Netherlands Environmental Assessment Agency

An introduction to the Globio model

Presentation for the Modelling Planning Workshop

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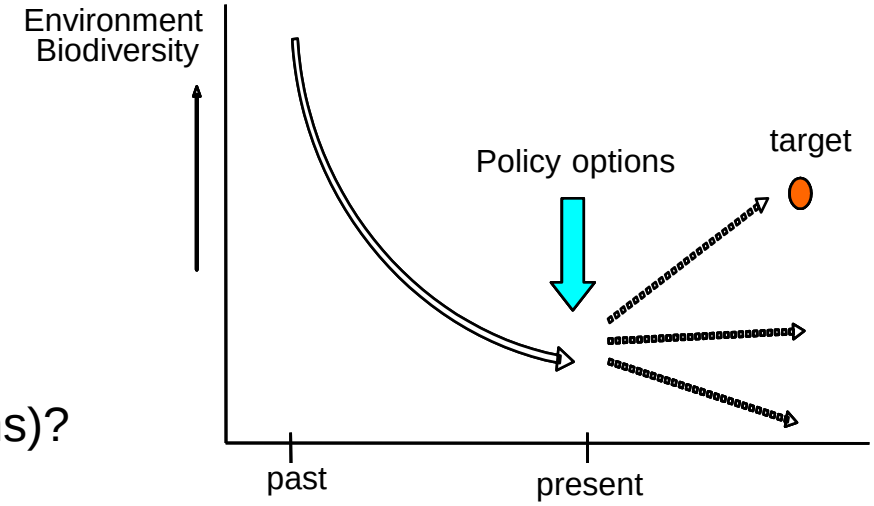
Netherlands Environmental Assessment Agency (PBL)

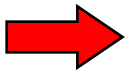
Global Biodiversity Model: GLOBIO3

- Initially developed to assess global terrestial biodiversity
- Based on GLOBIO 2 (Infrastructure), IMAGE 2.4 and Mean Species Abundance - biodiversity concept
- Aim: Assessments and evaluations
  - Trade off between socio-economical developments and environment
  - What is the current state (biodiversity)?
  - Causes of decline?
  - What is the future state?
  - Will agreed targets be met?
  - What can we do (evaluate policy options)?



Environmental pressures included

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



MSA

Dose - Response relations for each pressure

Biodiversity modelling (GLOBIO)

- Consortium: PBL, UNEP-GRID Arendal, UNEP-WCMC, SAUP-UBC
- Terrestrial
  - ‘dose-response models’ using meta-analysis: Land use, infrastructure, N-deposition, fragmentation, climate change
- Freshwater
  - Rivers system: dose response model for land use / nutrient loads
  - Lake systems
  - Wetlands
- Marine
  - EcoOcean model (Sea Around Us Project, UBC)

Modelling MSA with the Globio model

Information used to derive relation between Land use and biodiversity status (Desk study):

- 140 publications, Species richness, Abundances
- Africa: 24; Asia: 36; Europe: 21; North America: 23; South America: 27; Oceania: 7
- 62 tropical forests; 31 other forests; 17 grasslands; 9 shrub lands; 5 deserts
- Ca. 5700 species: 2100 plant species, 1700 insects, 1300 birds, 150 other vertebrates

Concept calculation of ‘naturalness’ of biota

~ Relative Biodiversity: ‘MSA’

[Abundance = nr. of individuals per species]

Species no.	Abundance in Pristine state	Abundance in Disturbed state
Spec. 1	100	80
Spec. 2	60	12
Spec. 3	27	0
Spec. 4	6	60
Spec. 5	0	20

Species 1: 80/100 = 0.8

Species 2: 12/60 = 0.2

Species 3: 0/27 = 0.0

Species 4: 1.0 (maximum)

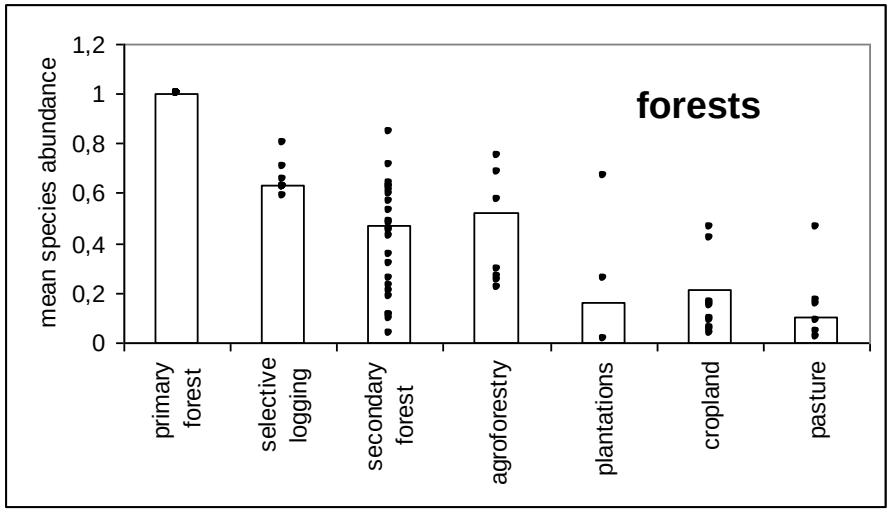
Species 5: -- (not original)

Σ (ratio)/ # of native species

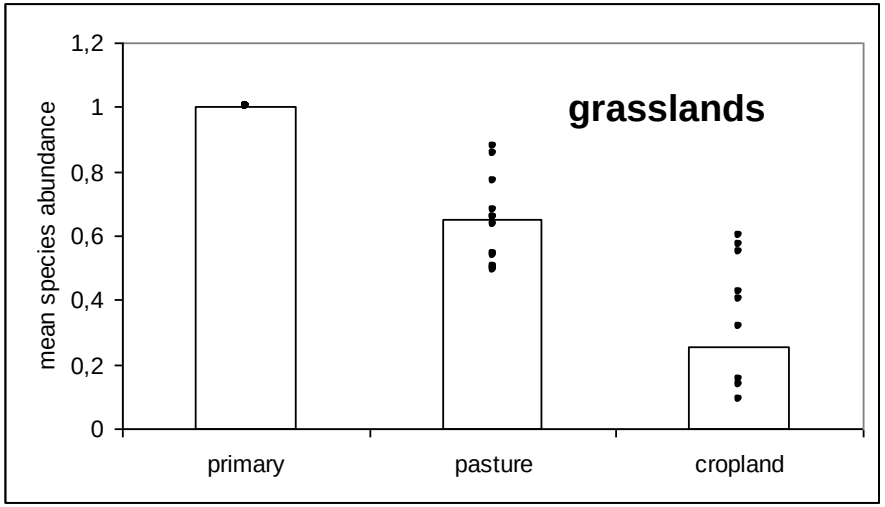
= Relative Biodiversity = 0.5

Relationships Pressure – Mean Species Abundance

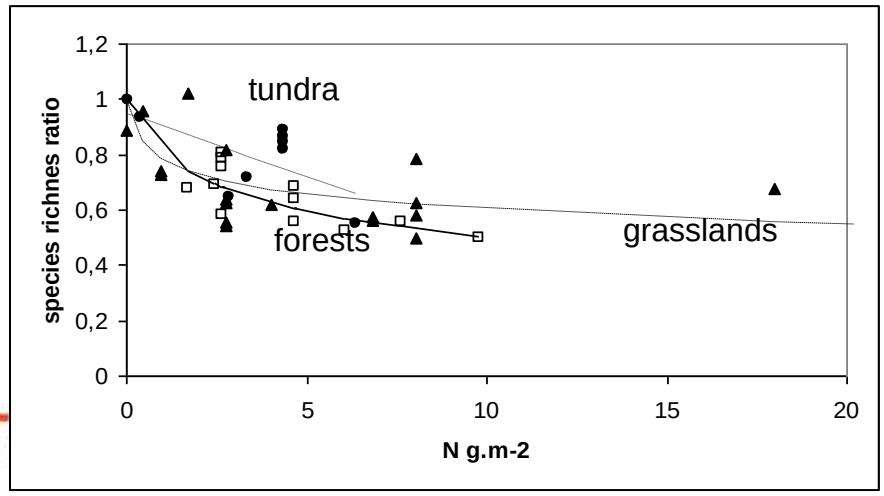
Land use change



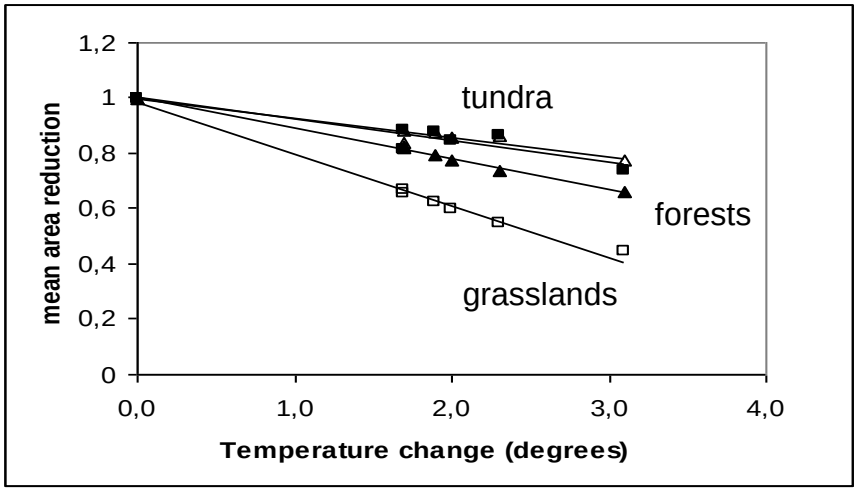
Land use change



Nitrogen deposition

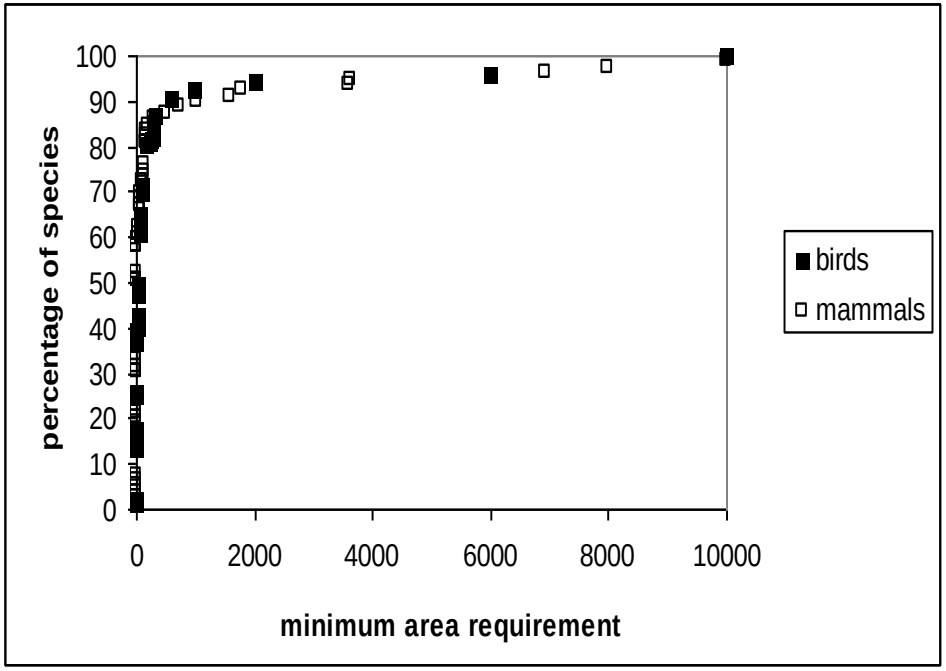


Climate

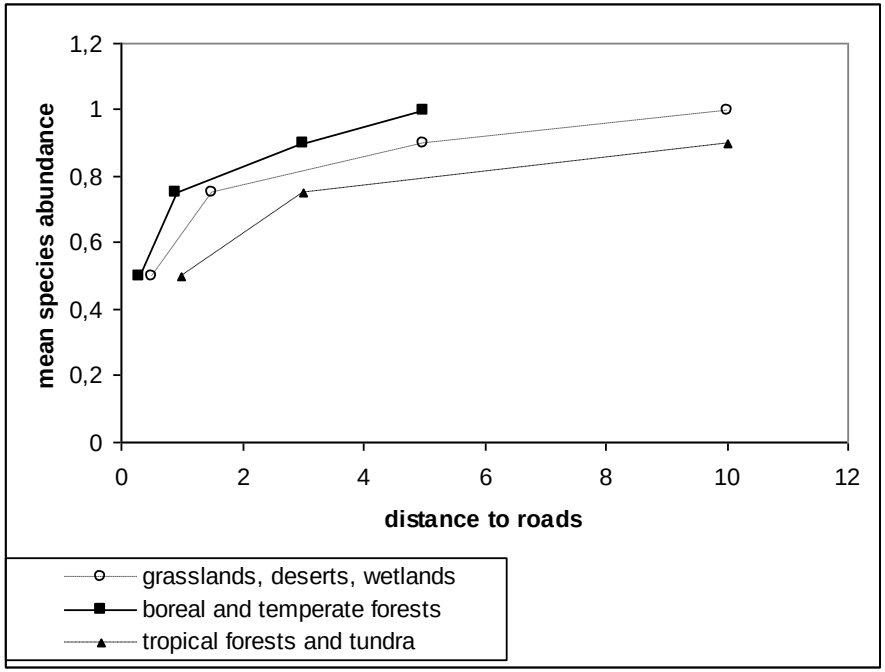


Relationships Pressure – Mean Species Abundance

Fragmentation (patch size)



Infrastructure



Design of model framework for GLOBIO 3 Global Scale

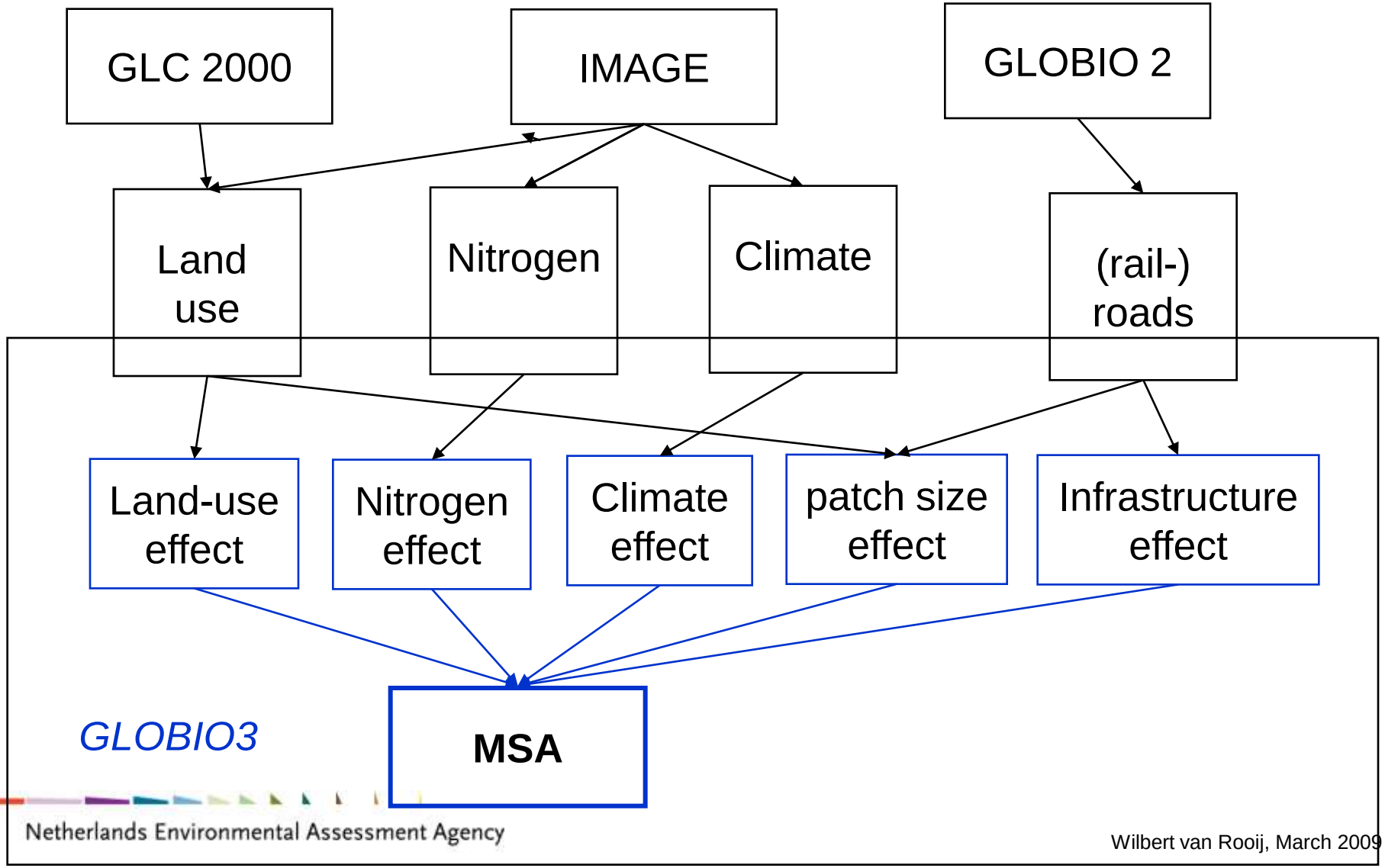
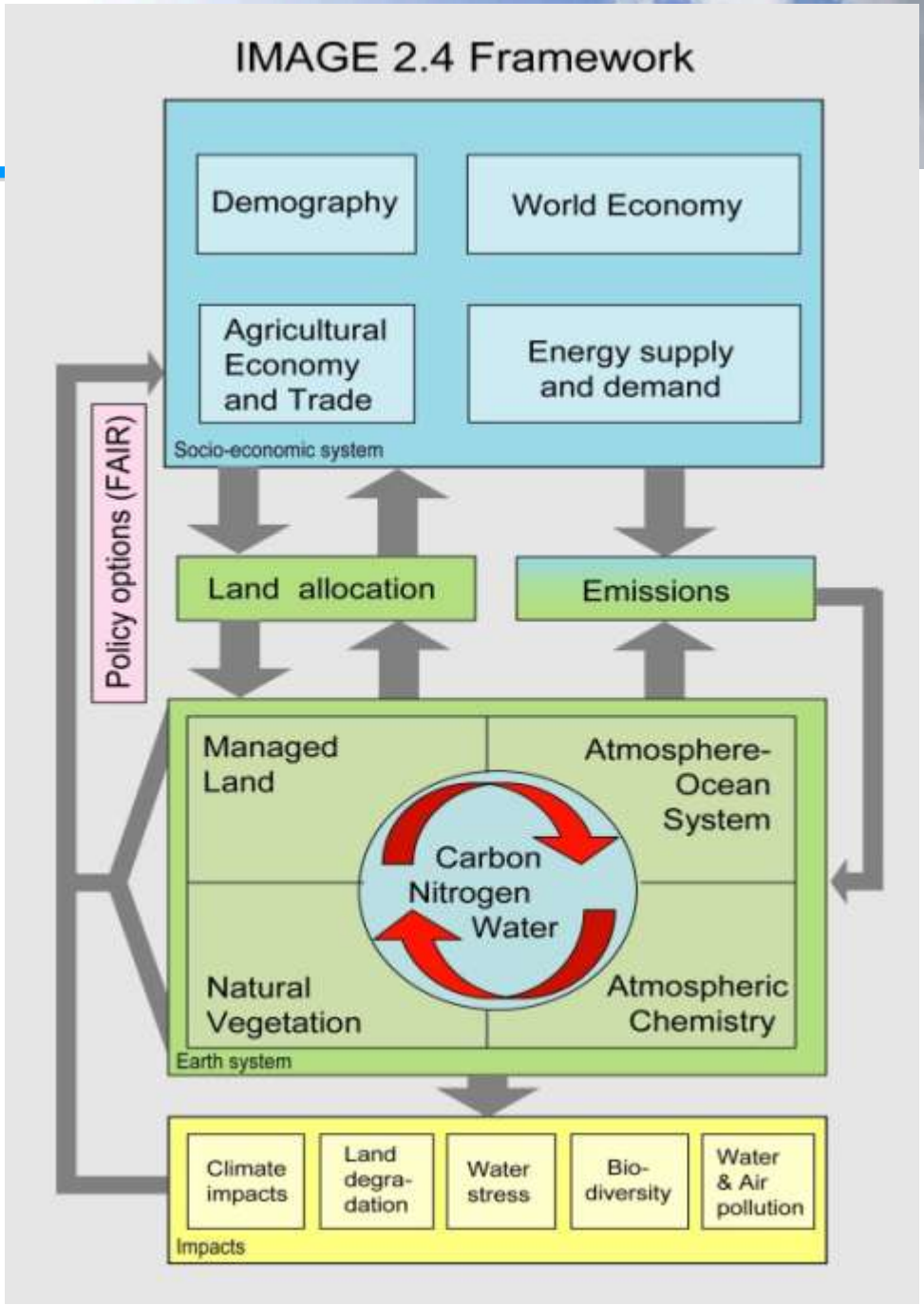


IMAGE 2.4:

Integrated Model for the Assessment of Global Environmental change

Globio3 uses, Land use + scenario, Nitrogen and Climate output from the IMAGE model

National application of Globio3 uses only the Nitrogen and Climate data.
Rest based on National data.



How is the biodiversity status calculated?

