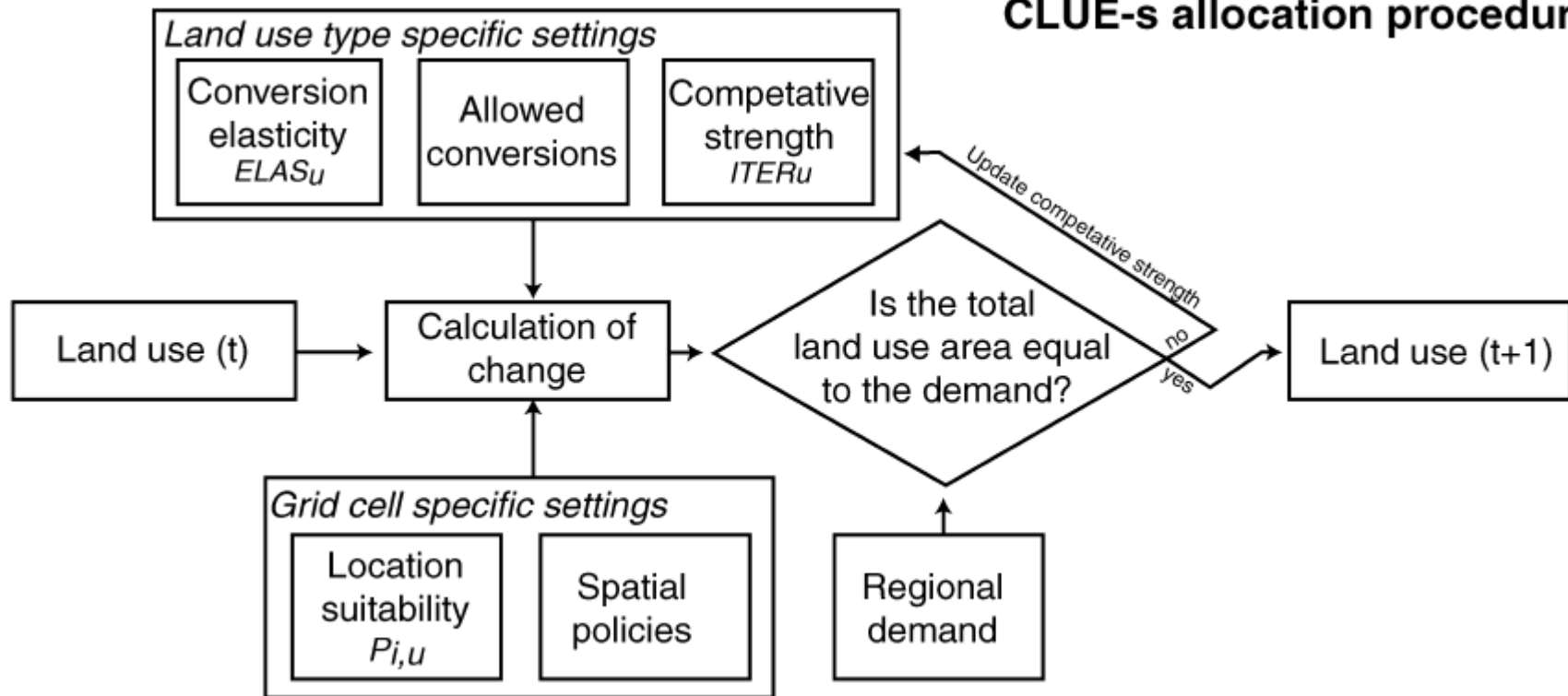
Spatial policies and restrictions

Nature parks

Land use type specific conversion settings

Conversion elasticity

### CLUE-s allocation procedure



scenarios

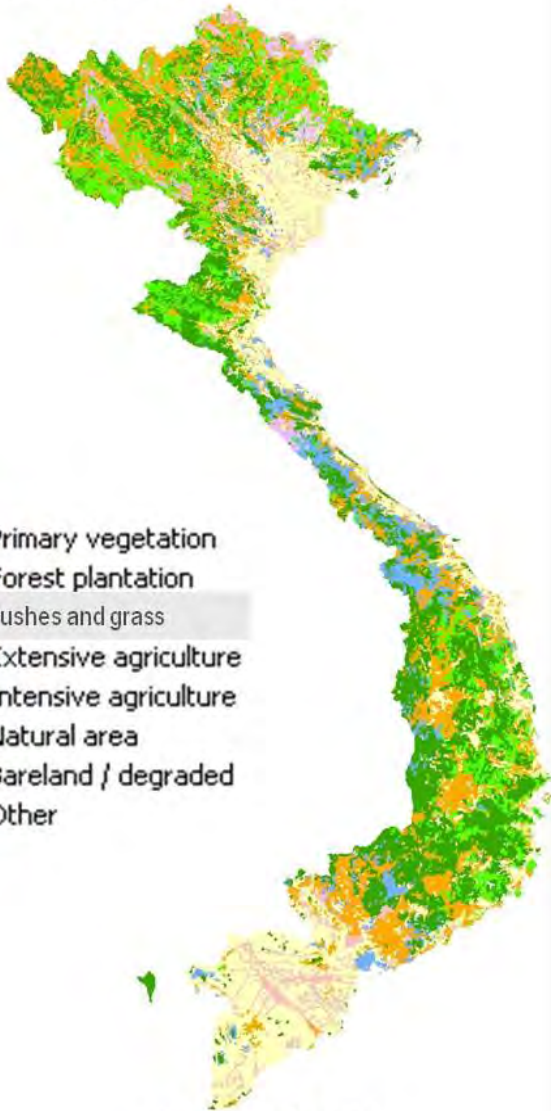
land use demand

advanced models

suitability

accessibility, etc.

## 2030 Baseline



MSA=34%

## 2030 Conservation

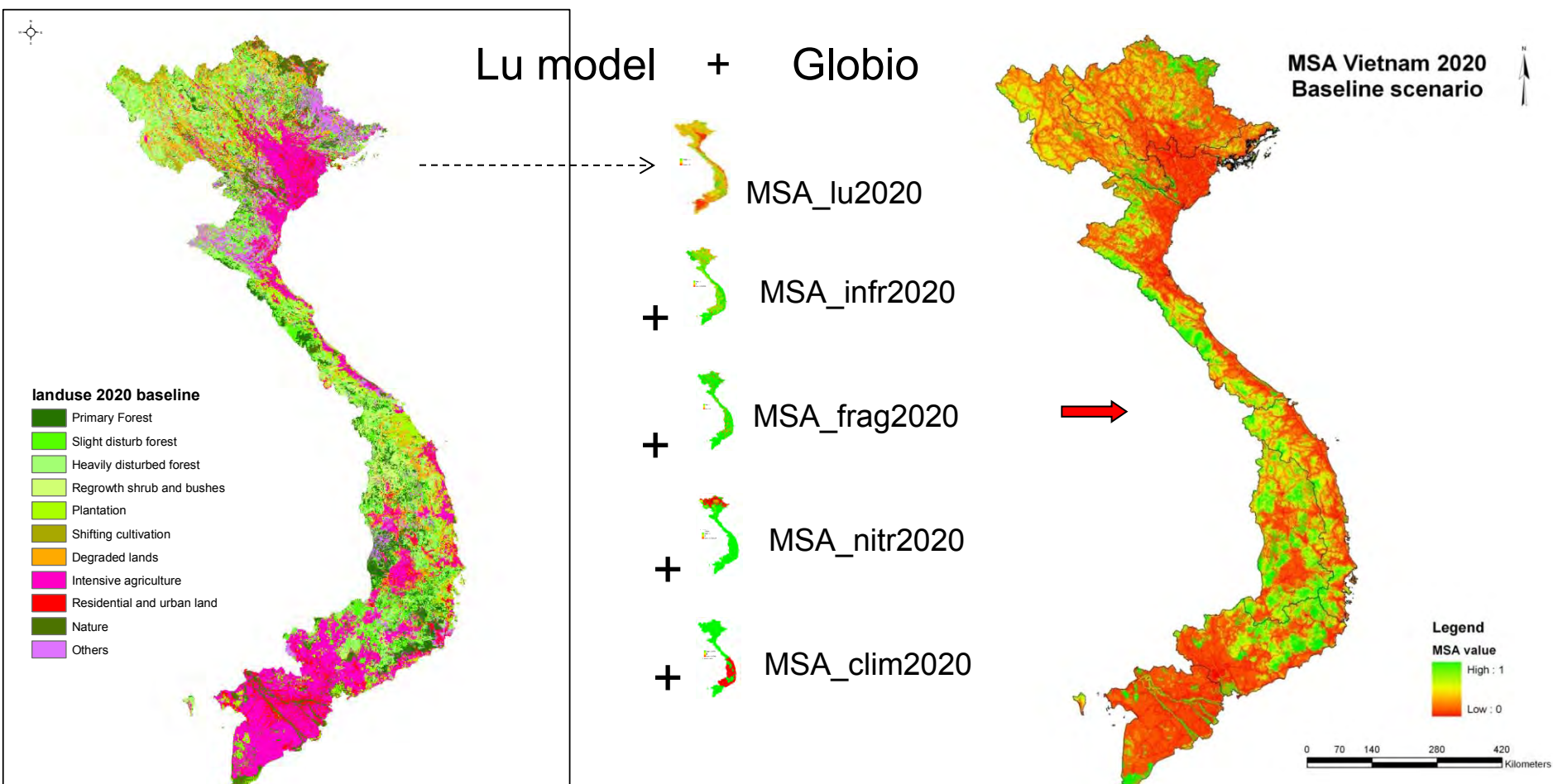


MSA=40%

## Protected areas 10%



# Calculation of future MSA\_total