Overall Biodiversity: combination of pressures:

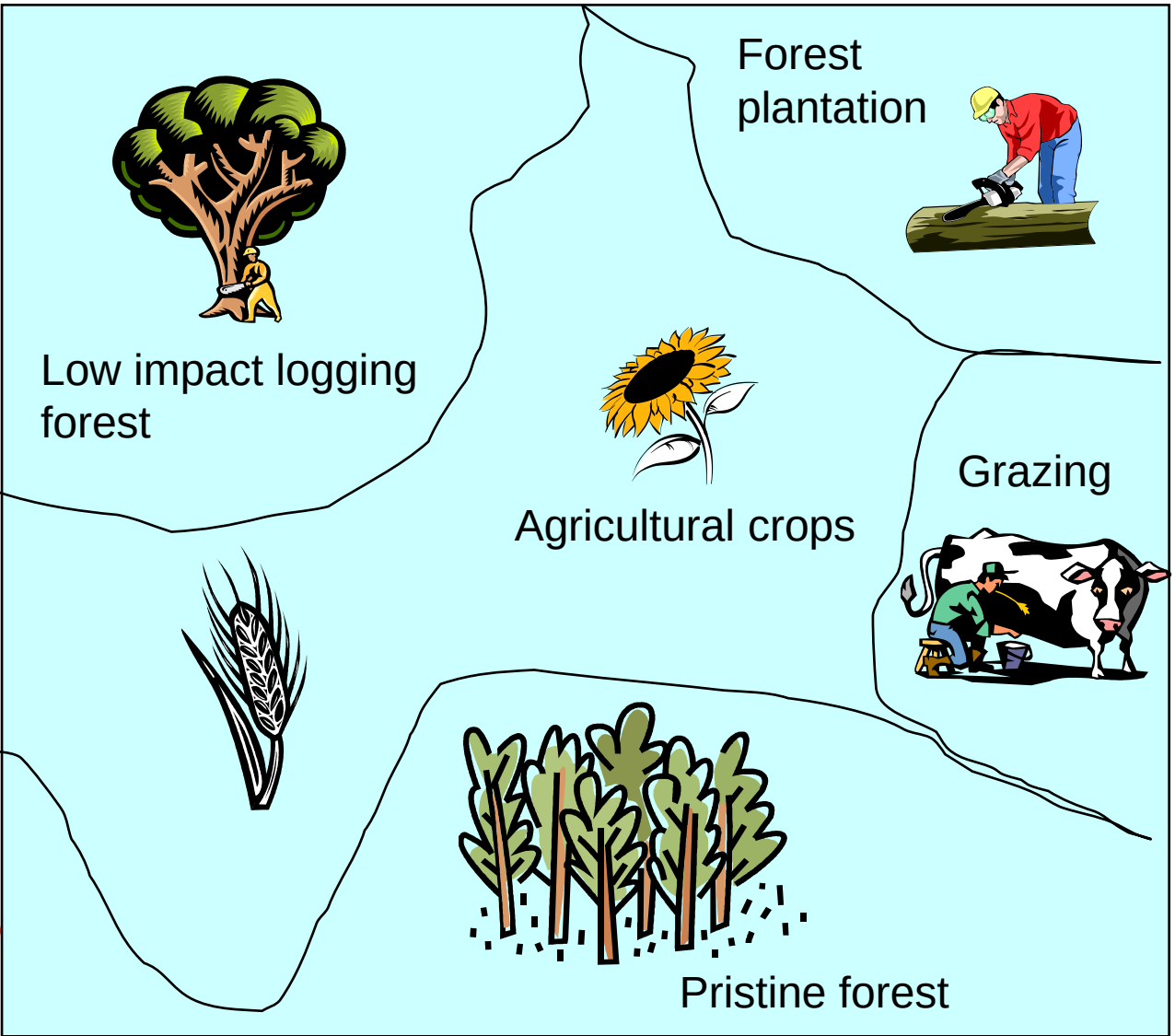
$$\mathbf{MSA = MSA_{LUC} * MSA_{CC} * MSA_N * MSA_I * MSA_F}$$

MSA= Mean abundance of original species relative to pristine

MSA_{LUC} = Remaining MSA for land use change
MSA_{CC} = Remaining MSA for climate change
MSA_N = Remaining MSA for Nitrogen pollution
MSA_I = Remaining MSA for Infrastructure
MSA_F = Remaining MSA for Fragmentation

$$MSA_U = \frac{\sum_i MSA_i * A_i}{\sum_i A_i}$$

MSA calculation: Biodiversity loss by Land use



MSA_{LU}

Pressures on nature:

Land-cover / land use

- Forest
- Grassland
- Agriculture

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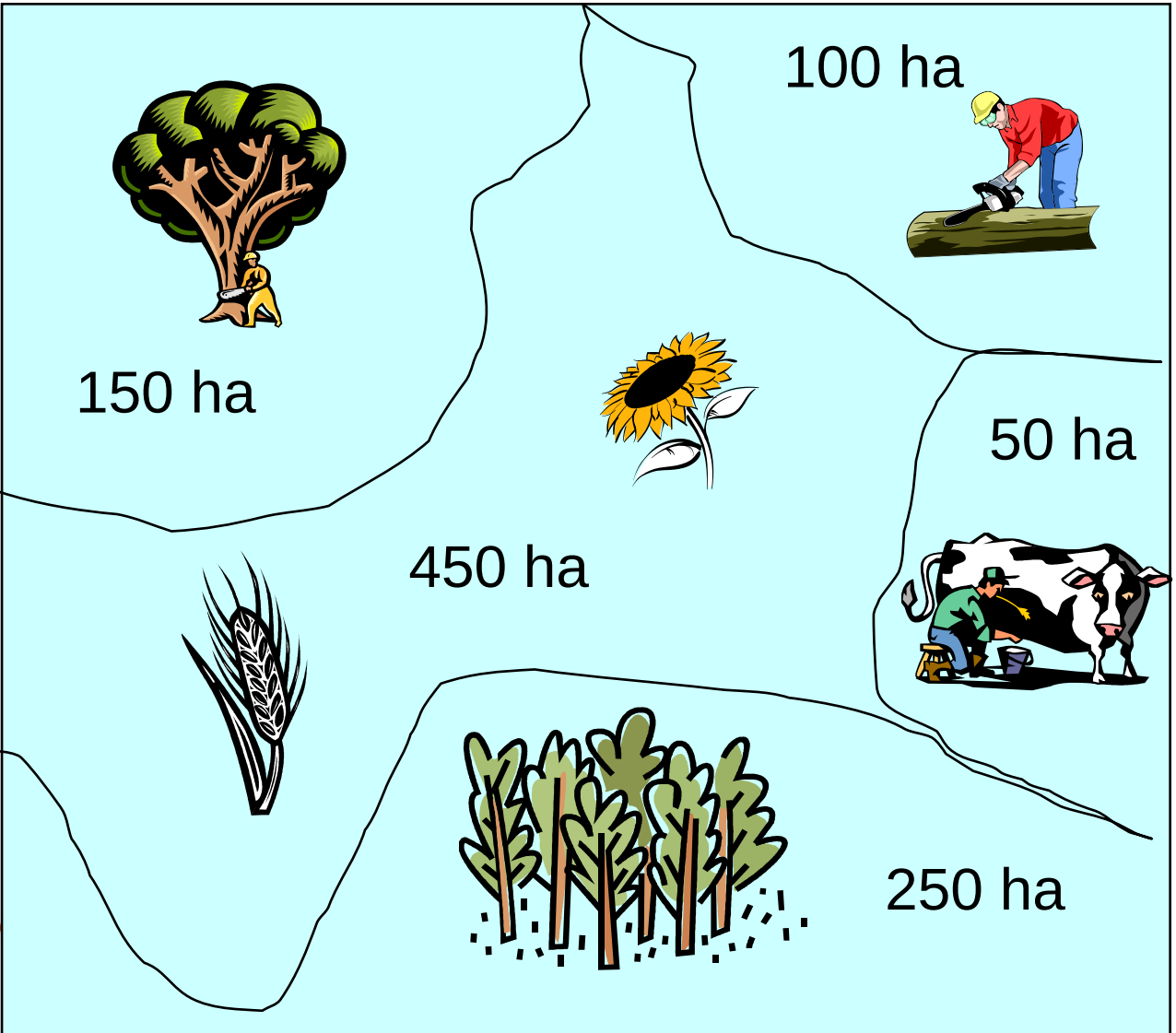
MSA calculation: Biodiversity loss by Land use

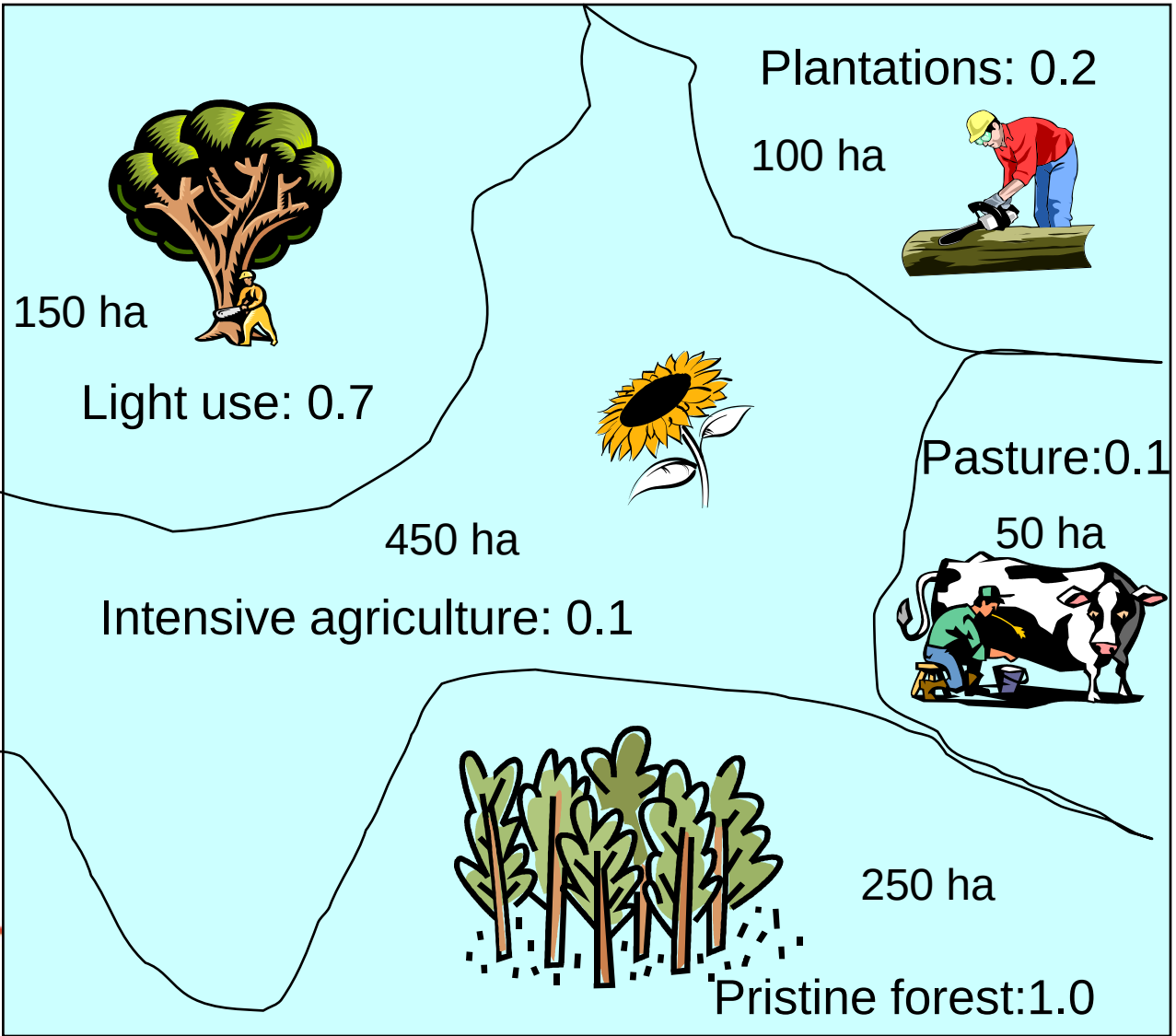


MSA_{LU}

Land-use intensities

- Unaltered forest
- Low impact logging
- Plantation forest
- Intensive grazing
- Intensive agriculture

MSA calculation: Biodiversity loss by Land use



MSA_{LU}

MSA_{lu}=

(0.7*150 + 0.2*100
+ 0.1*450 + 0.1*50
+ 1.0*250) / 1000

= 43% remaining biodiversity

→ 57% of biodiversity loss is caused by land use

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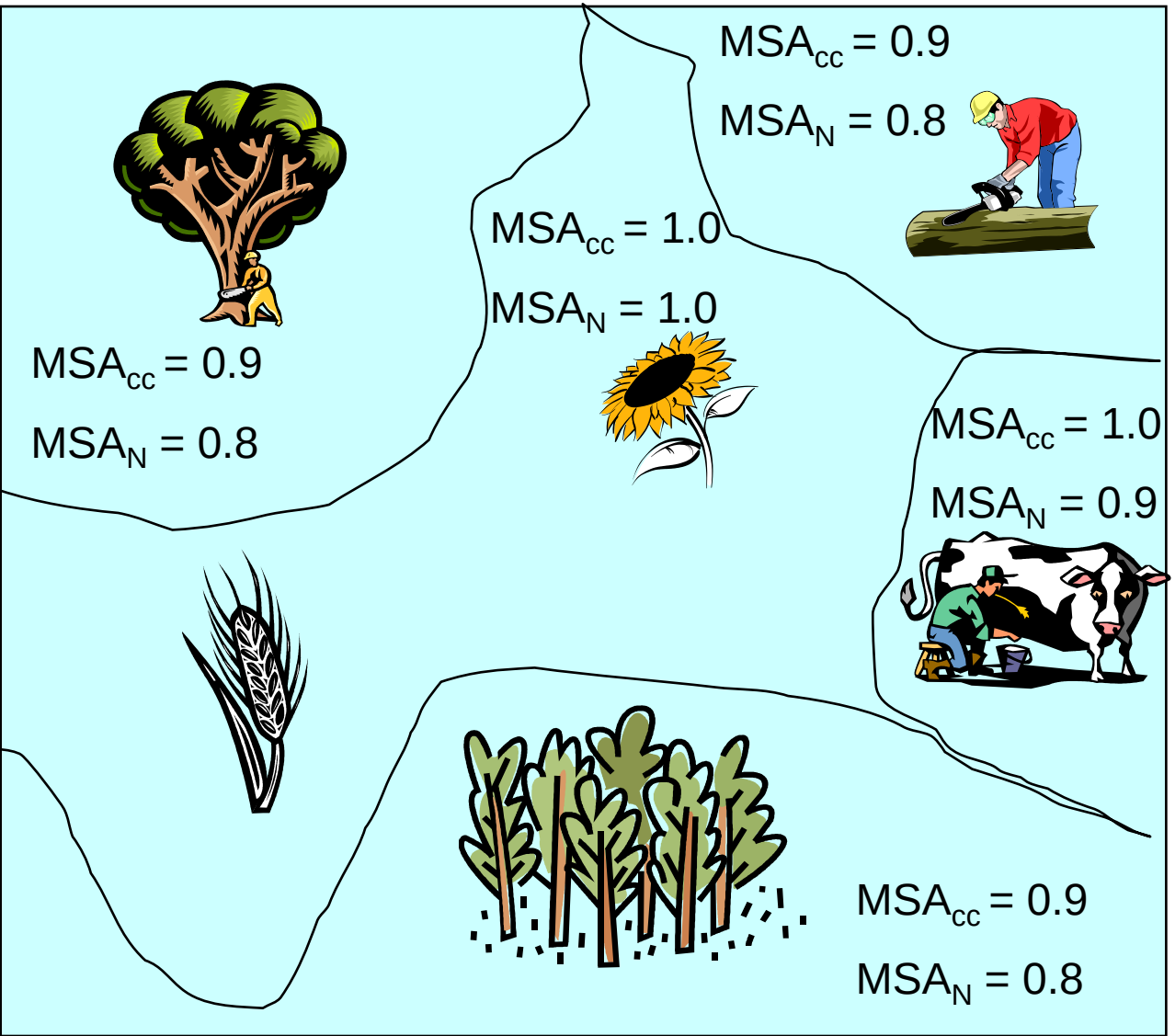
MSA calculation: Biodiversity loss by Nitrogen deposition and Climate change



MSA$_N$

MSA$_{CC}$

Pressures on nature:

- **N-deposition**
- **Climate change**

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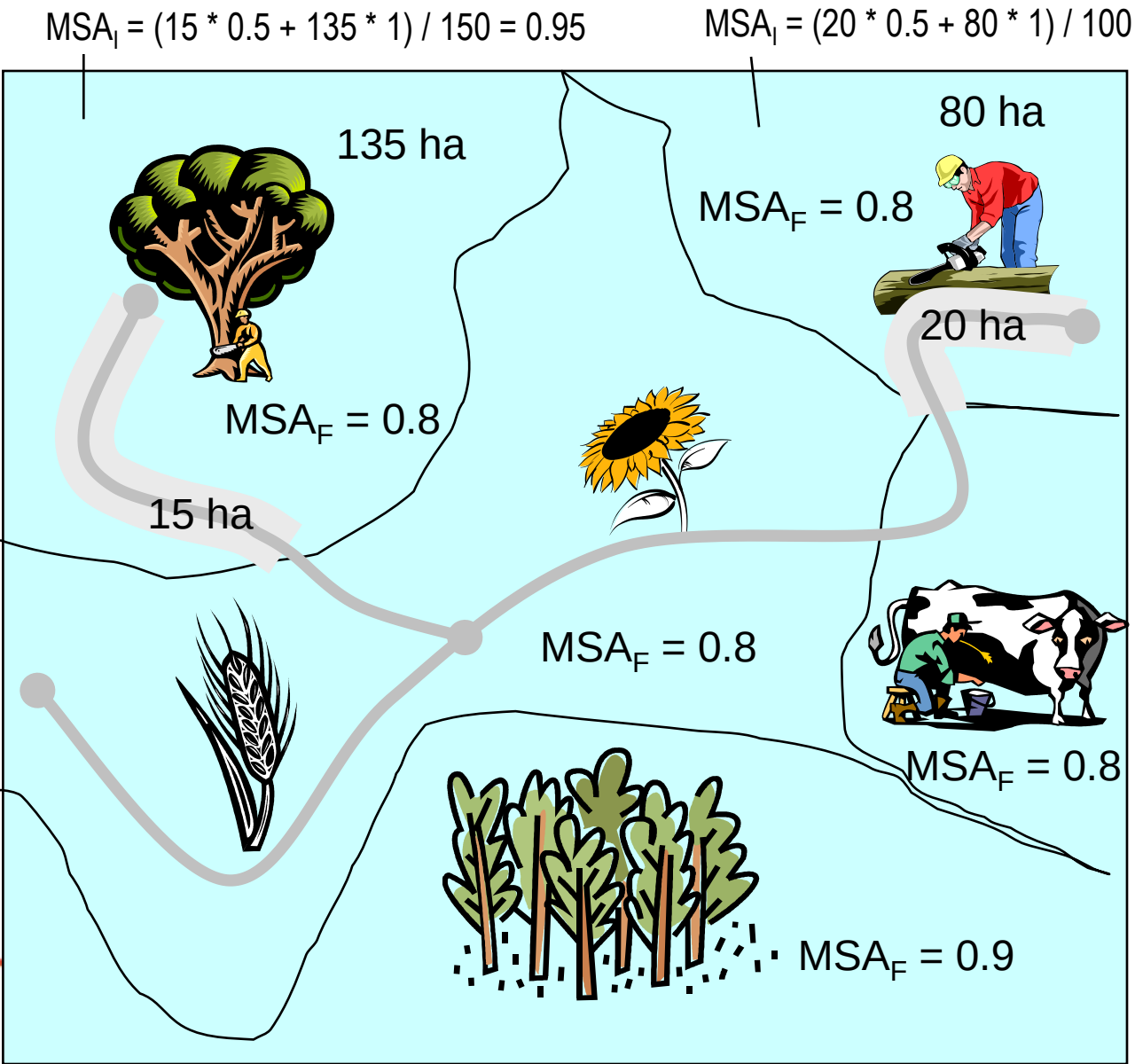
MSA calculation: Biodiversity loss by Infrastructure and Fragmentation



MSA$_I$

MSA$_F$

Pressures on nature

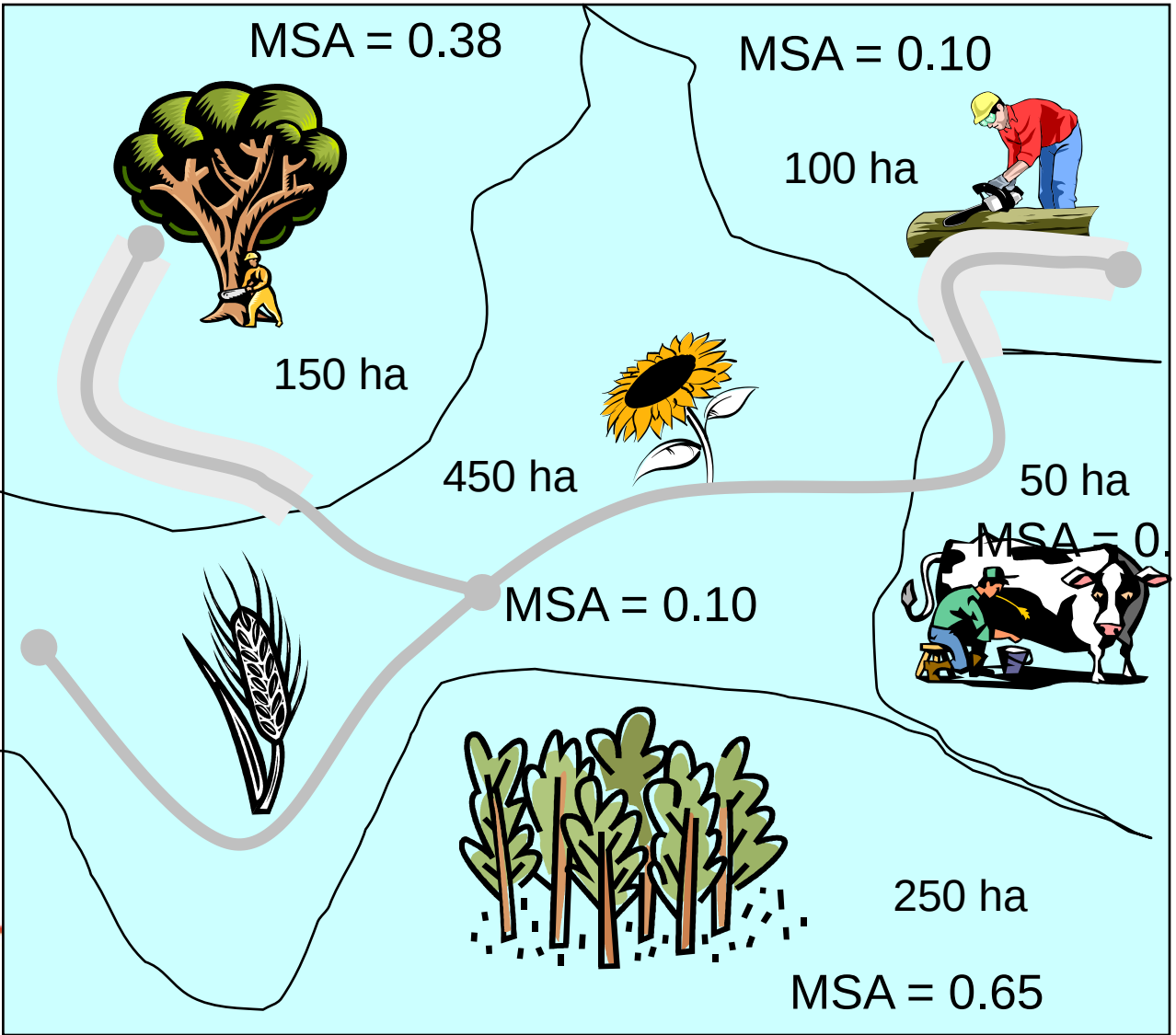
- **Infrastructure**:

  Influence area (buffer)
  x impact factor

- **Fragmentation**:

  Factor patch size **x** area

MSA calculation: Overall biodiversity



Total MSA

MSA =
Σ (Area x MSA) /Tot Area

=

(150 * 0.38 + 100 * 0.1
+ 450 * 0.1 + 50 * 0.09
+ 250 * 0.65) / 1000

= **0.28**

= 28% of original biodiversity is left

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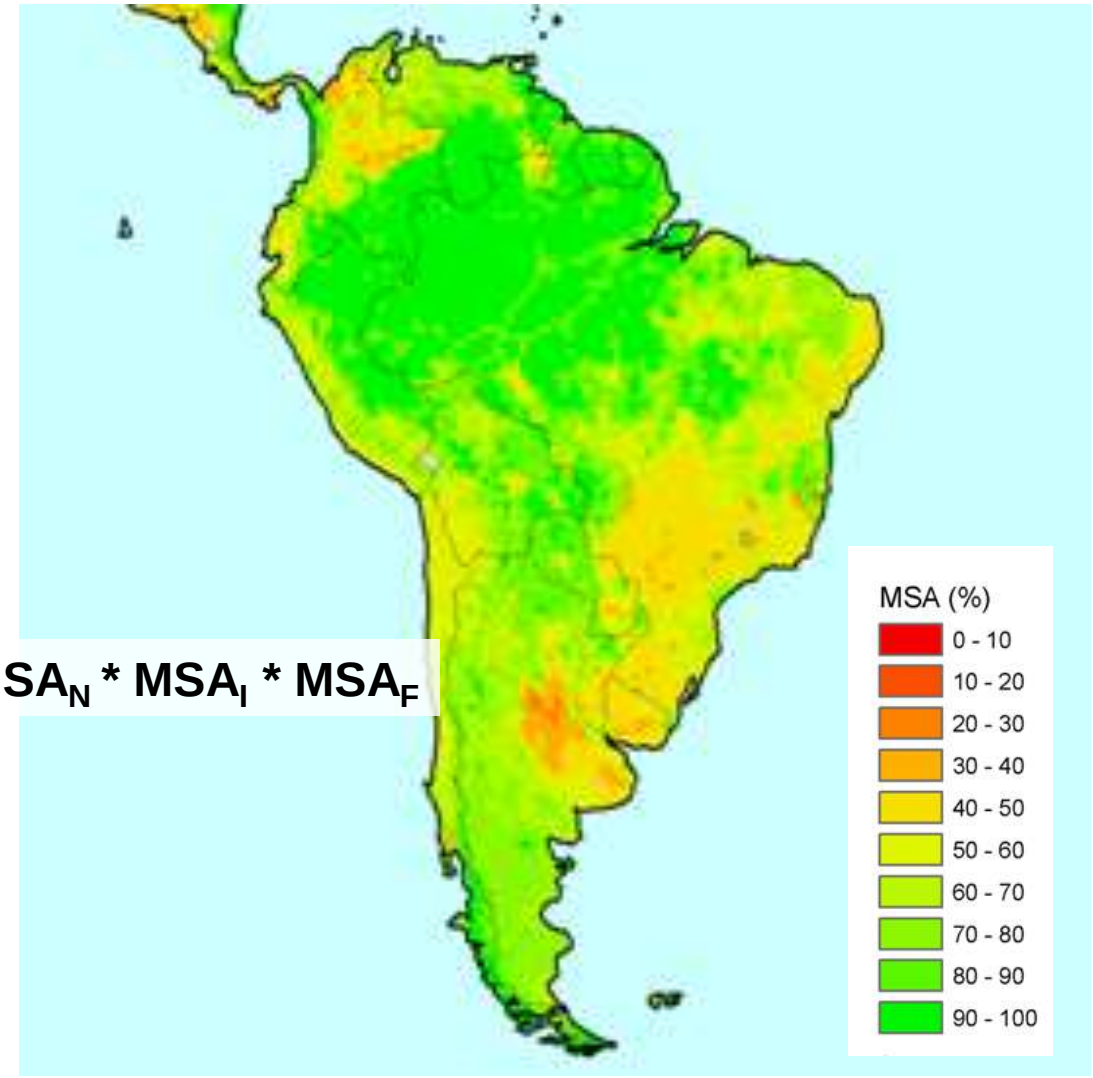
GLOBIO3: Global model output: MSA 2000 South America

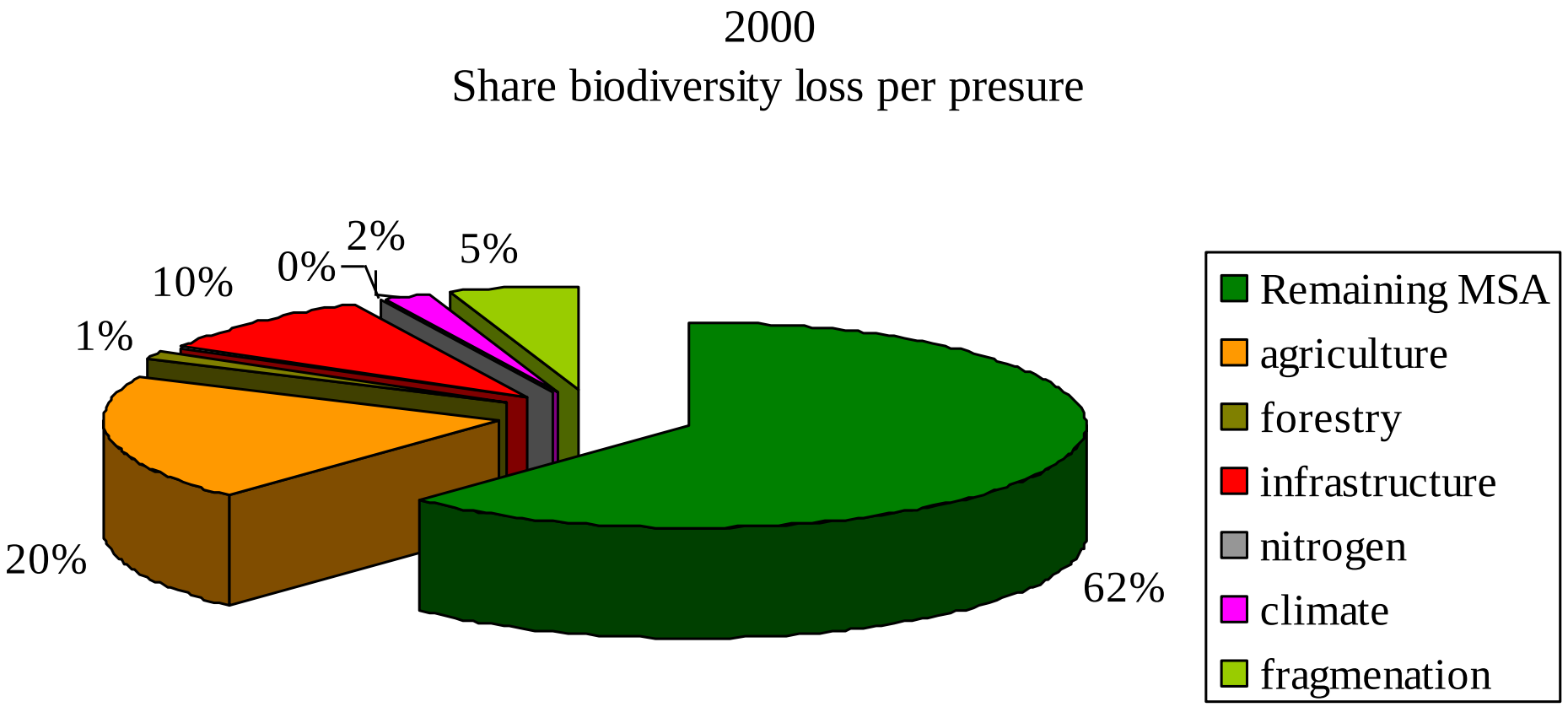
Output MSA maps for each pressure are combined

by multiplication:

$$MSA_{tot} = MSA_{LUC} * MSA_{CC} * MSA_{N} * MSA_{I} * MSA_{F}$$



Biodiversity loss per pressure: Latin America and the Caribbean



Generic land use biodiversity table

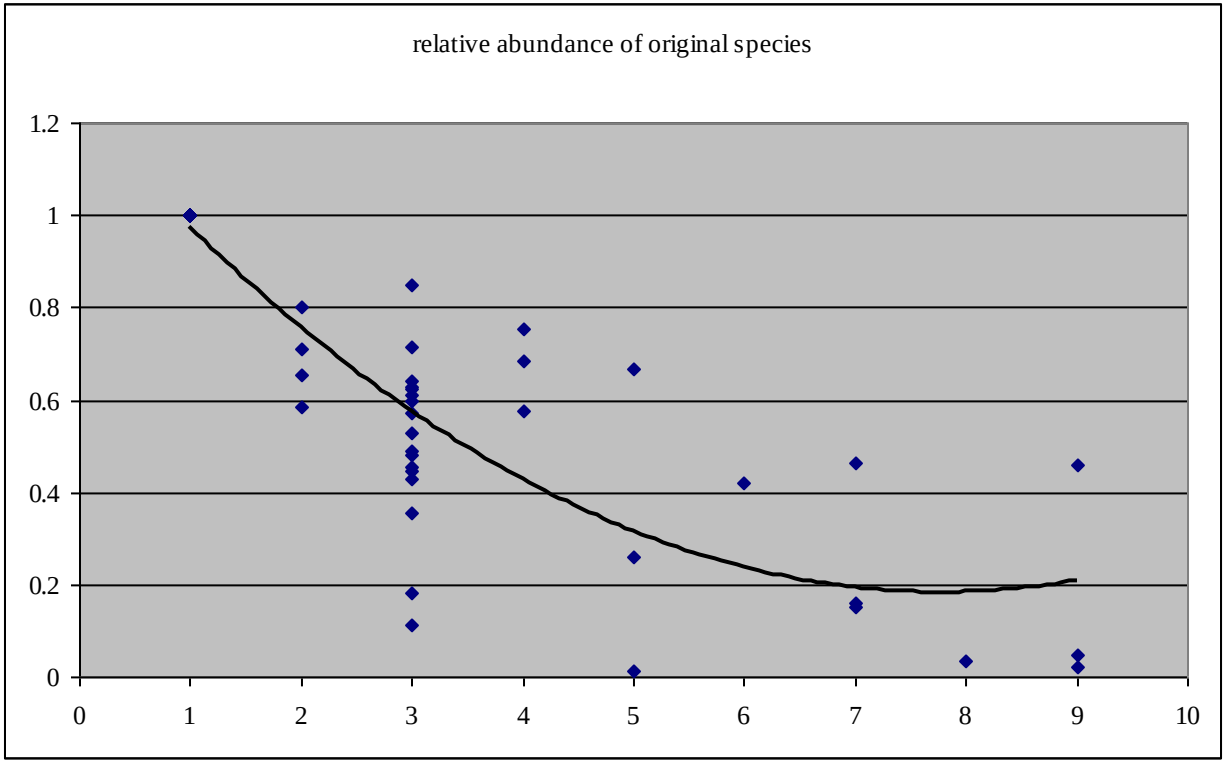
Biodiversity values (MSA) are derived for a set of generic land use types

The model is not limited to these generic classes,

but added relations have to be based on scientific literature too

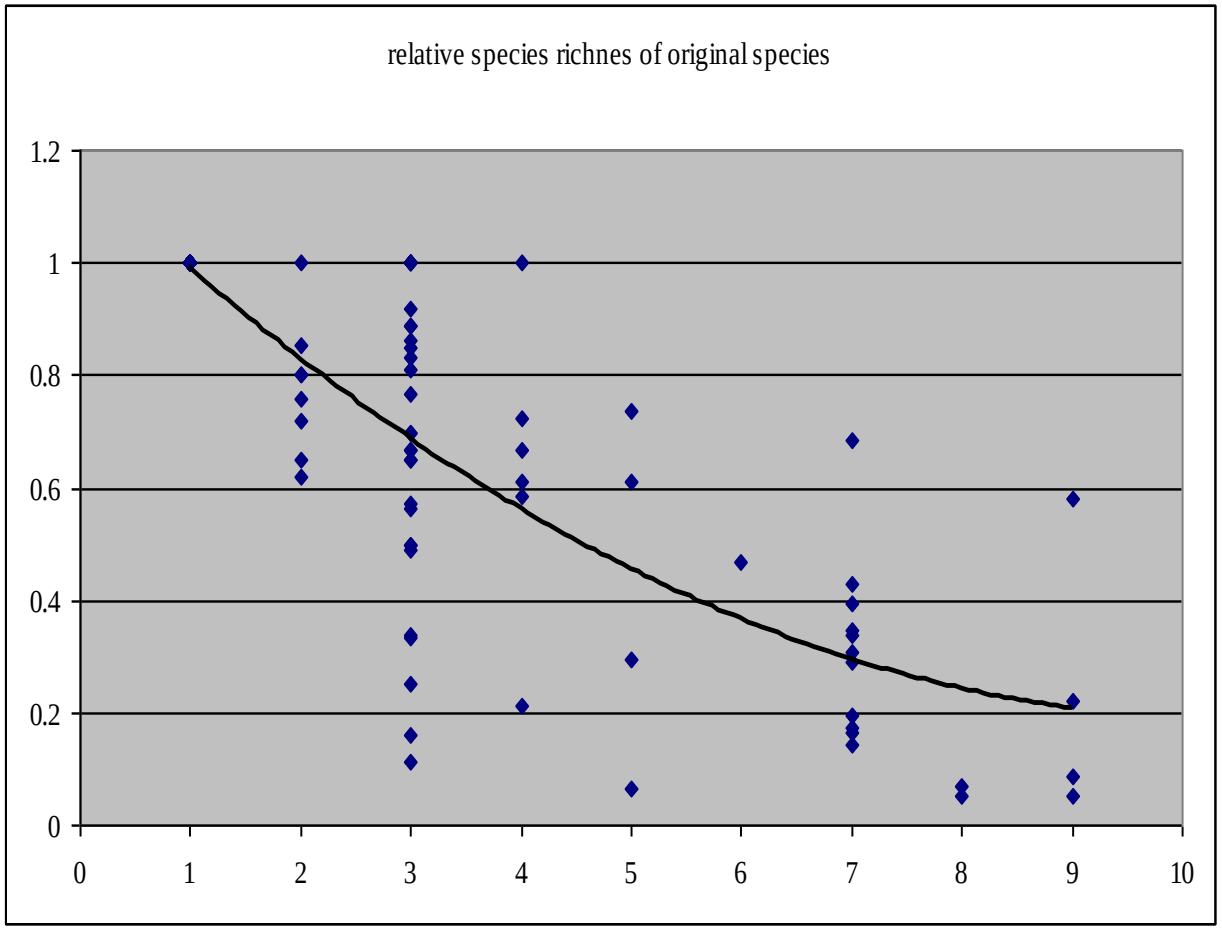
Biodiv class name	MSA value
Primary forests	1.0
Forest plantations	0.2
Secondary forests	0.5
Light used primary forests	0.7
Agro forestry	0.5
Extensive agriculture	0.3
Irrigated intensive agriculture	0.05
Intensive agriculture	0.1
Perennials & bio fuels	0.2
Natural grass & shrub lands	1.0
Man made pastures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

Impact of land use on forests: Mean abundance



1: primary
2: lightly used
3: secondary
4: agro-forestry
5: plantations
6: perennials
7: low input agri
8: intensive agri
9: pasture

Impact on forest: species richness original species



- 1: primary
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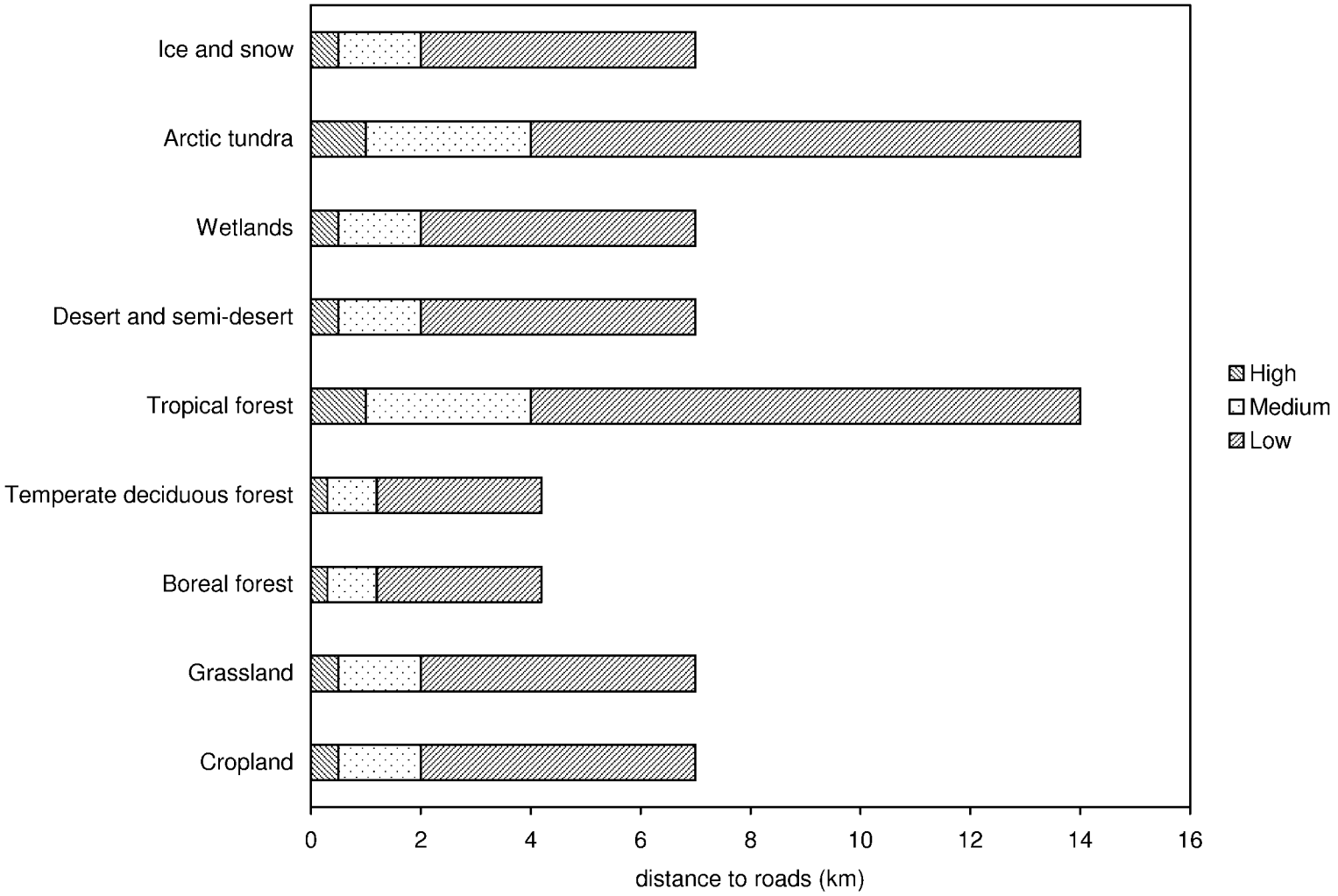
Impact zones of infrastructure



Infrastructure: MSA vs Distance to Road

Influence of population and different impact per buffer zone for future years

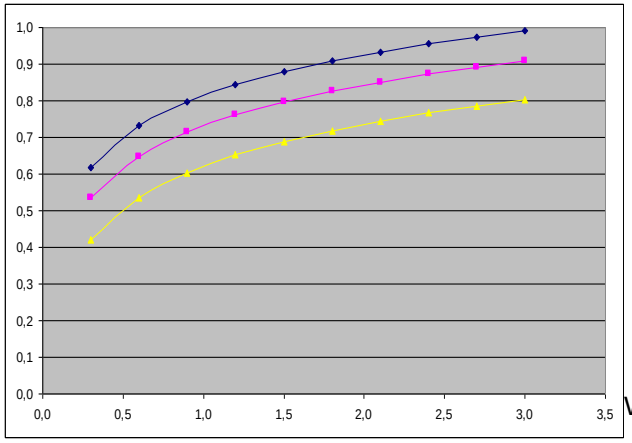
Relative impact per ecosystem

cropland	**1**
grassland	**0.75**
boreal forest	**1.25**
temp. deciduous	**1.75**
tropical forest	**1.75**
semi-deserts/ deserts	**0.5**
wetalnds	**1**
arctic tundra	**0.75**
Ice ans snow / barren	**0.25**