$$MSA_{total} = MSA_{LUC} * MSA_I * MSA_F * MSA_N * MSA_{CC}$$

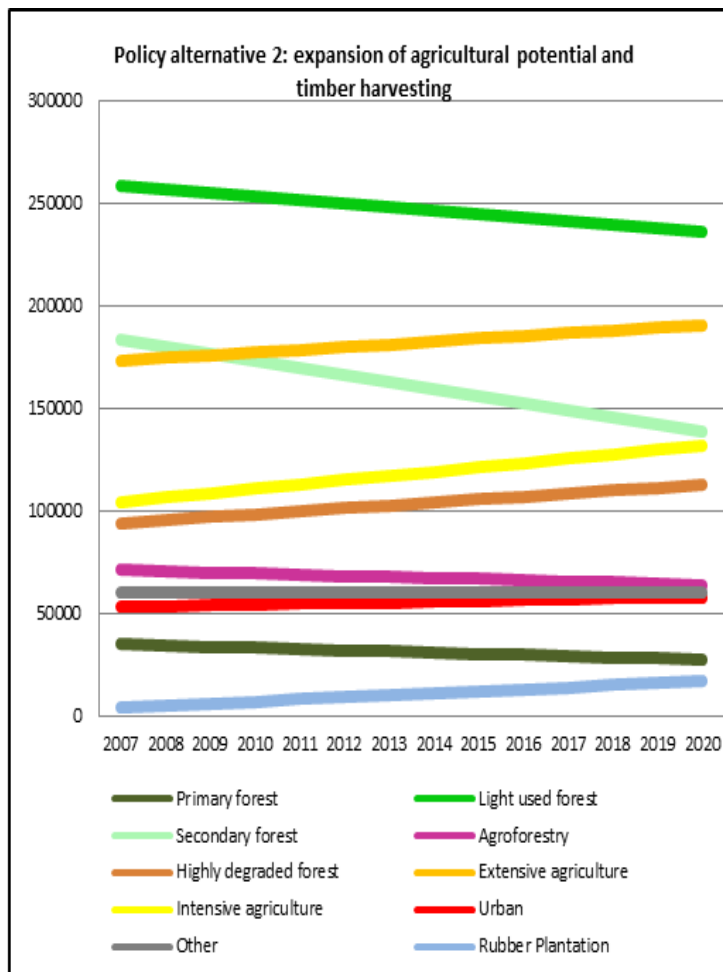
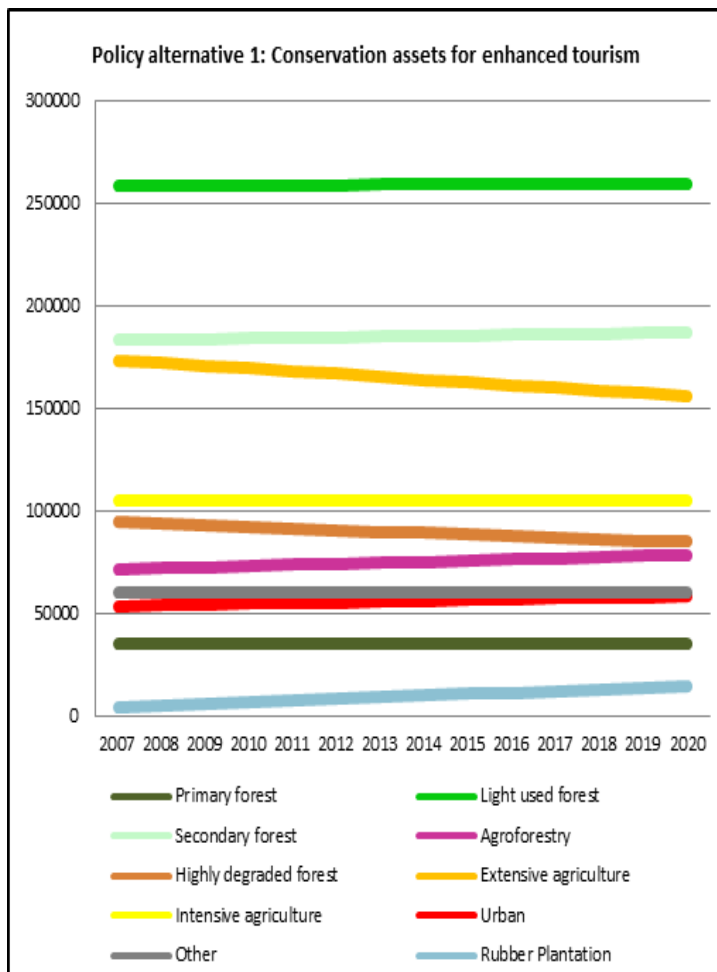
# Future land use: scenario and policy alternatives

Example provincial level: Quang Nam

- **Land demand scenario 1 – Conserve to retain function:**
  - Conservation of environmental assets
  - Secure performance and enhance potential of tourism and energy sectors (need healthy ecosystems)
- **Land demand scenario 2 – Convert to maximize output:**
  - Timber harvesting
  - Expansion of commercial plantations for increasing demand from manufacturing sector

# Future land use: scenario and policy alternatives

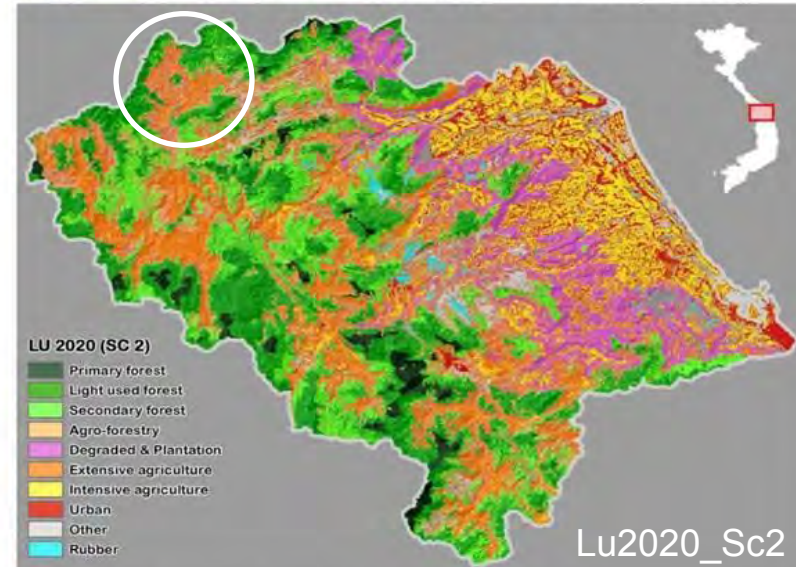
## Example provincial level: Quang Nam



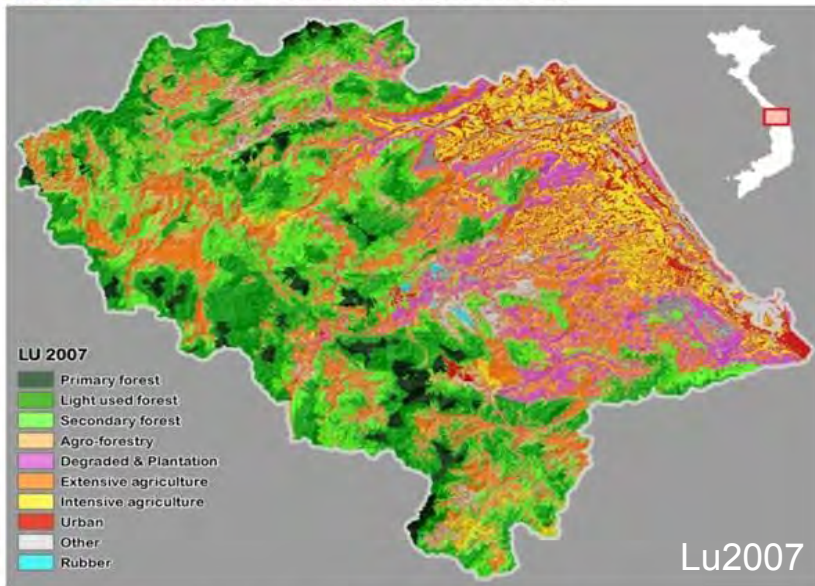
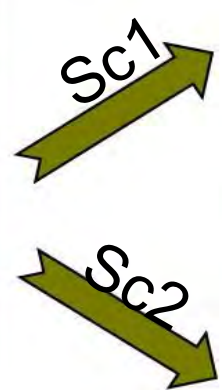
# Example Generation of future land use map per scenario (Quang Nam province)



SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.