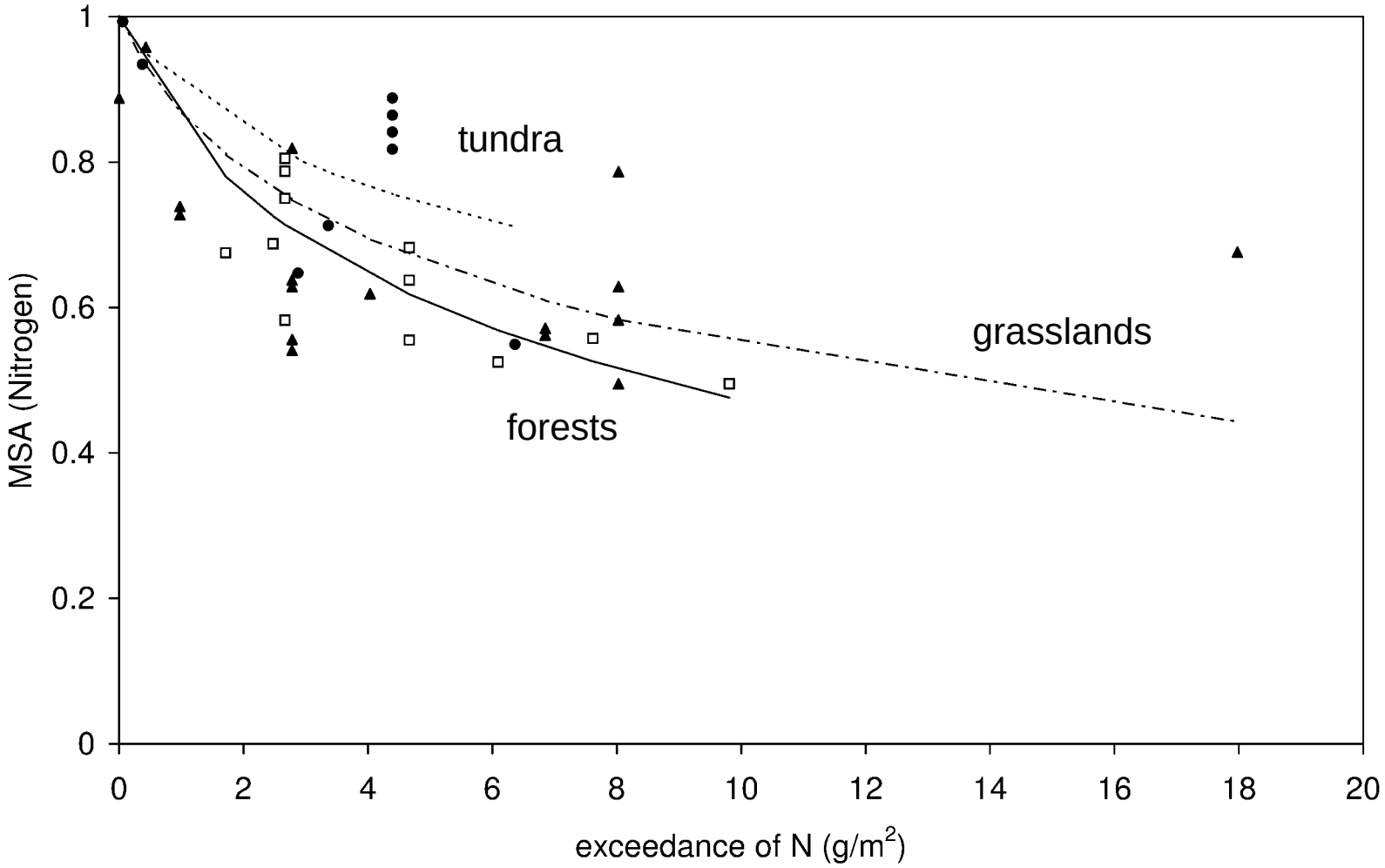
2000	Zone in km
impact 1 (MSA = 0.5)	0.5
impact 2 (MSA = 0.75)	1.5
impact 3 (MSA = 0.9)	5
2030	
impact 1 (MSA = 0.5)	0.67
impact 2 (MSA = 0.75)	2.02
impact 3 (MSA = 0.9)	6.74
2050	
impact 1 (MSA = 0.5)	0.82
impact 2 (MSA = 0.75)	2.47
impact 3 (MSA = 0.9)	8.22

Example cropland with population density

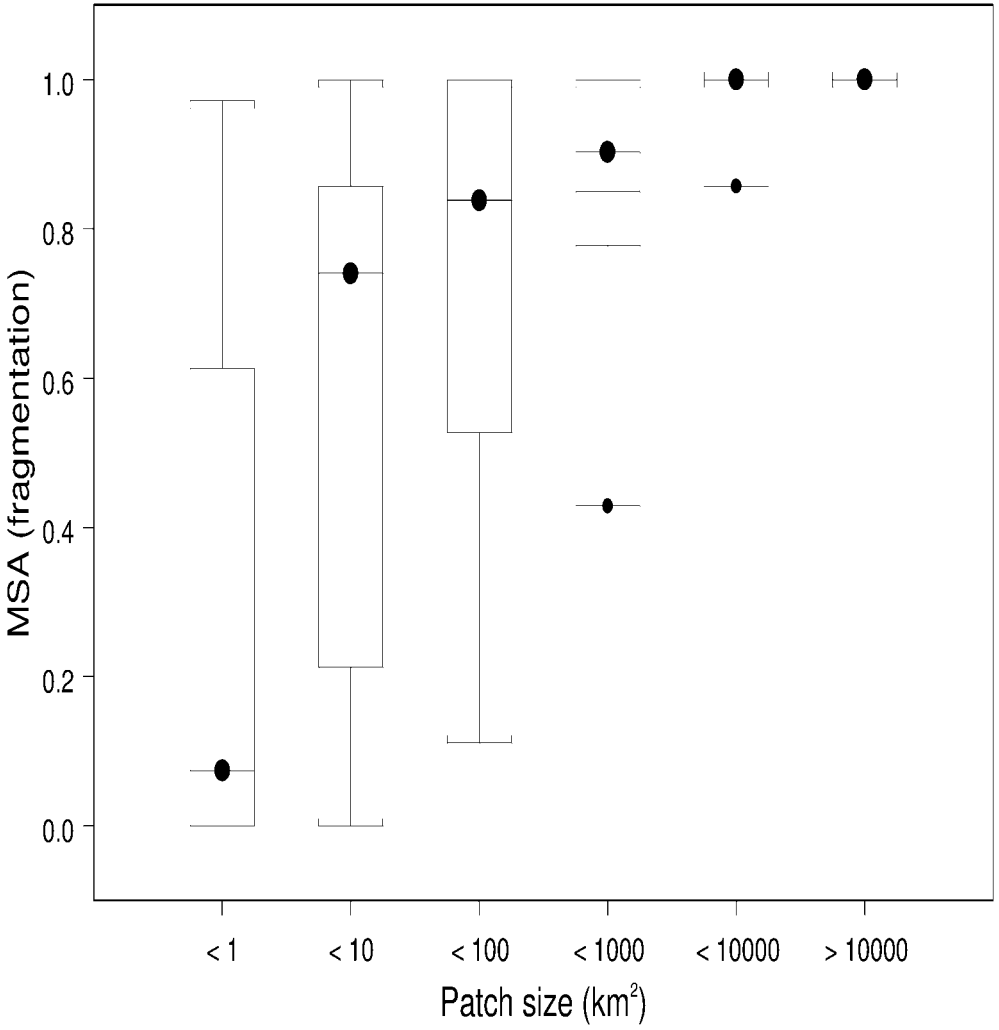
2000	Zone in km
Impact 1 (standard, MSA = 0.5)	0.500
with population density 0-10 / km2	0.250
with population density 10-50 / km2	0.500
with population density >50 / km2	0.750
Impact 2 (standard, MSA = 0.75)	1.500
with population density 0-10 / km2	0.750
with population density 10-50 / km2	1.500
with population density >50 / km2	2.250
Impact 3 (standard, MSA = 0.9)	5.000
with population density 0-10 / km2	2.500
with population density 10-50 / km2	5.000
with population density >50 / km2	7.500

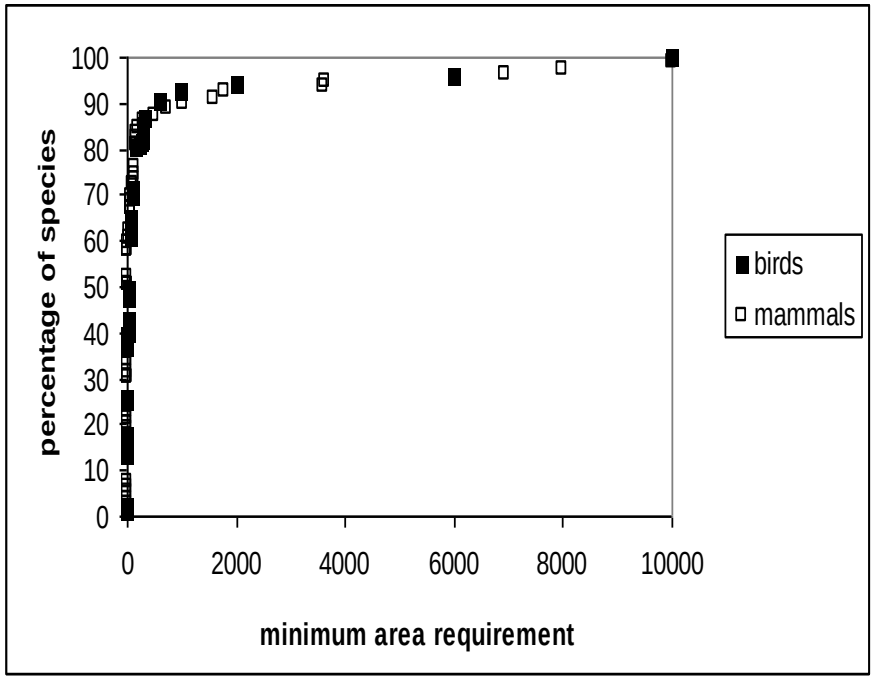


MSA versus nitrogen deposition

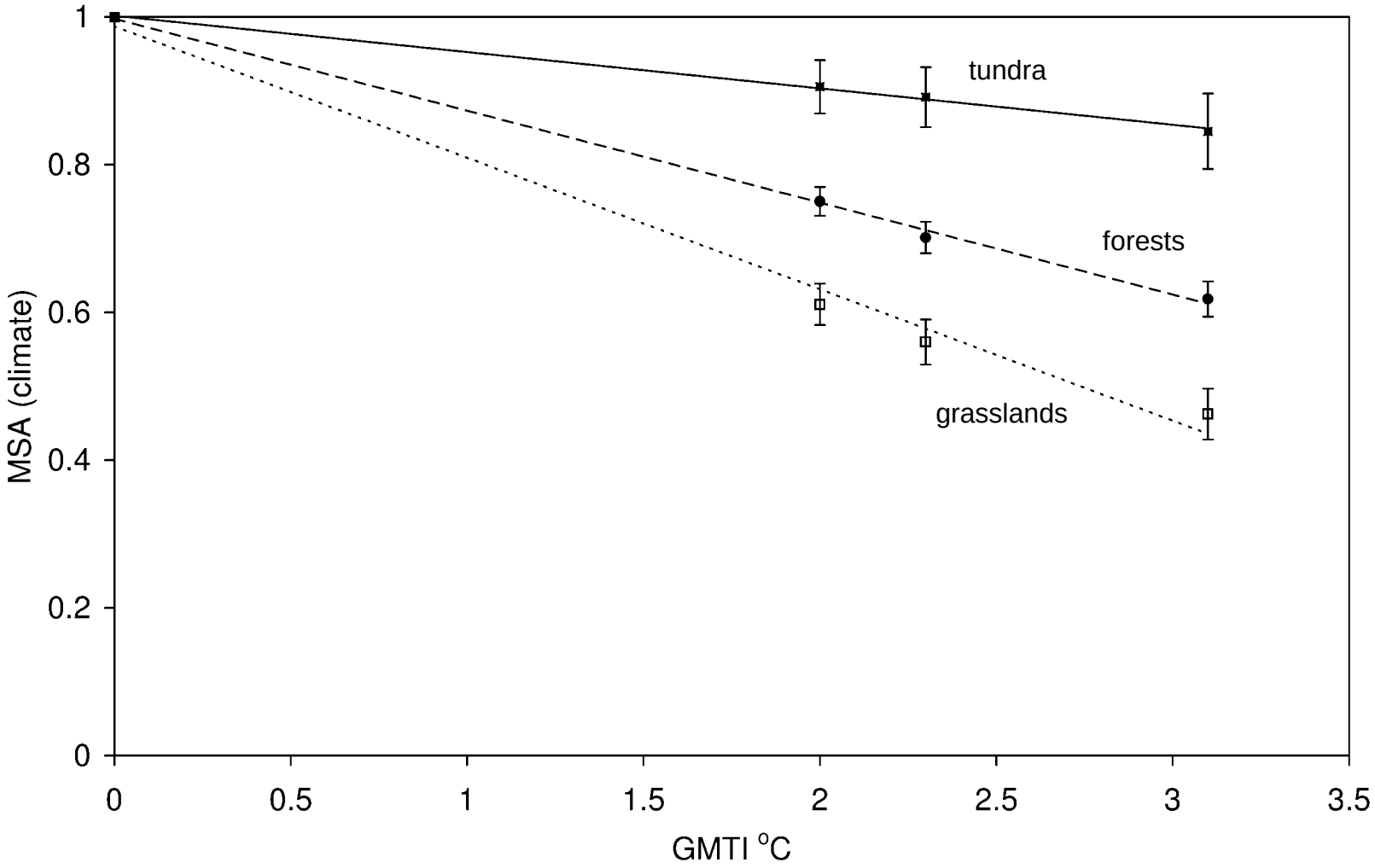


MSA versus patch size (fragmentation)





MSA versus climate change



Temp change: IMAGE OECD Baseline scenario
Increase since pre-industrial era

year	Degrees
1970	0.187
1975	0.179
1980	0.217
1985	0.302
1990	0.382
1995	0.496
2000	0.569
2005	0.647
2010	0.759
2015	0.882
2020	1.007
2025	1.149
2030	1.298
2035	1.432
2040	1.573
2045	1.714
2050	1.847

1890 – 2009: + 0.74 ºC degrees

1890 – 2020: + 1 ºC degrees

Biome	Slope ($^{o}C^{-1}$)	
	Image	EuroMove
Ice	0.023*	0.05
Tundra	0.154	0.07*
Wooded tundra	0.284	0.051*
Boreal forest	0.043*	0.079
Cool conifer forest	0.168	0.080*
Temperate mixed forest	0.045*	0.101
Temperate deciduous forest	0.100*	0.109
Warm mixed forest	0.052*	0.139
Grassland and steppe	0.098*	0.193
Hot desert	0.036*	-
Scrubland	0.129*	0.174
Savanna	0.093*	-
Tropical woodland	0.039*	-
Tropical forest	0.034*	-

Global to national: Scale differences

- Resolution too coarse for national application
  - Global model 0.5 degree ~ 50*50 km
  - Global land use / cover map GLC2000 to general. Detailed information national land use maps lost by grouping into generic classes
  - Use of eco-regions (WWF) to determine original ecosystems to coarse and often not familiar in several countries
- Build in land allocation model in IMAGE is designed for global scale
- Scenarios used in IMAGE model are Global (sub continental) Only regional models for: economy, demography, agricultural trade, energy supply and demand

Solution: Use of national input data in combination with high resolution land allocation model

Vietnam case

- Split the model into relative simple parts per pressure type
  Modular version in ArcGis
- Resolution map grid cells set to 1km * 1km
- National land use map
  - More than 43 land cover / use classes
  - Estimate current biodiversity values per land use class based on expert knowledge
- National road map.
  Use of 100m buffer zones for calculation of impact zones
- Using CLUE model to allocate future land use

Allocation of biodiversity values to land use classes

Generic Lu biodiv. table

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

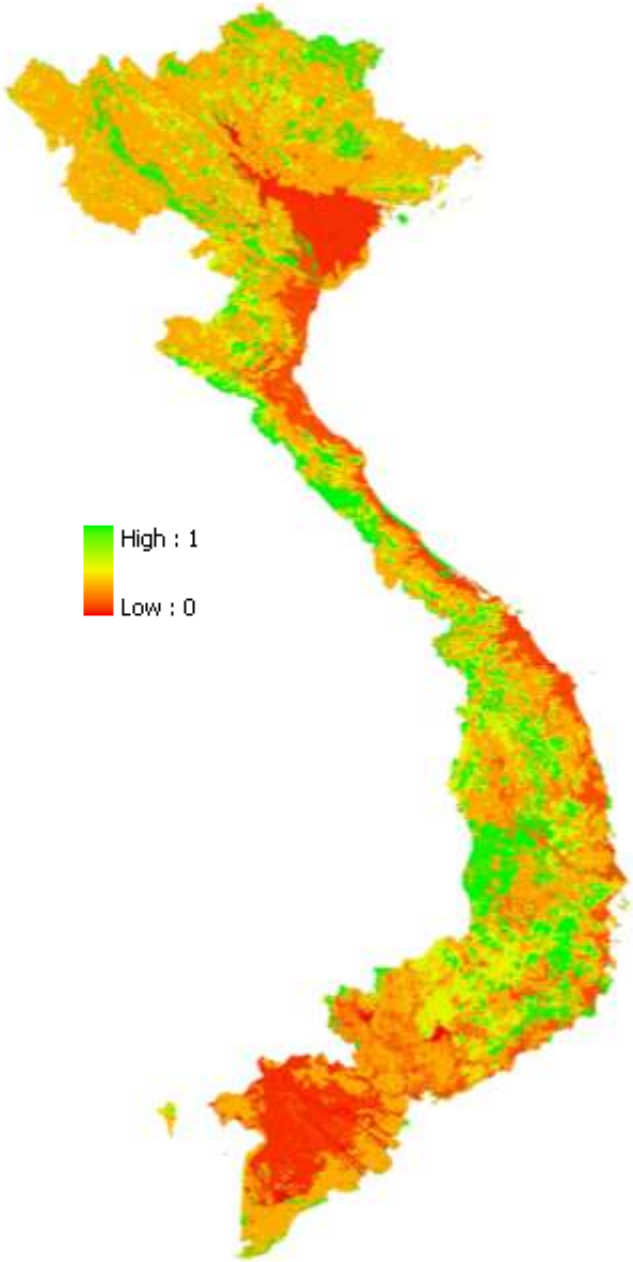
Interpolation of values

based on expert knowledge

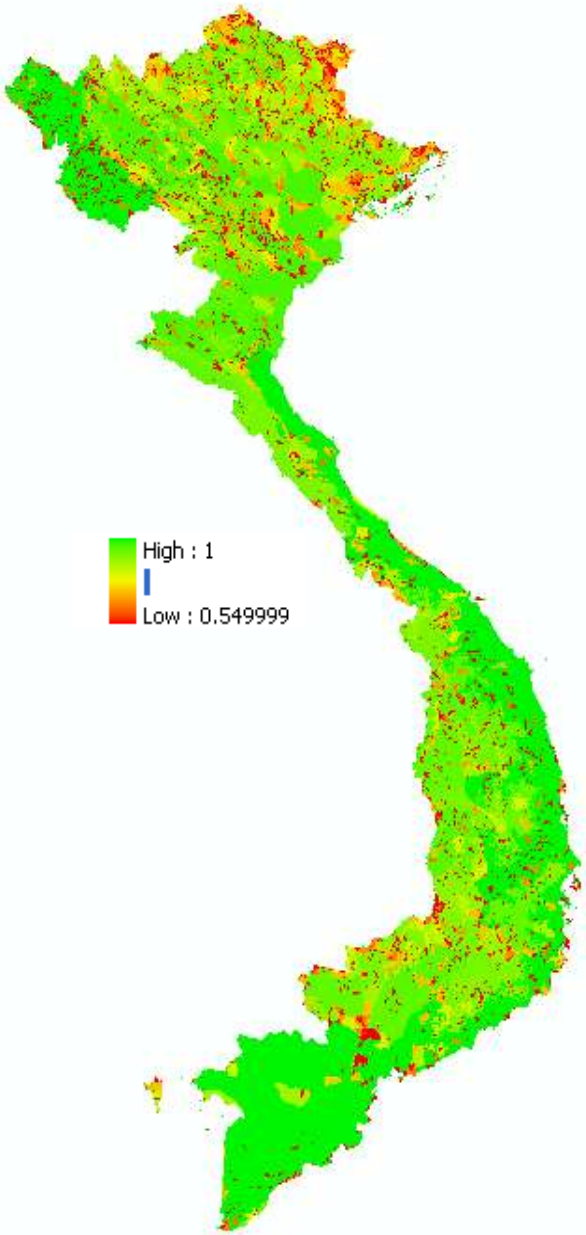
Vietnam Lu biodiversity value table

Code	Lu original (2002)	Local MSA value
10	Natural Timber Forest	0.9
11	Rich Forest	1
12	Medium Forest	0.8
13	Poor Forest	0.6
20	Young Forest	0.55
21	Reforestation Rich	0.45
22	Reforestation Medium	0.4
23	Young forest with volume	0.55
24	Young forest with no volume	0.45
31	Dipterocarp forest (deciduous)	0.95
32	Semi- deciduous forest	0.95
41	Natural conifer forest	0.95
42	Mix forest (Broad leaf and conifer forest)	0.8
51	Bamboo forest	0.45
52	Mix forest (Timber+bamboo forest)	0.55
60	Mangrove forest	0.8
70	Plantation forest	0.2
71	Speciality forest	0.9

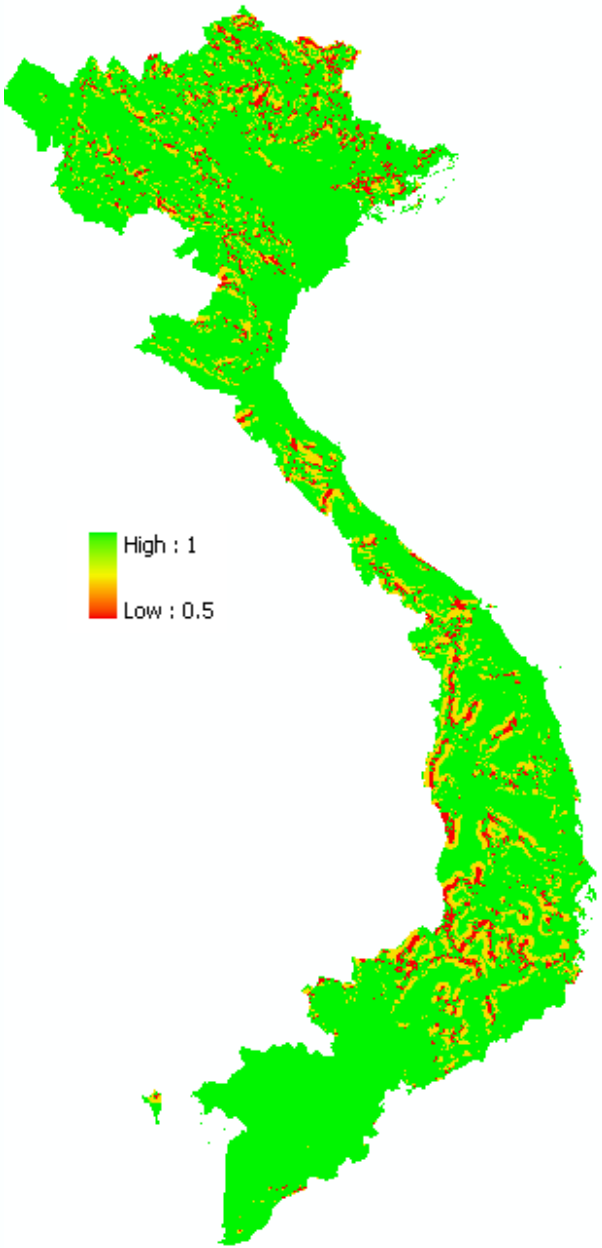
MSA loss Land use



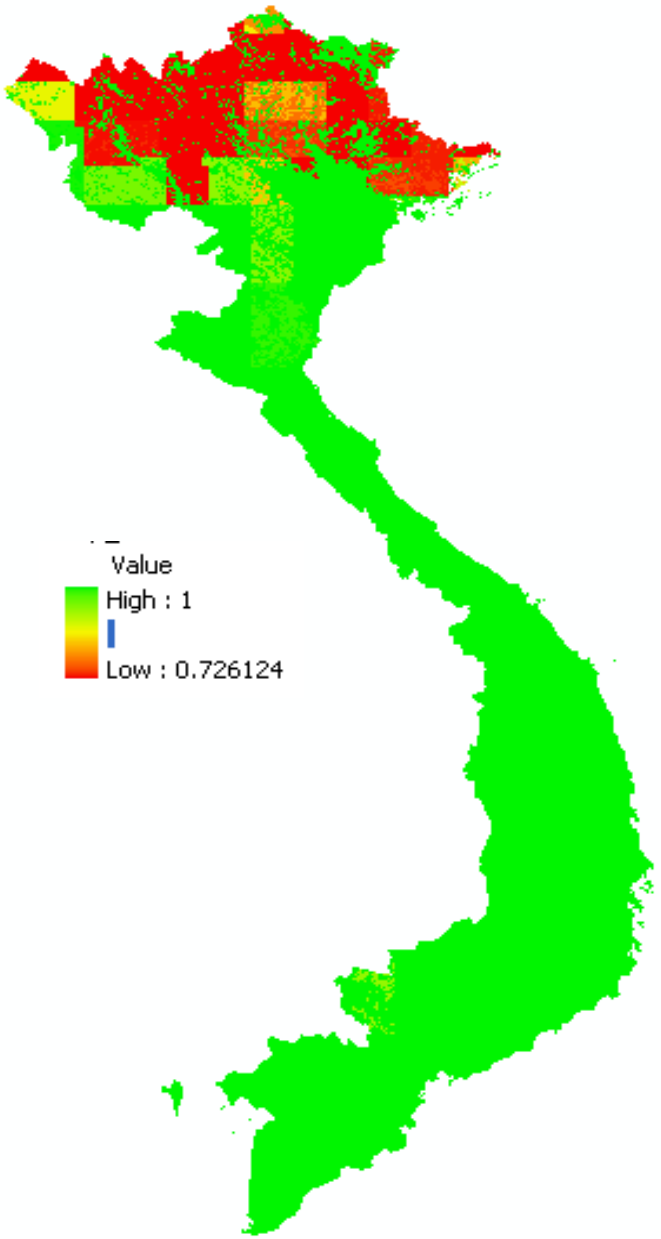
MSA loss Infrastructure



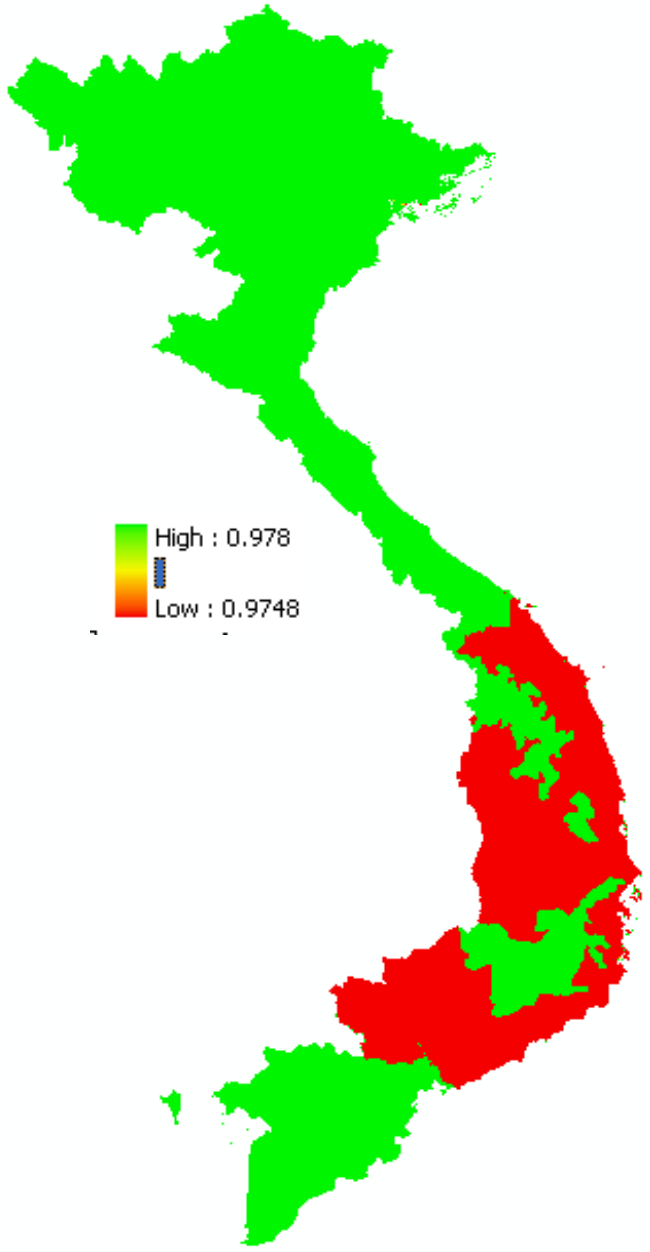
MSA loss Fragmentation



MSA loss Nitrogen deposition



MSA loss Climate change



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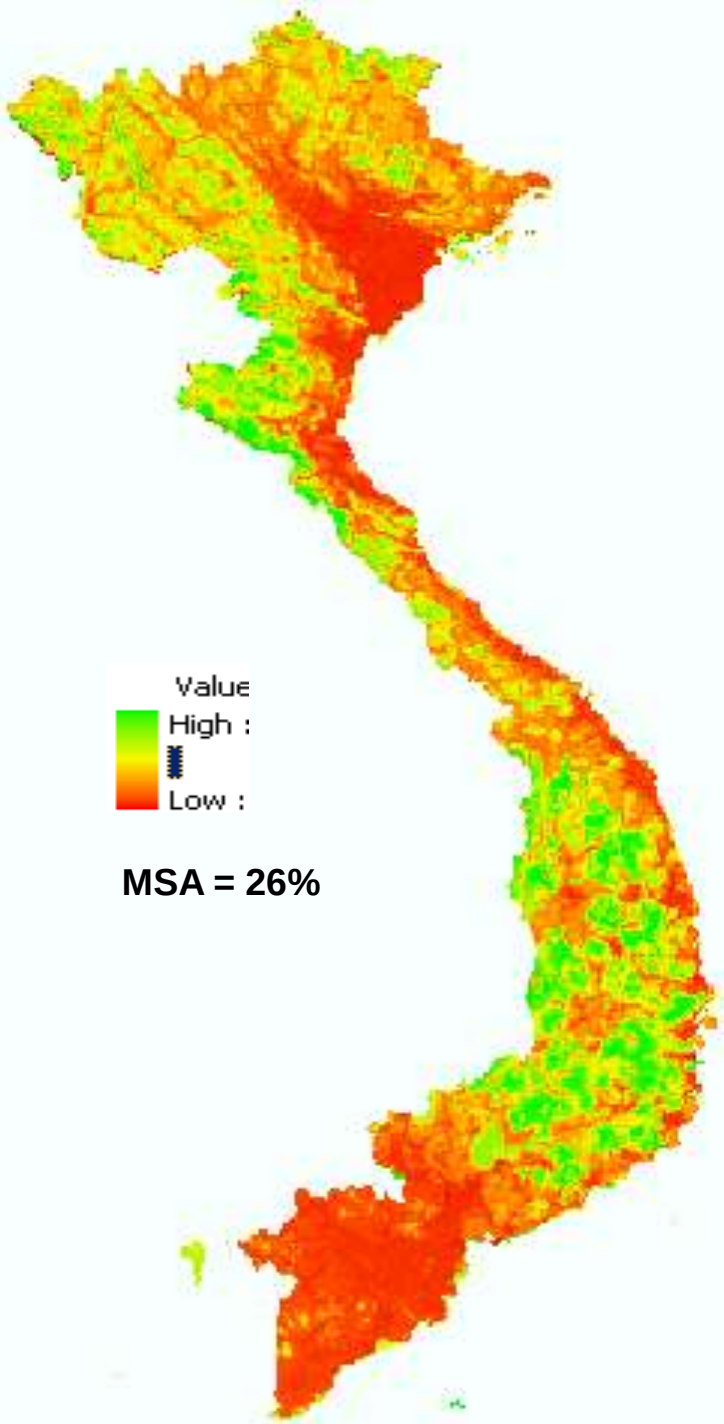
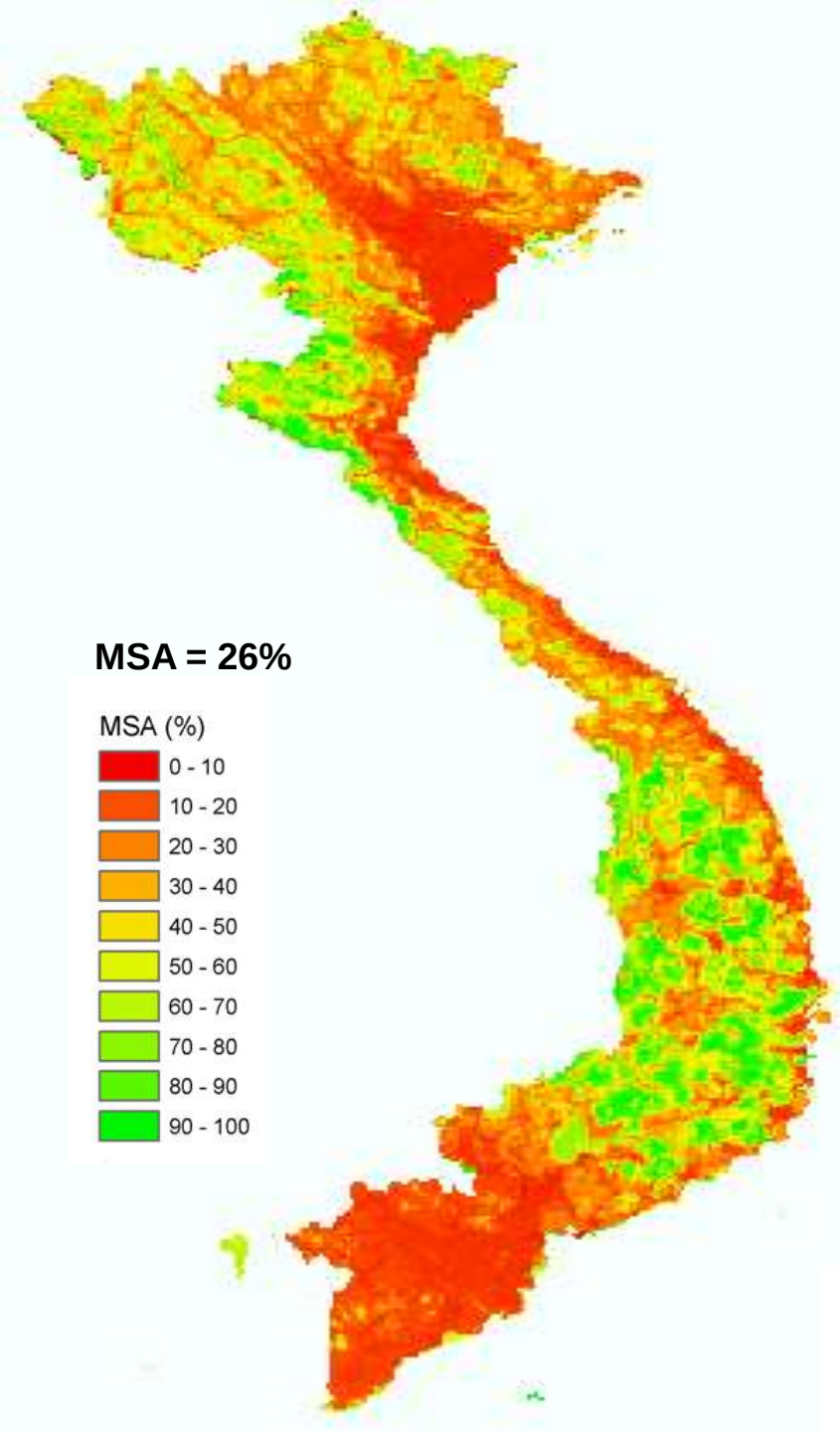
MSA Vietnam in the year 2000

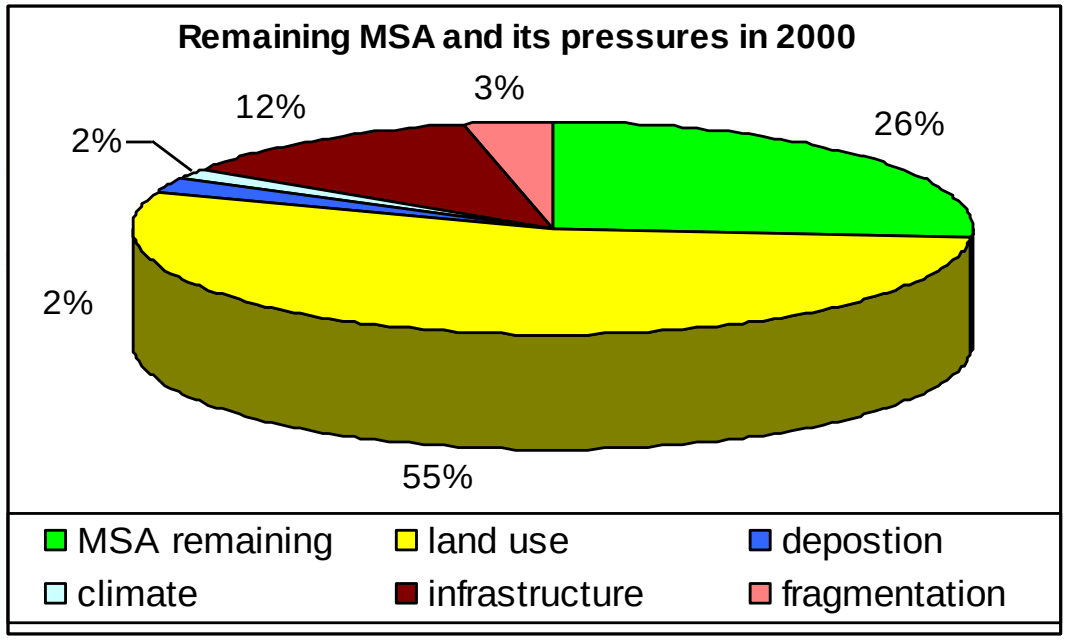
Calculation MSA total in ArcGis
by multiplication of all MSA_pressure maps

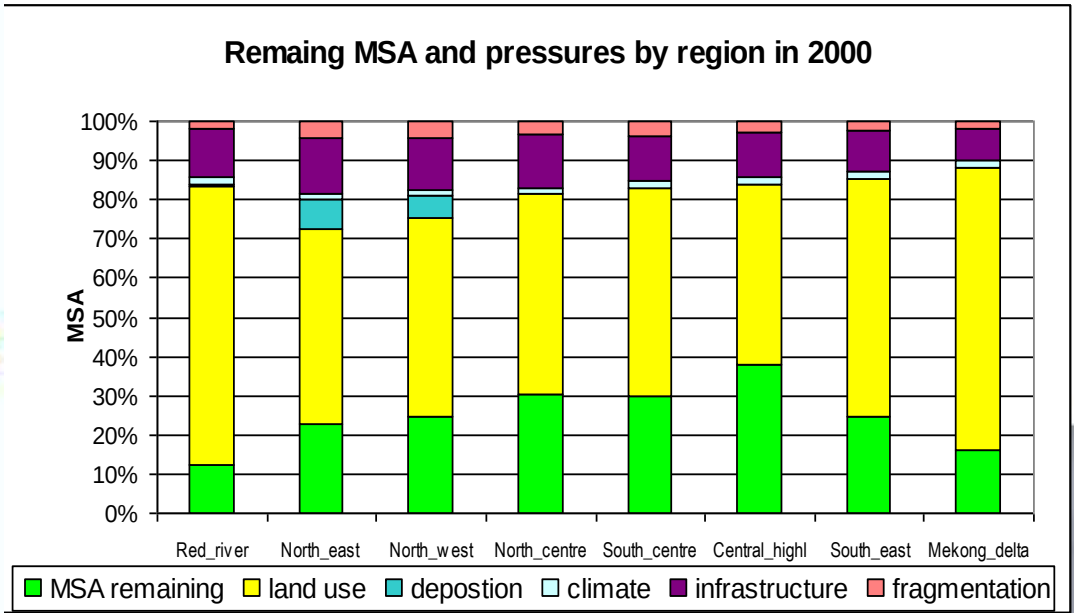
In the raster calculator by:

$MSA = MSA_{LUC} * MSA_{CC} * MSA_{N} * MSA_{I} * MSA_{F}$



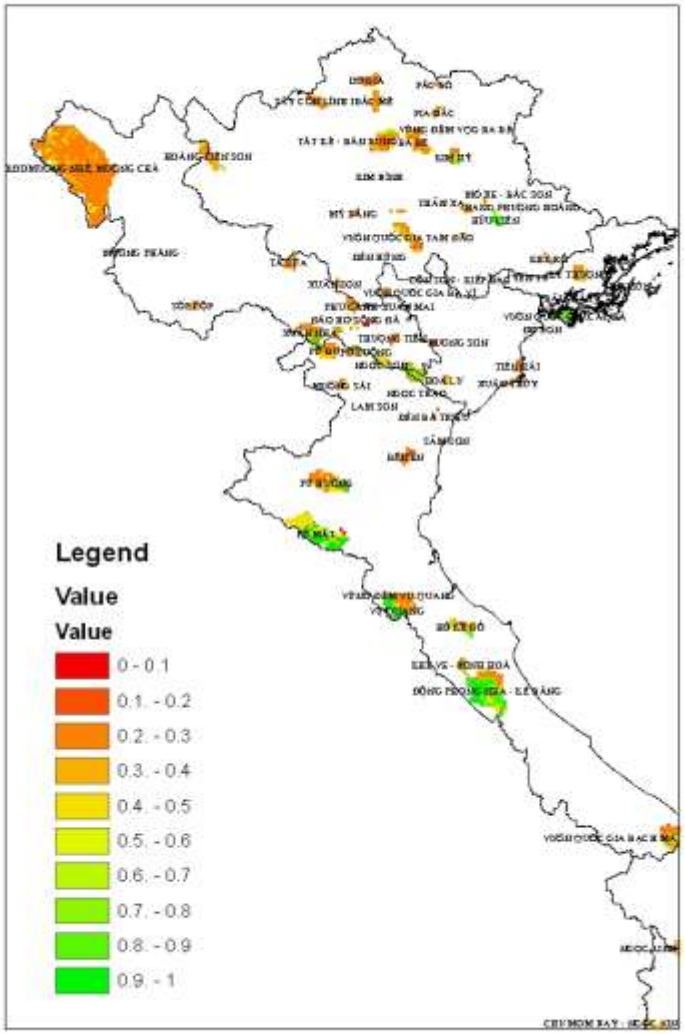


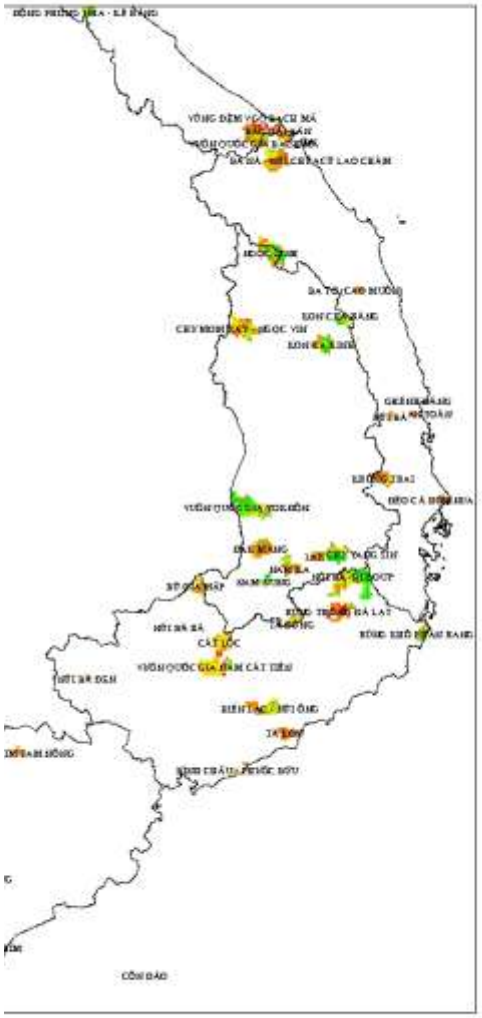




MSA values and factors contributing to biodiversity loss by region in 2000

Review of environmental policies





- Representativeness and effectiveness of protection in protected area (2002)
- MSA loss per original eco-region ecosystem or habitat and in critical habitats