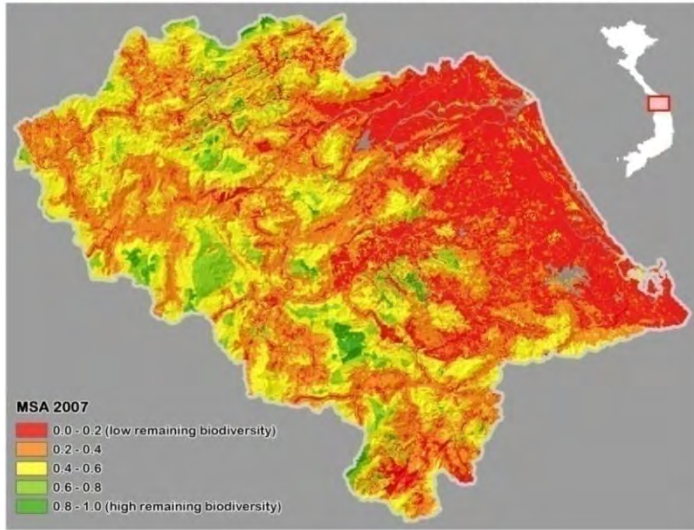
SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.



SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.

# Example output GLOBIO3: QN

**ADB** BIODIVERSITY PRESSURE MODELLING  
QUANG NAM, VIET NAM: MEAN SPECIES ABUNDANCE 2007 (BASELINE)

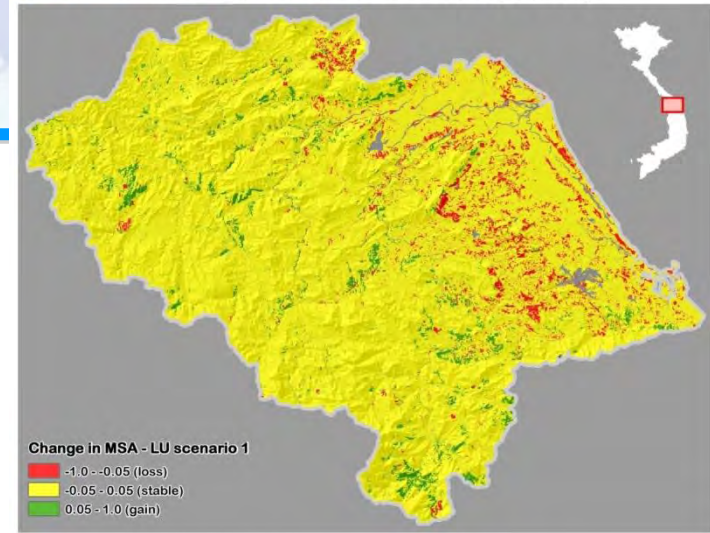


SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.