Globio3: Current and future biodiversity status

Model calculations in two parts:

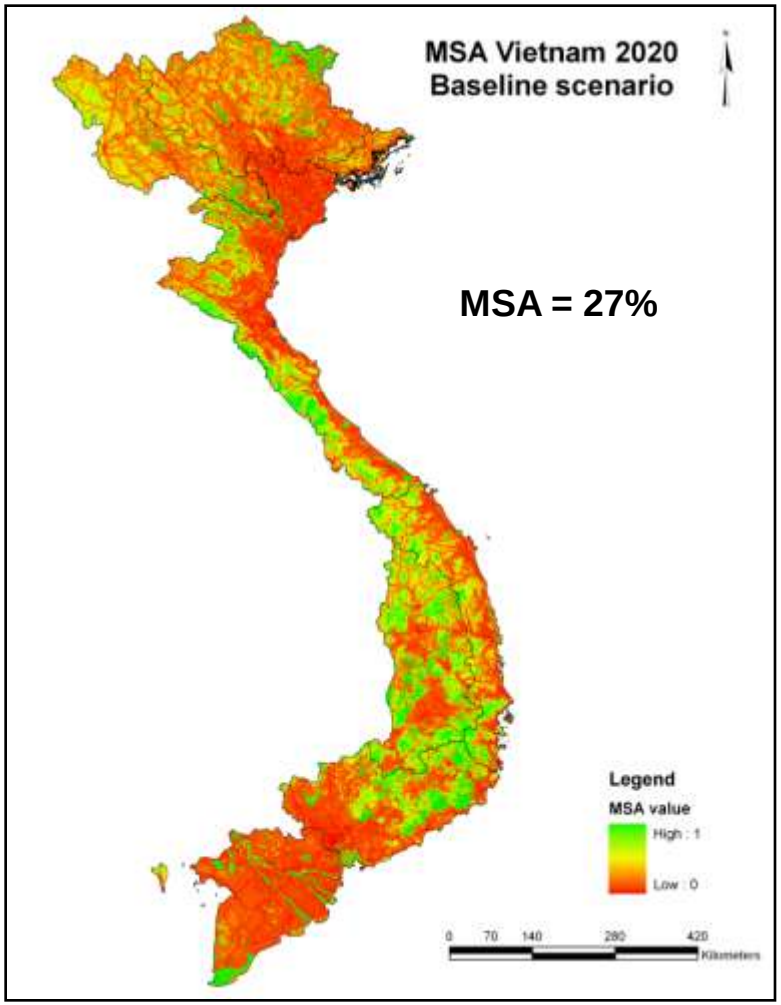
1. Current biodiversity status calculation
   The share of the biodiversity loss per pressure type per admin. unit
   → Global: Current MSA per regions or countries

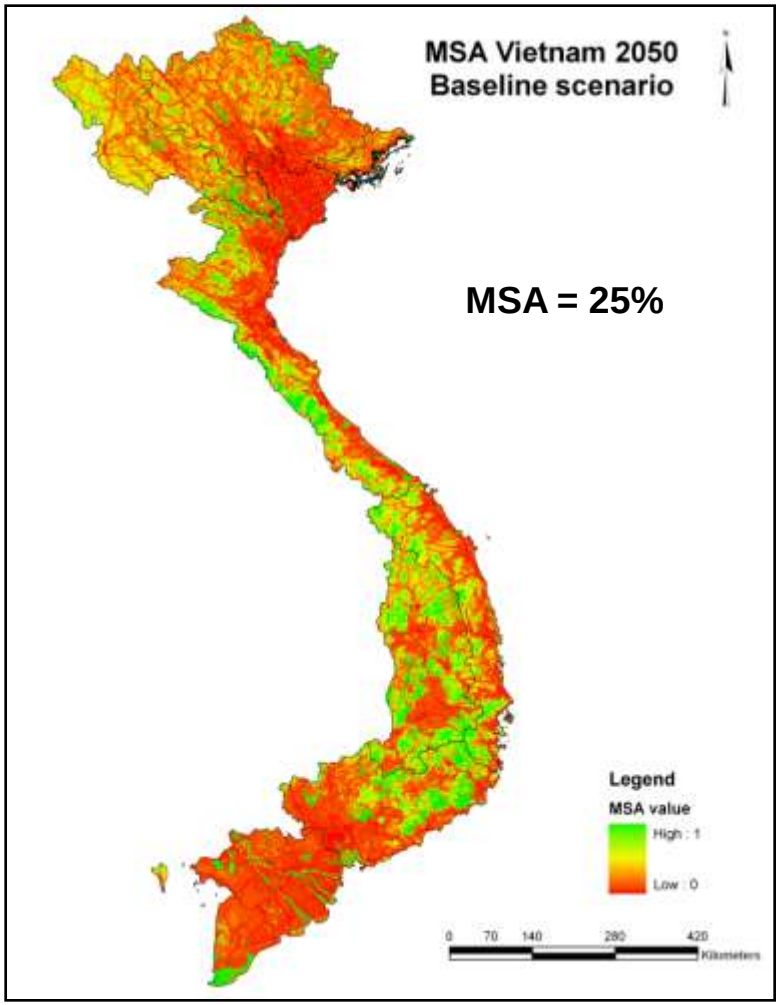
2. Future biodiversity status calculation
   Scenario input is used for the estimation of future land use*
   Calculation future status based on the future land use, impact Infra, Fragm, Nitr & Climate used to calculate future.

Result: Relative trend

* e.g. expected increase of crop area by 10% and decrease of forest area by 5% in 2020. This information is used for estimation land allocation in 2020 (Global model: OECD scenario information from IMAGE model)

MSA future status





MSA maps for 2020 and 2050 based on baseline scenario.

Limitations experienced in national applications

- Resolution nitrogen deposition and climate change maps too coarse: No national data. (IMAGE 0.5 º). National models needed
- Generic biodiversity value per land use class
  No biodiversity values for country specific classes. Additional field work will increase quality
- Included fragmentation contains patch size but no connectivity yet.
- More data needed in order to add more pressures. New pressure should be independent (no double counting of effect)

Limitations experienced in national applications

- National scenario information often limited.
  Information from different institutes often conflicting or not comparable because of different definitions land use classes

- Marine (global EcoOcean model of UBC) and Freshwater models not included yet. Fresh water model nearly completed but difficult to integrate (quality * quantity). No coasts (future). No G&S.

- Integrating with other models (e.g. species models) will improve result

Some results from training in Honduras

Project with IRBIO, Zamorano UV Honduras

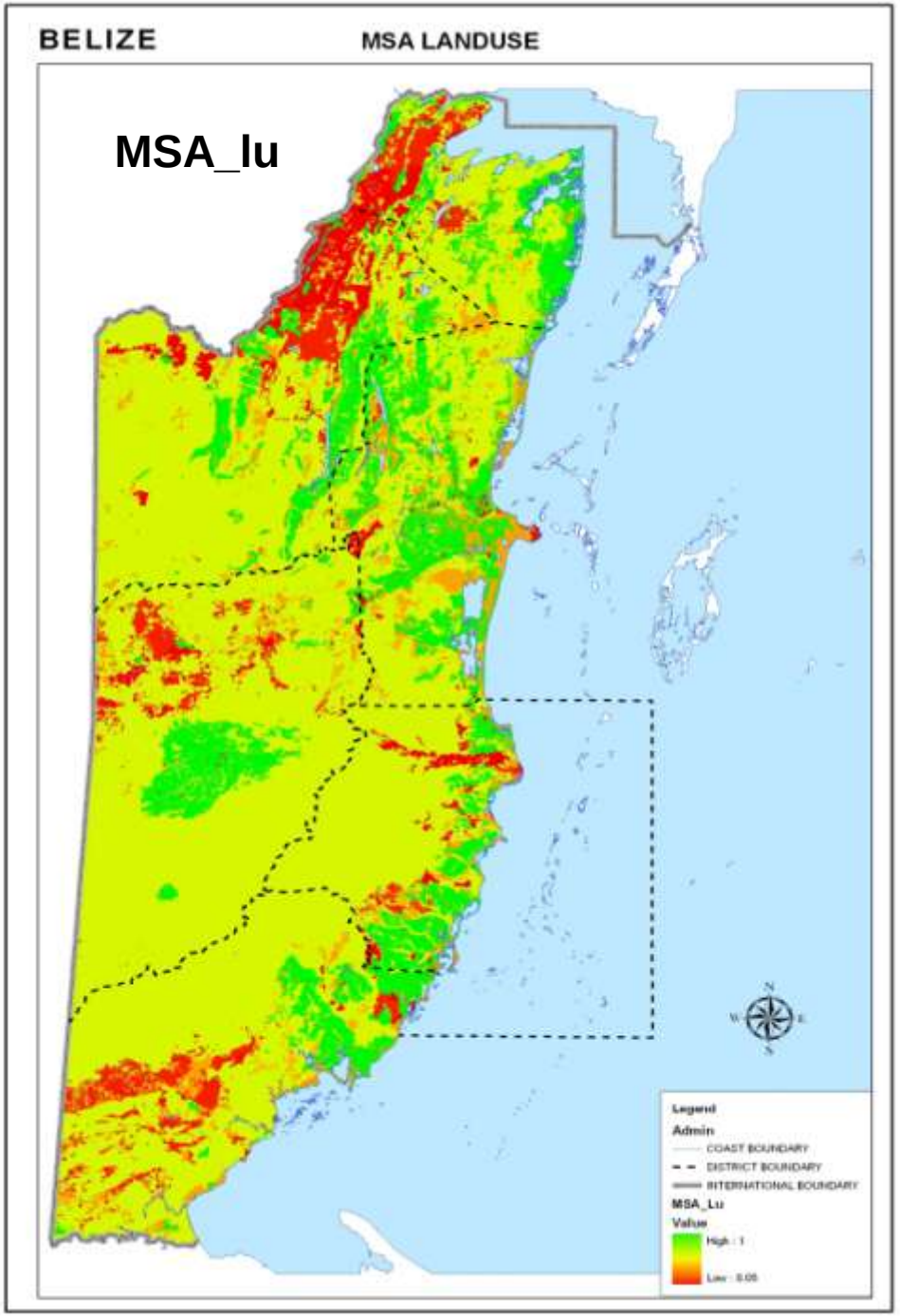
National biodiversity assessments for 7 Central American countries

Land Use Map

Impact Land Use Change

Poor quality of land use map limits accuracy calculation of msa impact by land use

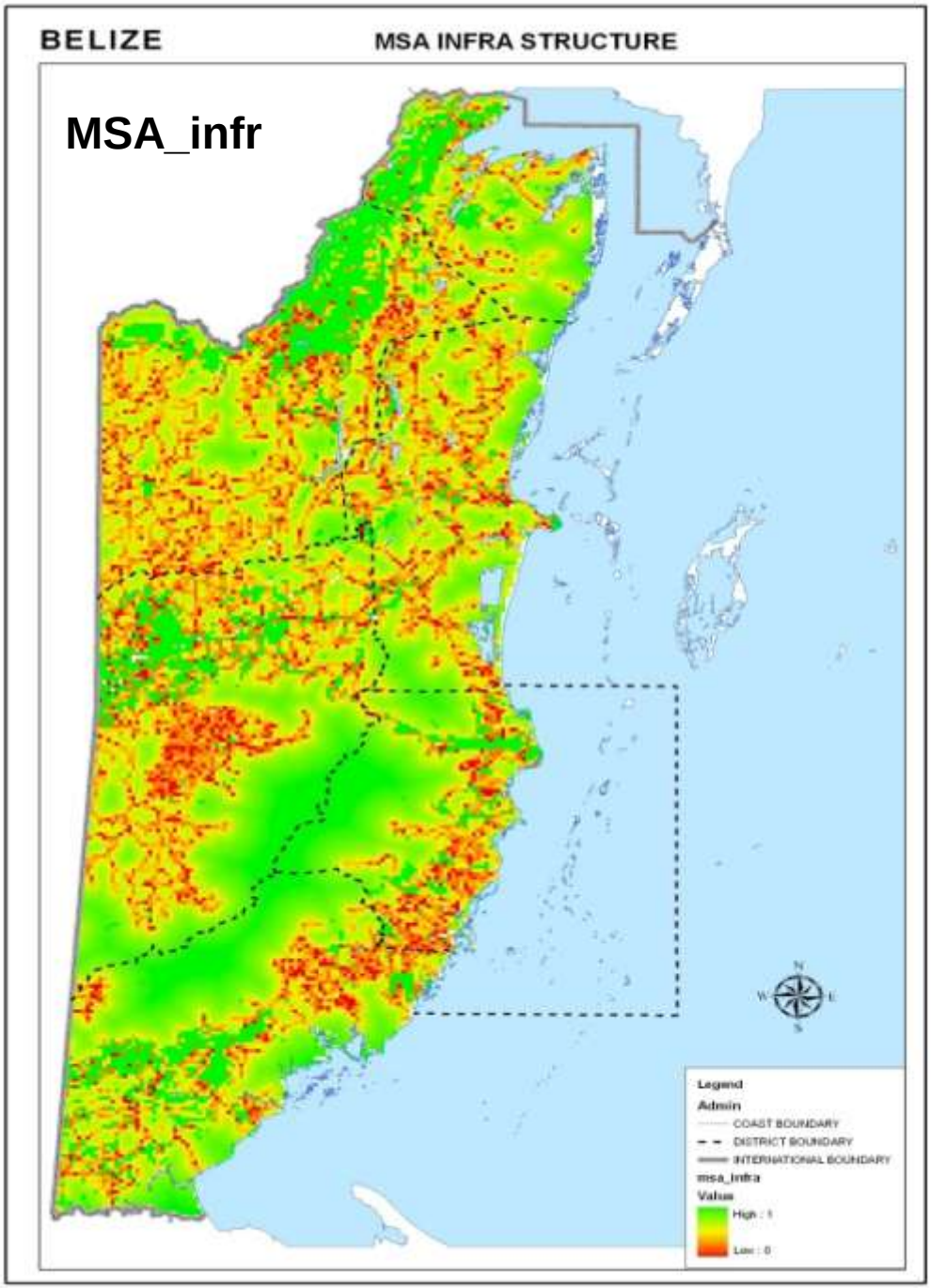
Map large scale, old (1993), and few land use / forest intensity types result in interpretation differences



MSA infra

Impact Infrastructure Change

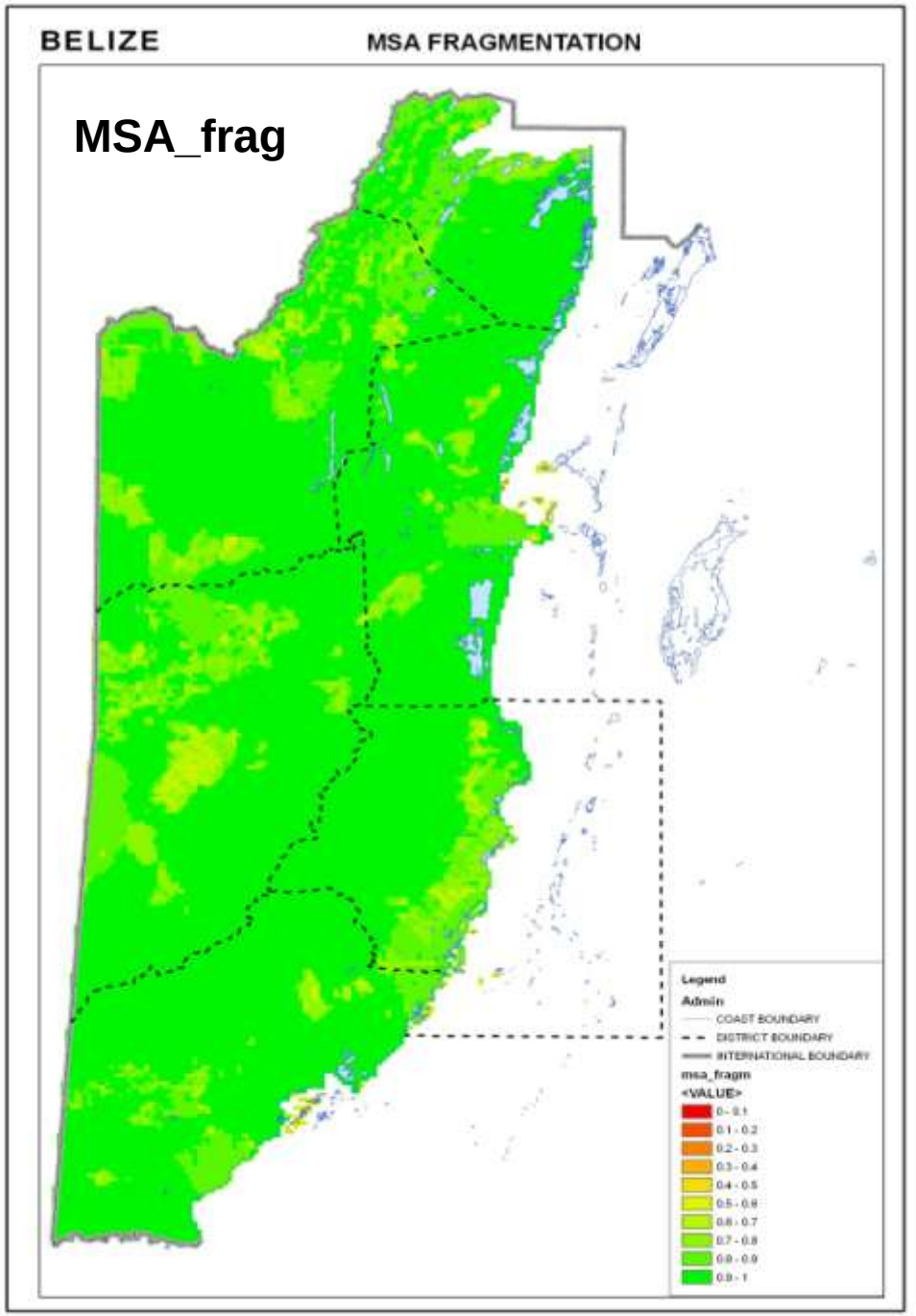
Participants Belize used all roads incl. minor tracks and footpaths. Therefore road impact on this exercise map exaggerated



MSA Fragmentation

Impact Fragmentation

Clusters of natural area, dissected by roads or surrounded by other land uses



MSA Climate

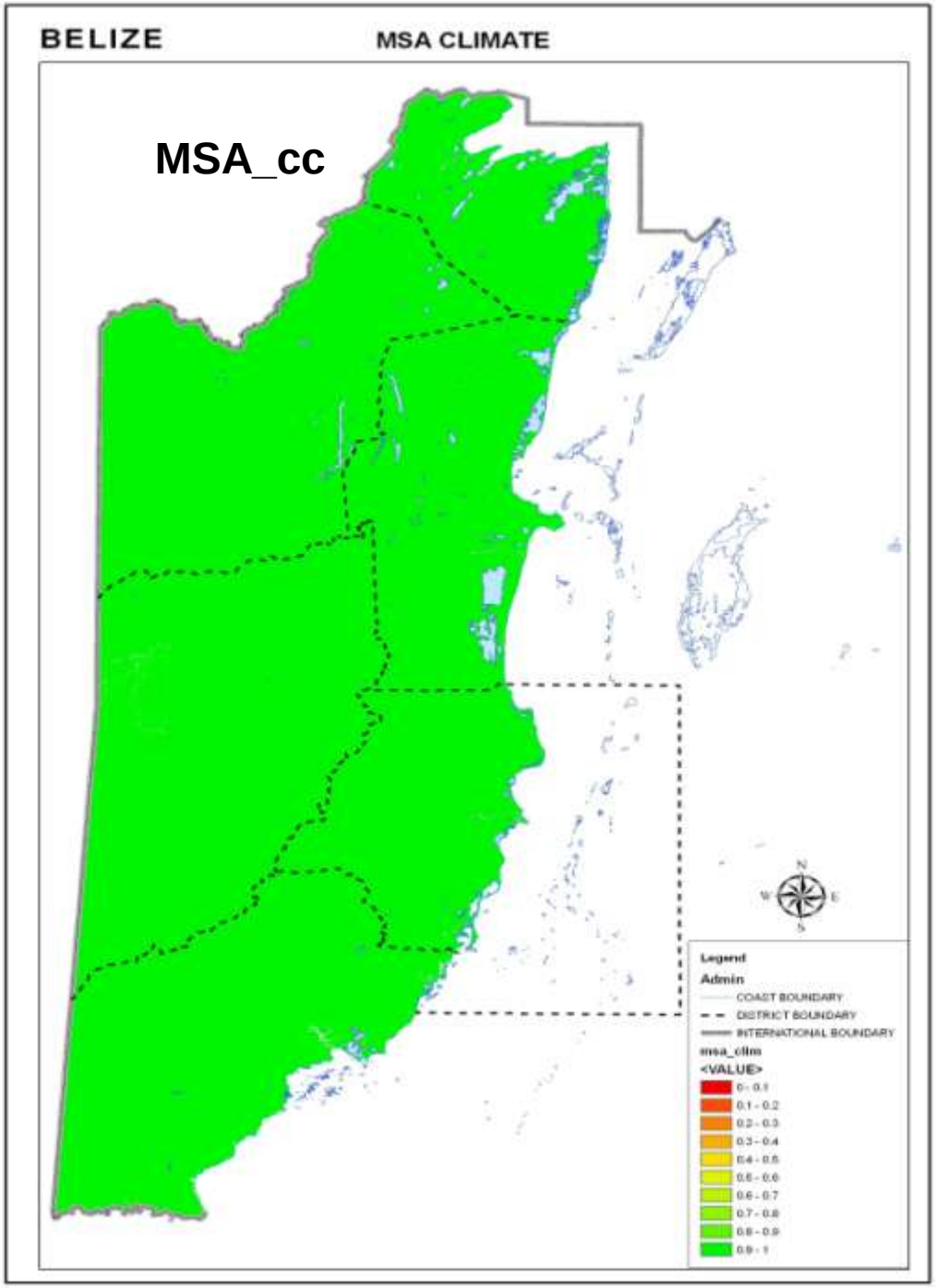
Impact Climate Change

temp change year 2000:

range between 0.9 and 1

Therefore not visible on this map

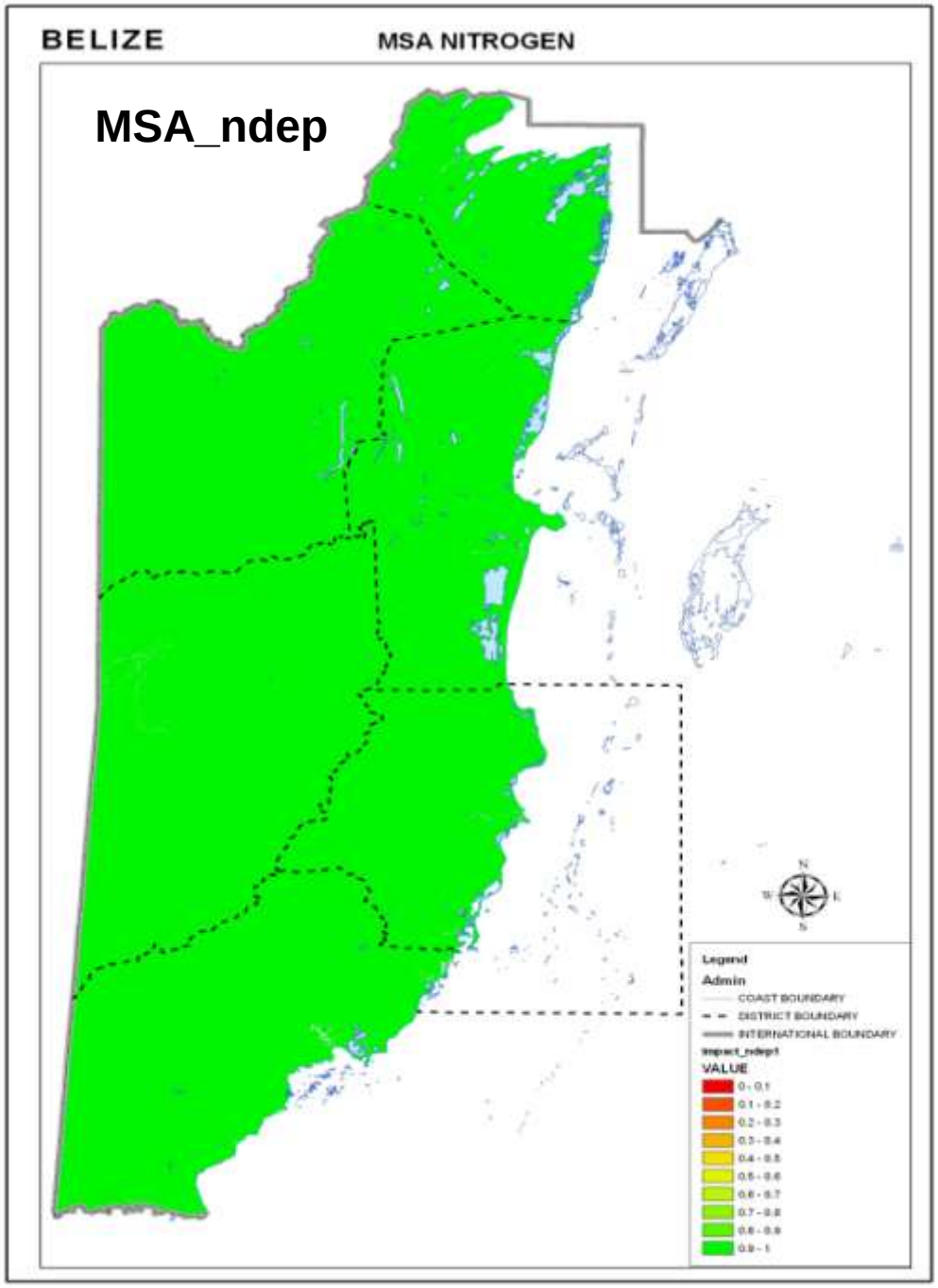
Impact gets larger in future



MSA Nitrogen

Impact Nitrogen deposition Change

Impact year 2000:
No Nitrogen deposition above critical level → no impact



Total MSA

MSA tot = 39%

This training example appears to give an underestimation of Belizes remaining biodiversity because of exaggeration infra impact and too generalized Lu map

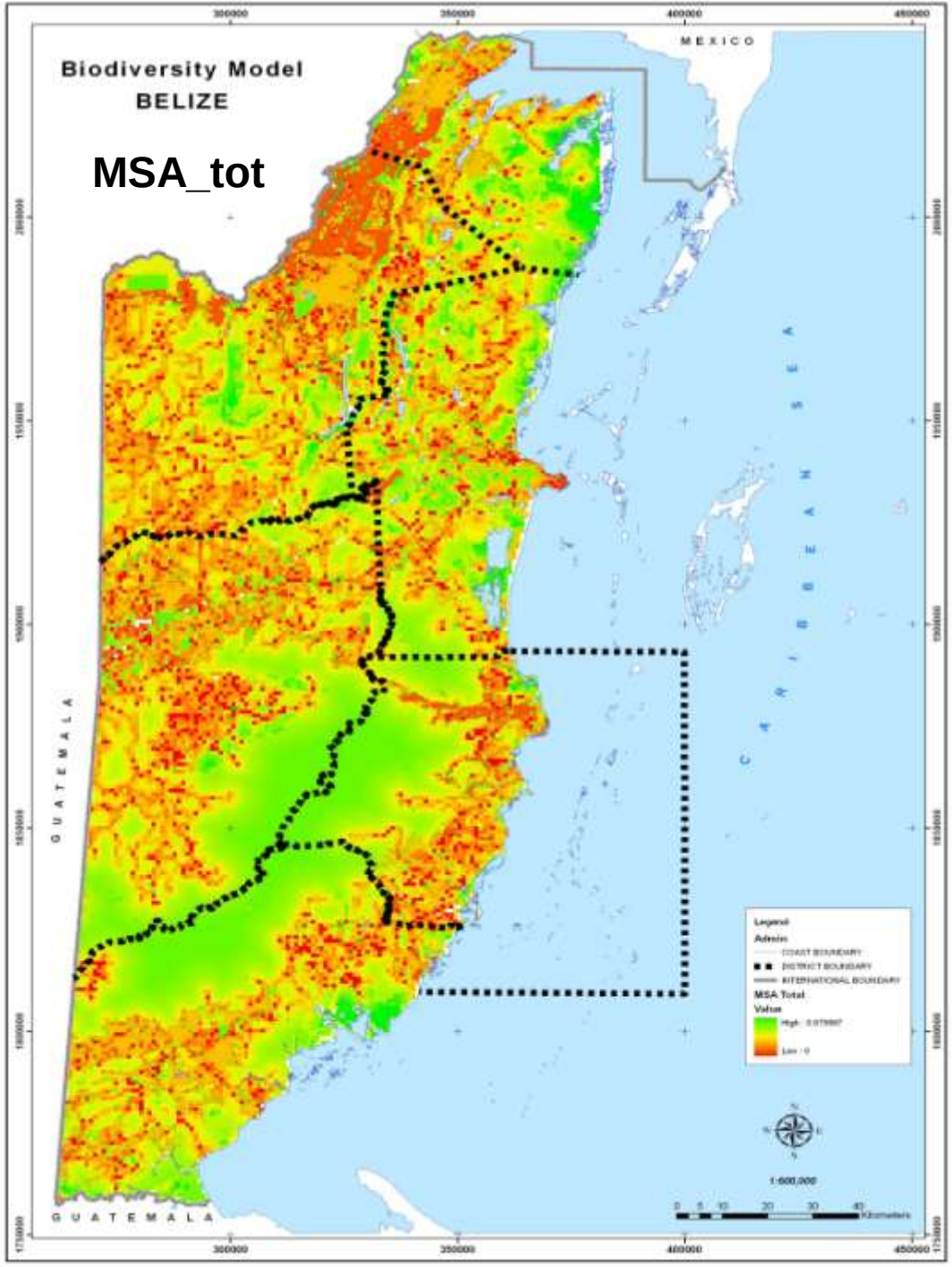
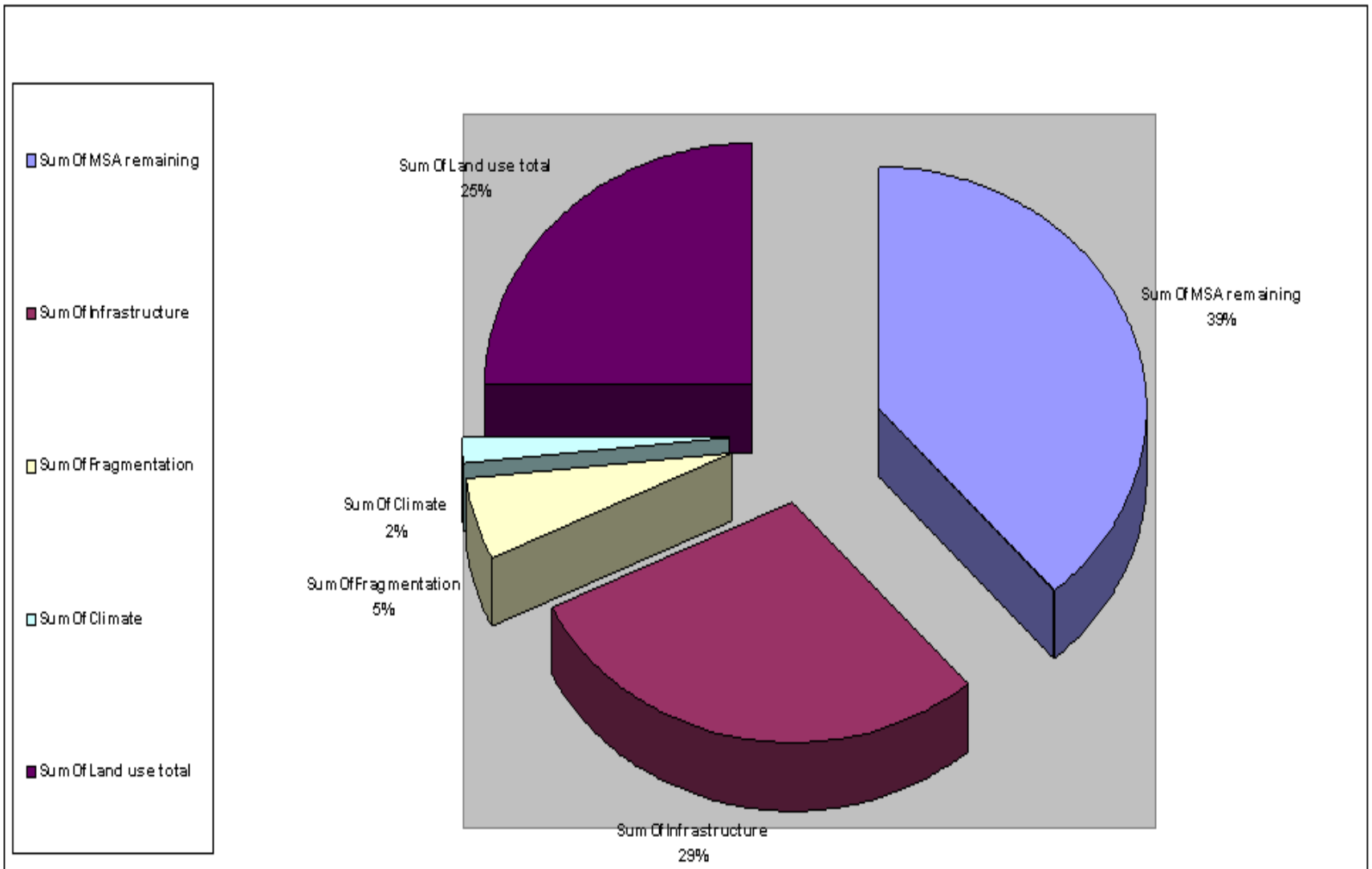
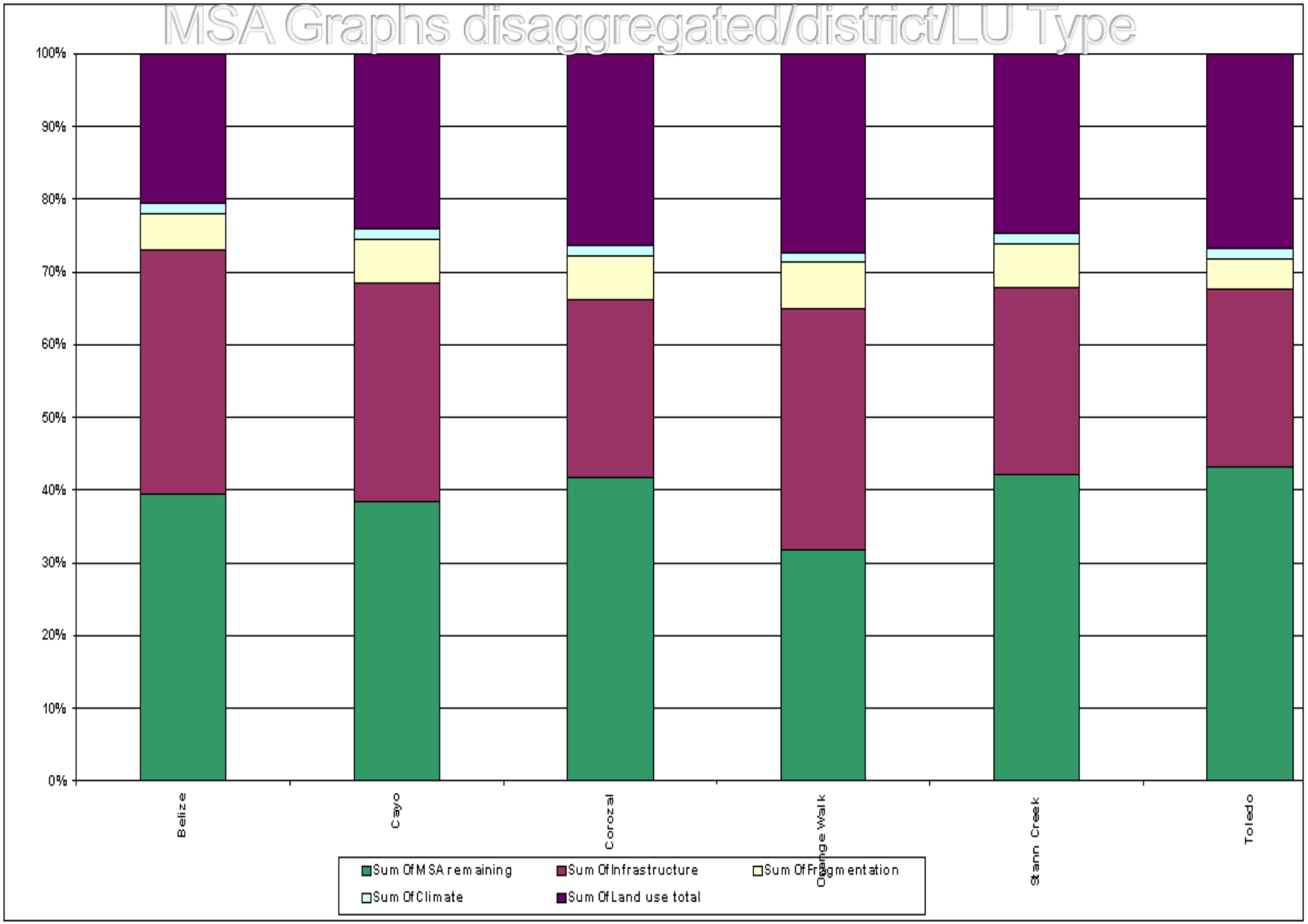