Scenario 1  
→

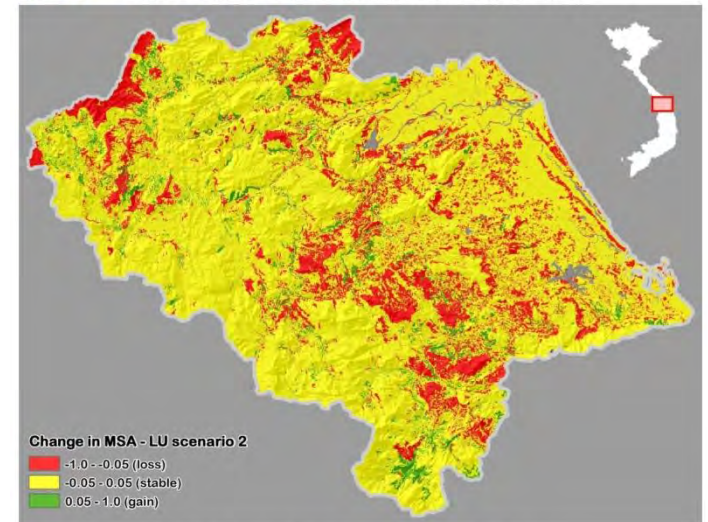
Scenario 2  
↘

**ADB** BIODIVERSITY PRESSURE MODELLING  
QUANG NAM, VIET NAM: CHANGE IN MSA 2007-2020 (SCENARIO 1)



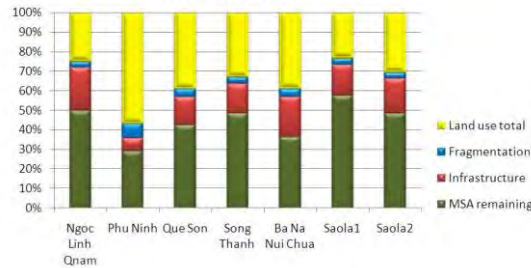
SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.

**ADB** BIODIVERSITY PRESSURE MODELLING  
QUANG NAM, VIET NAM: CHANGE IN MSA 2007-2020 (SCENARIO 2)

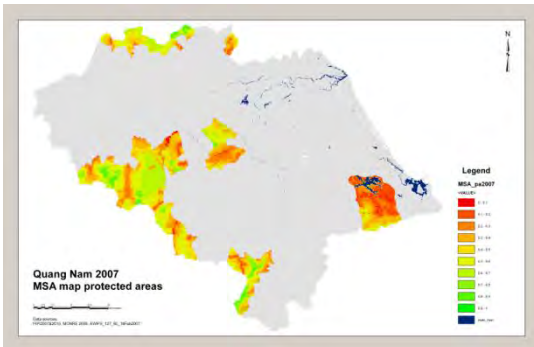
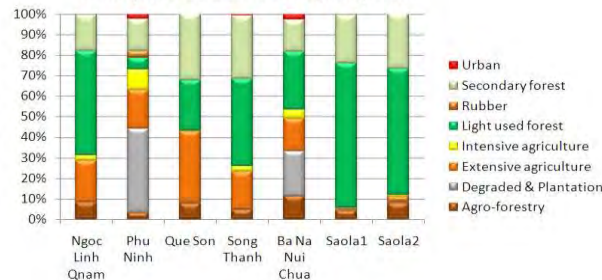


SOURCE: GMS ENVIRONMENT OPERATIONS CENTER, WITH SUPPORT INFORMATION FROM MARD-FPI AND DONRE QUANG NAM  
DISCLAIMER: THE CONTENTS OF THIS MAP, PARTICULARLY THEMATIC DATA AND BOUNDARIES, ARE NOT NECESSARILY AUTHORITYATIVE.

Biodiversity loss per protected area  
Quang Nam, 2007



Share biodiversity loss per land use type  
within protected areas in Quang Nam, 2007



Protected areas

# Summary

- GLOBIO3 model can be used to assess current and future impact of socio-economic developments on land use and biodiversity.
- CLUE model is used to calculate future land use, based on scenario info
- Future land use is used as input for GLOBIO model for the assessment of future biodiversity (*next to assessment future impact of other 4 pressures*)
- Quality of Arctic input data determines the quality of the model output
- Land use maps Arctic Regions are in general poor and available information per land use class needs to be diversified: adjustments + local expertise!
- MSA should not be used as the only biodiversity indicator but next to others. It is expected to complement the Norwegian Nature Index and Arctic Species Trend Index.

# Further reading

- Alkemade et al (2009). GLOBIO3: Framework to assess global terrestrial biodiversity. Options to reduce Global Biodiversity Loss. Ecosystems.
- Secretariat of the Convention on Biological Diversity and Netherlands Environmental Assessment Agency (2007). Cross-roads of Life on Earth – Exploring means to meet the 2010 Biodiversity Target. Solution oriented scenarios for Global Biodiversity Outlook 2. Secretariat of the Convention on Biological Diversity, Montreal, Technical series no. 31, 90 pages.
- MNP (2006). Integrated modelling of global environmental change. An overview of IMAGE 2.4. MNP, Bilthoven, The Netherlands.
- Yongyut Trisurat , R. Alkemade and P. Verburg (2010): Projecting Land-Use Change and Its Consequences for Biodiversity in Northern Thailand. Environmental Management
- TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.
- Verburg et al 2002. Modeling the Spatial Dynamics of Regional Land Use: The CLUE-S Model
- Verburg P and K. Overmars 2009. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model
  
- National implementation models: [www.plansup.nl](http://www.plansup.nl)