Grafico Reultados

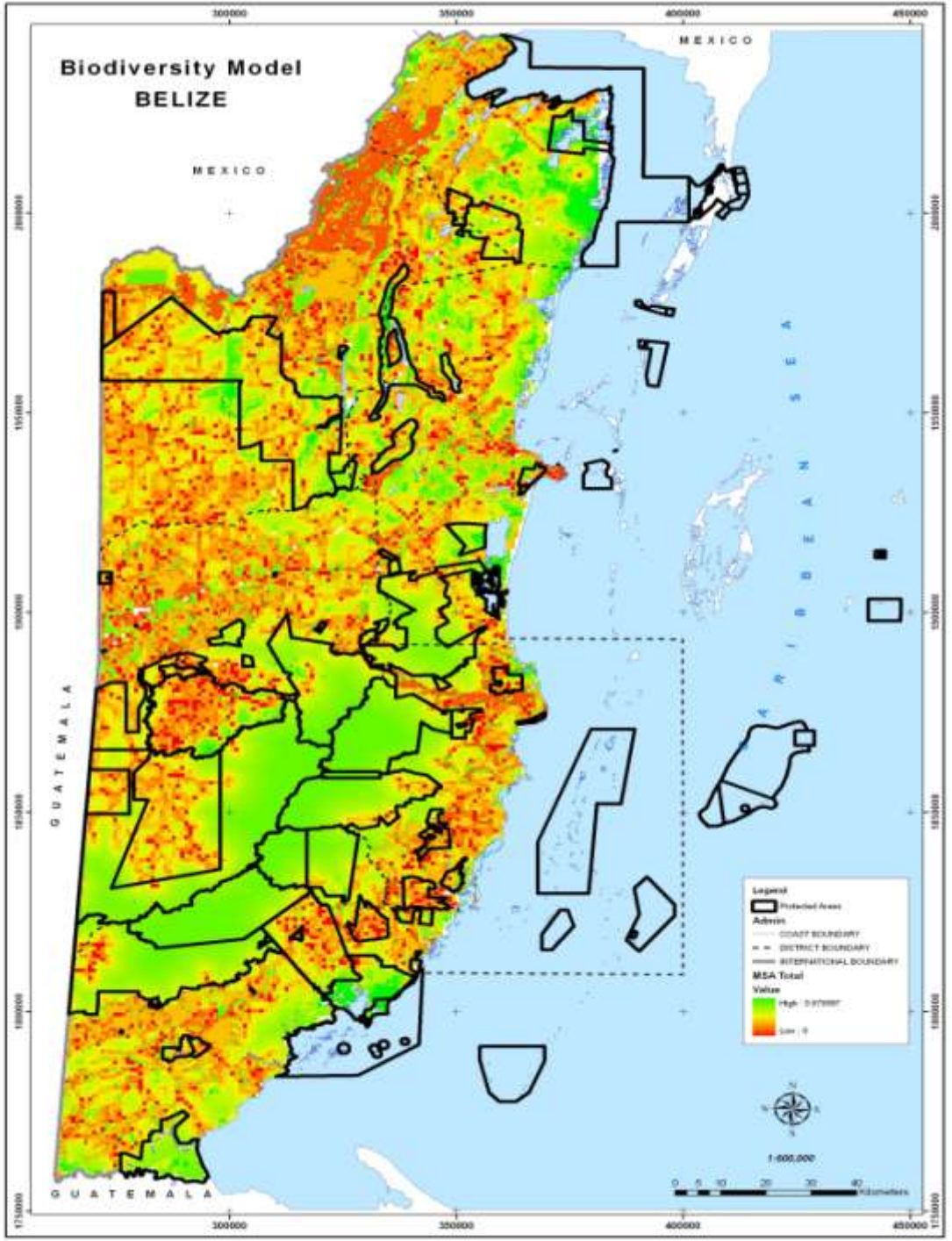


MSA Graphs disaggregated/district/LU Type



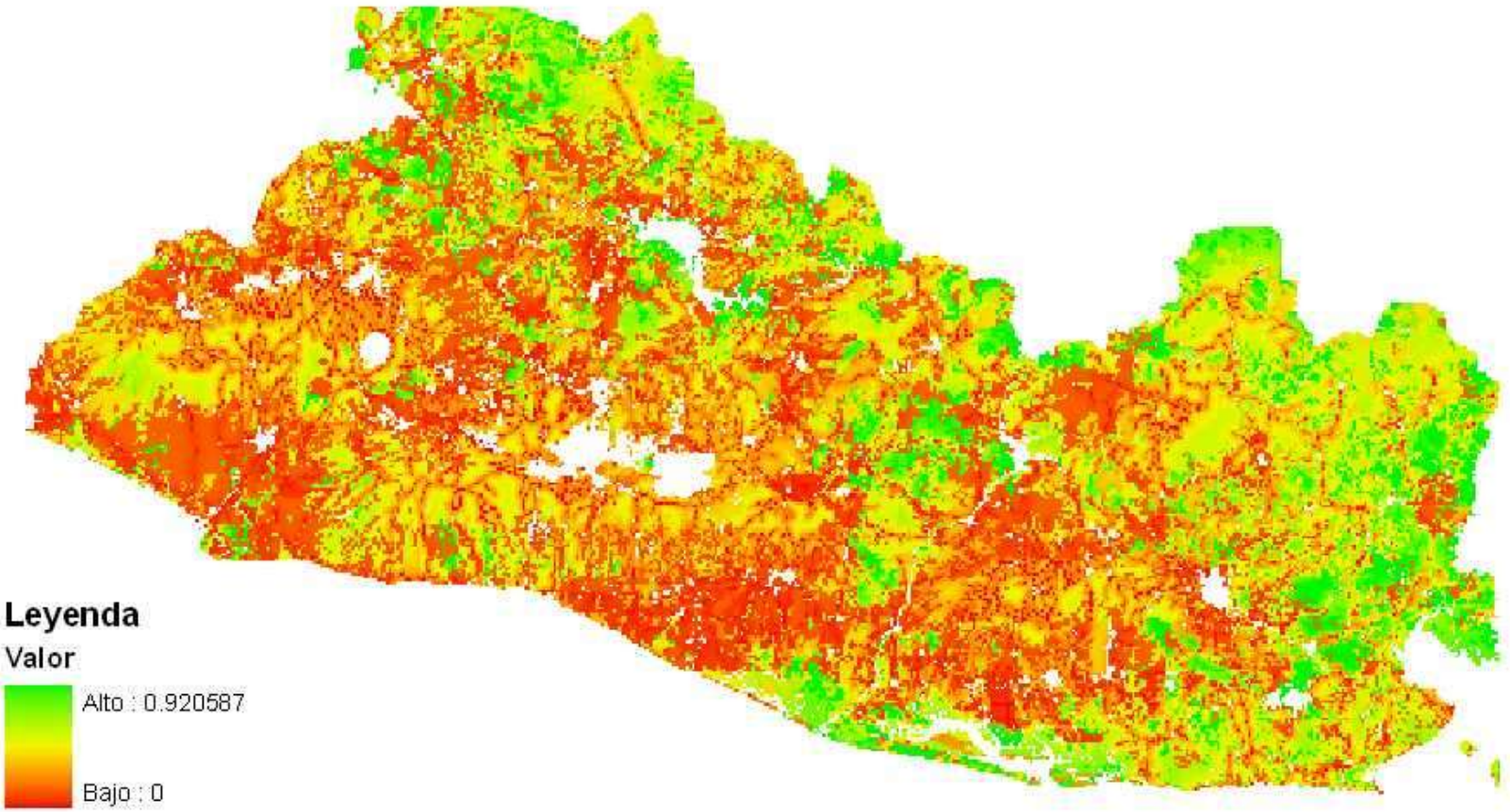
P.A. with MSA maps

Analysis of biodiversity status in protected areas

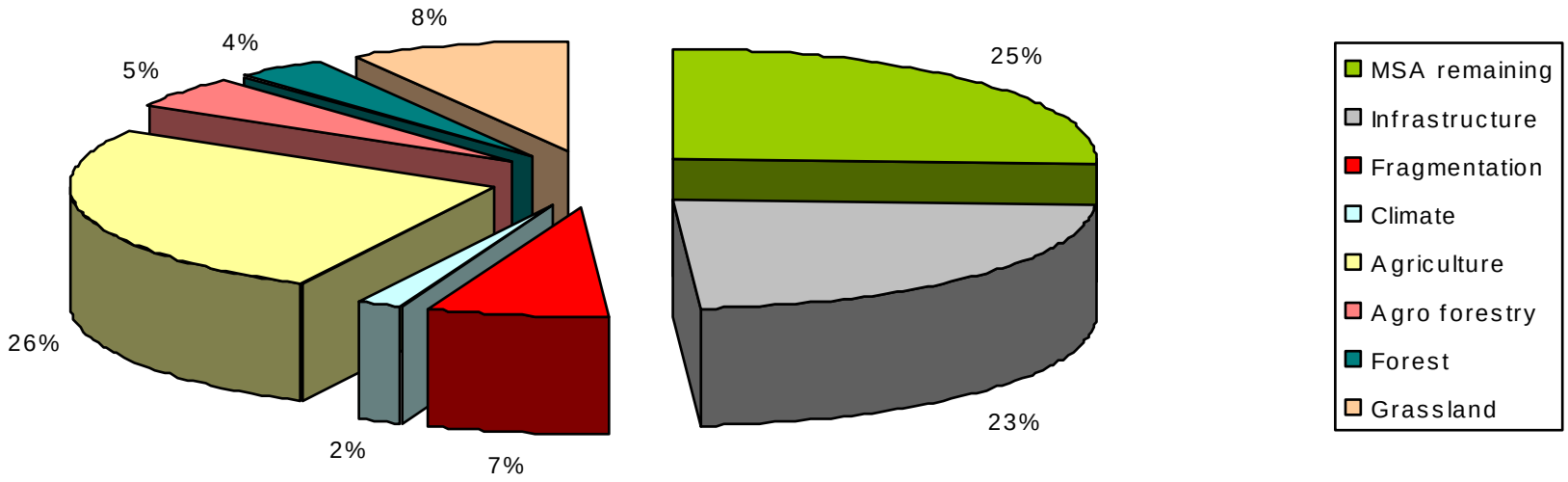


MSA_tot El Salvador

MSA = 25%

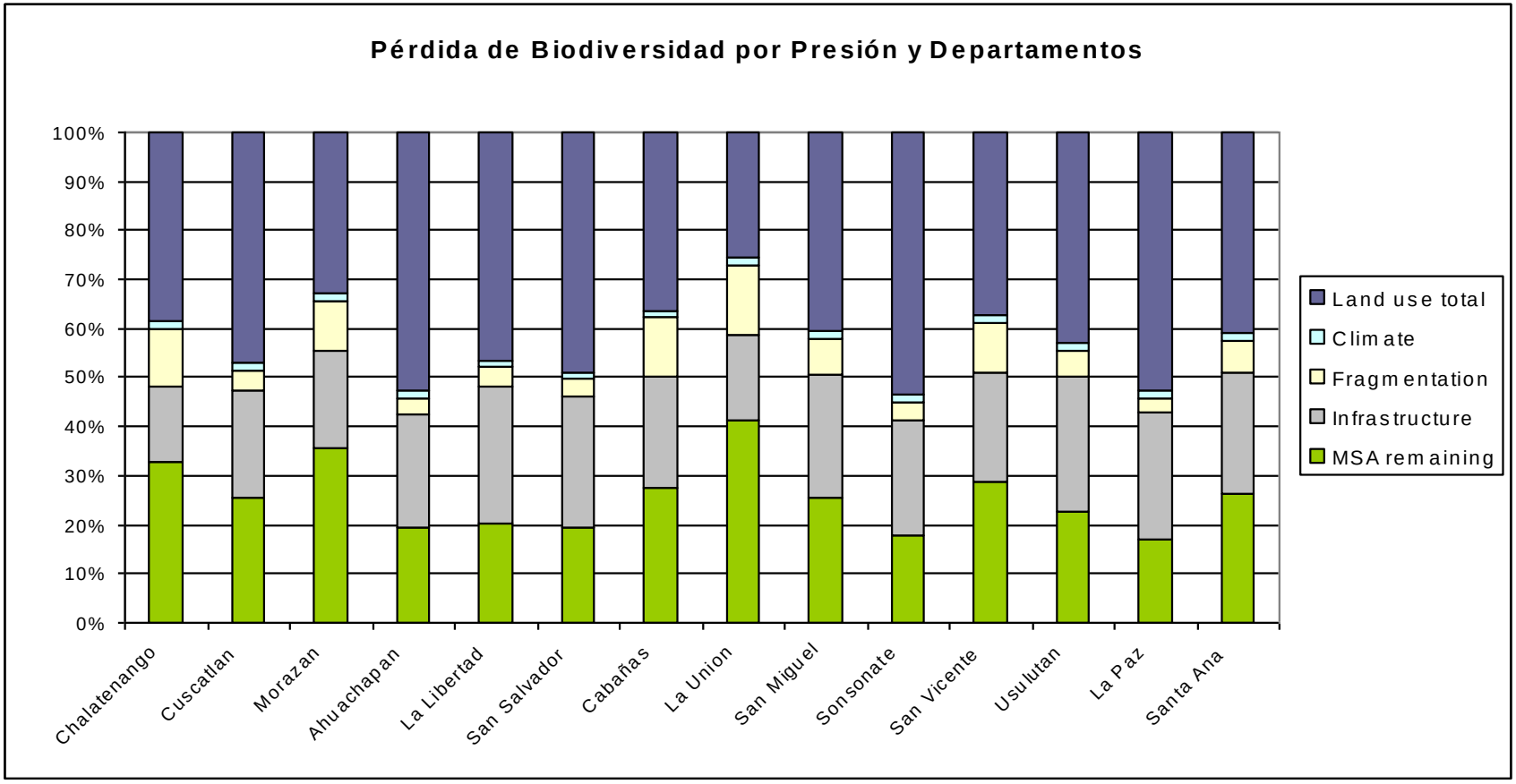


Contribution Biodiversity loss per Pressure type



Biodiversity loss per district per pressure type

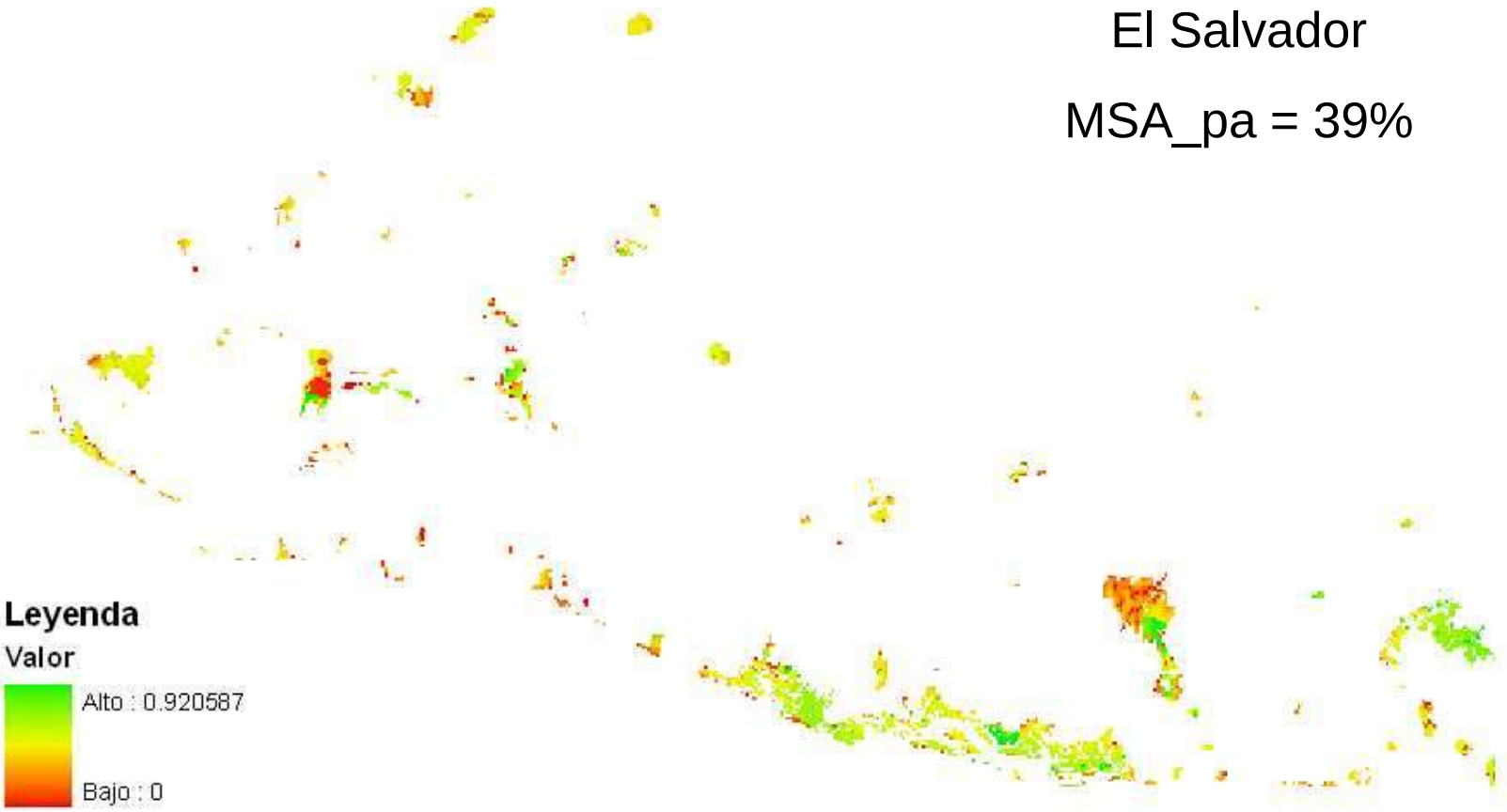
Resultados de MSA para El Salvador

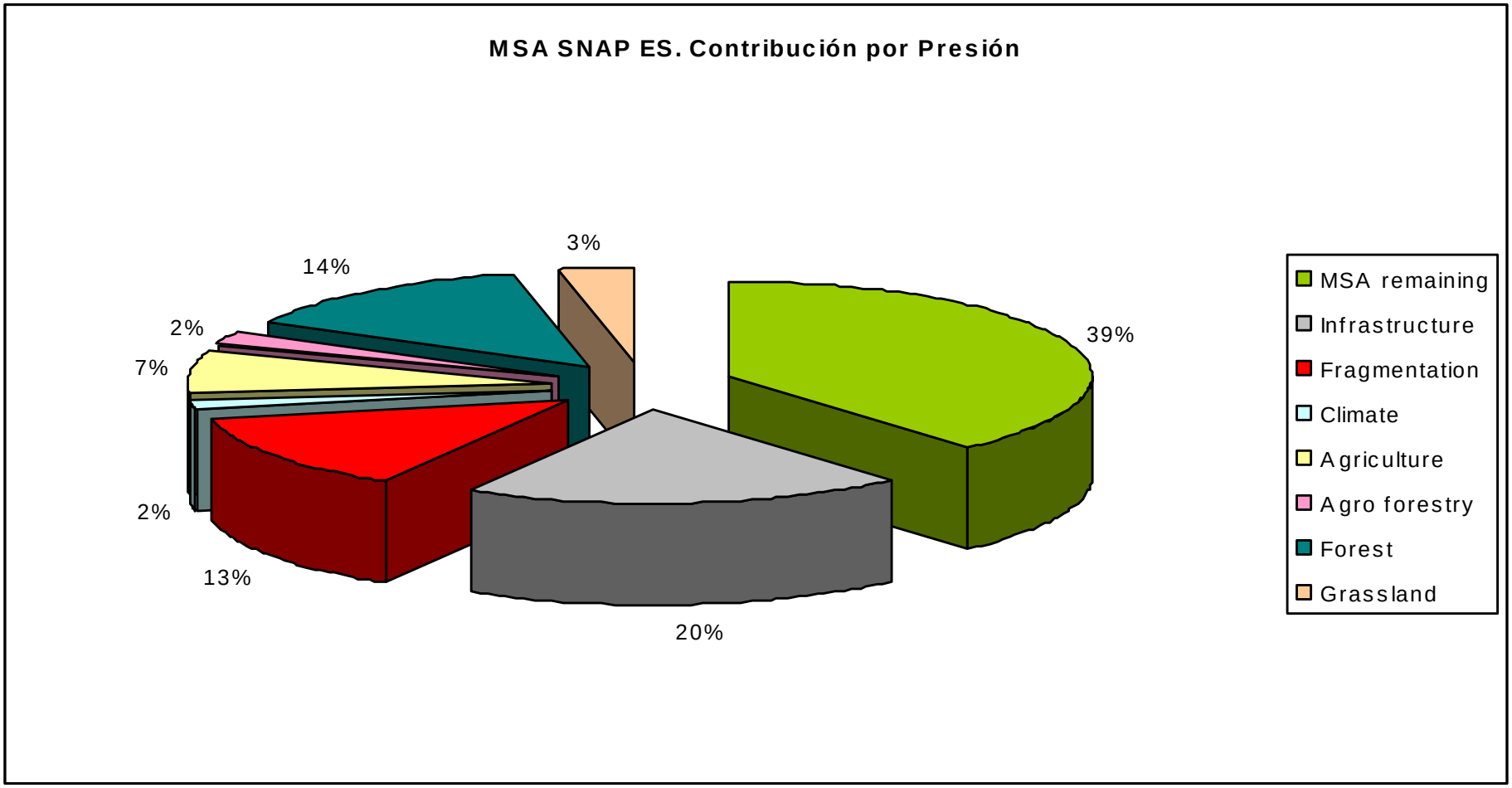


MSA para Áreas Naturales Protegidas

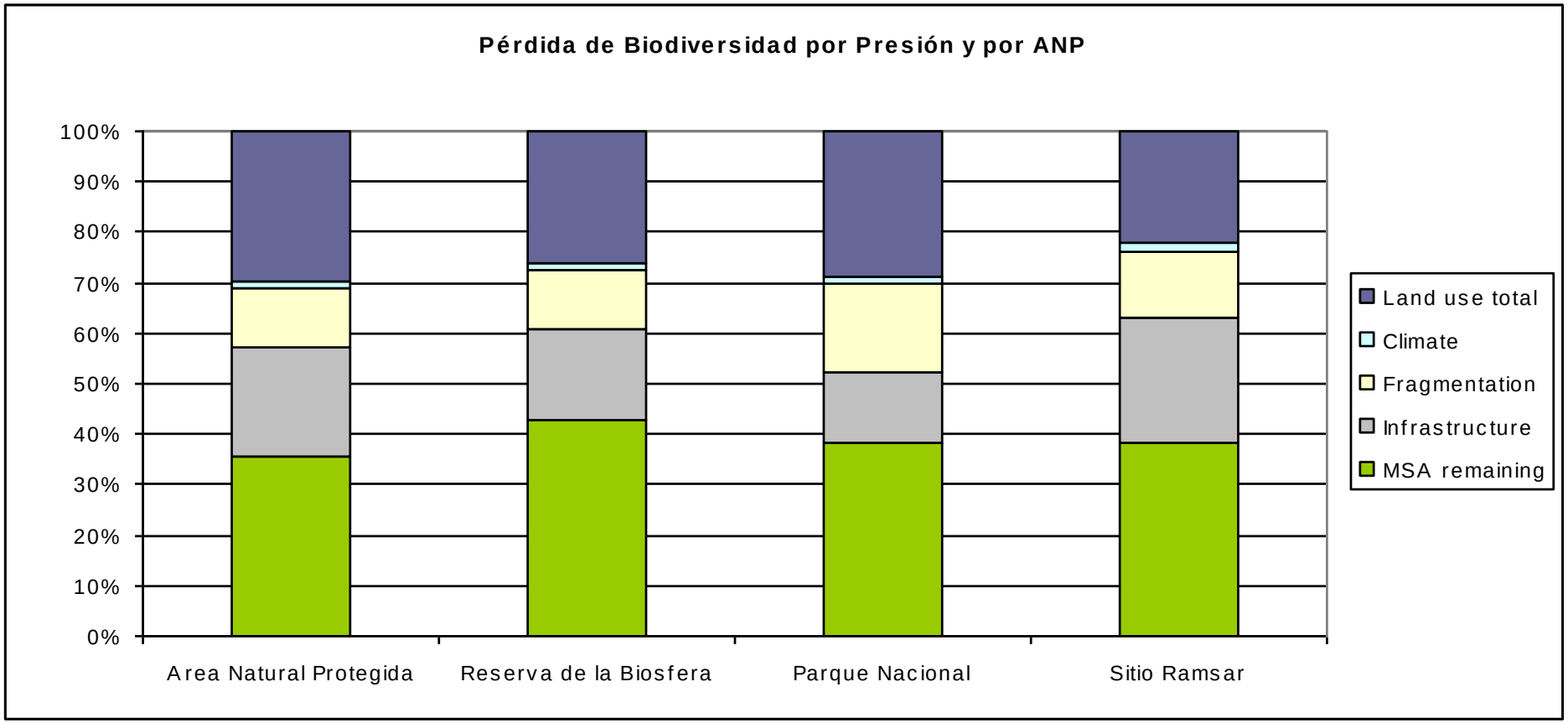
MSA_tot_pa
El Salvador

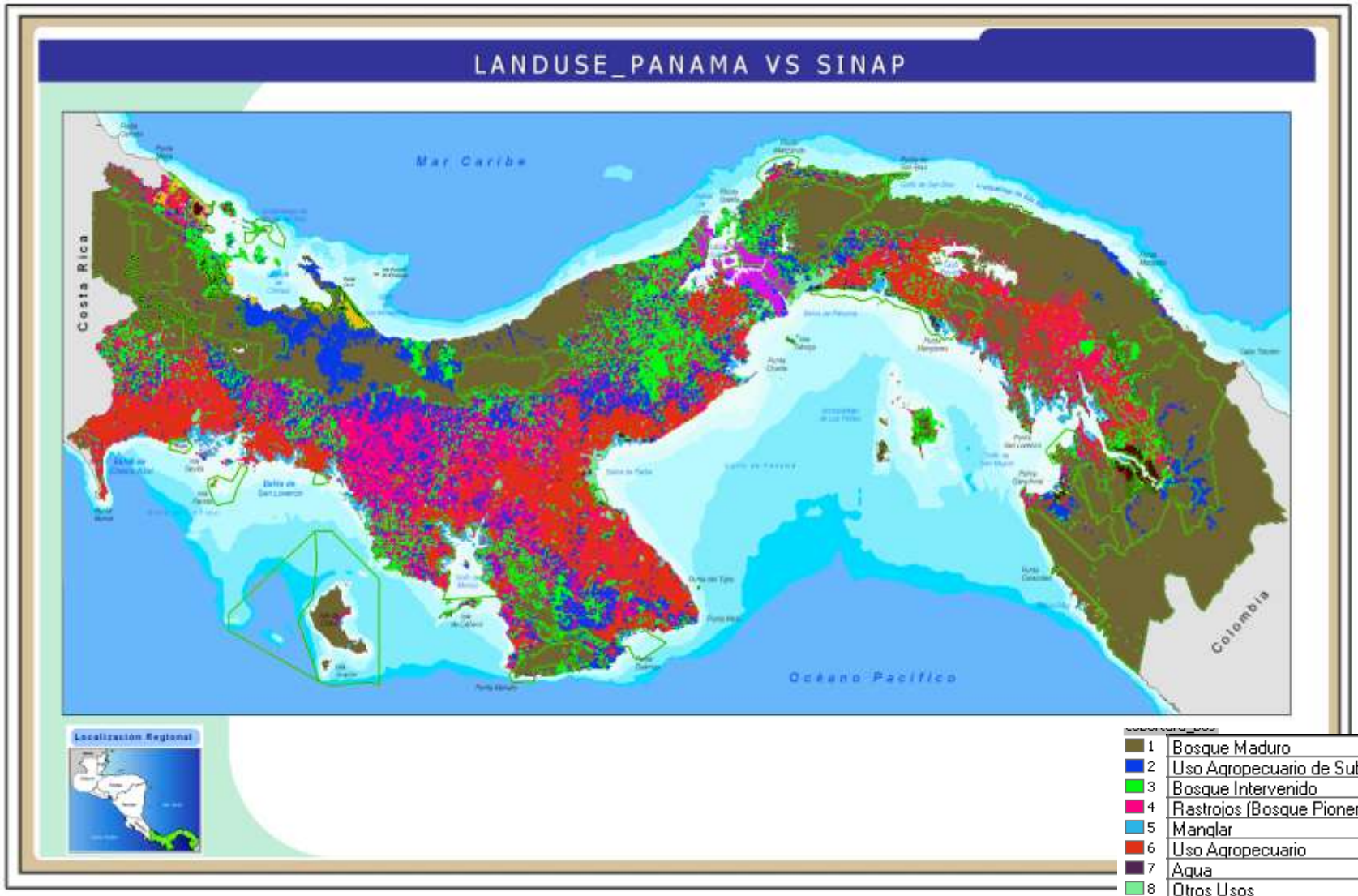
MSA_pa = 39%

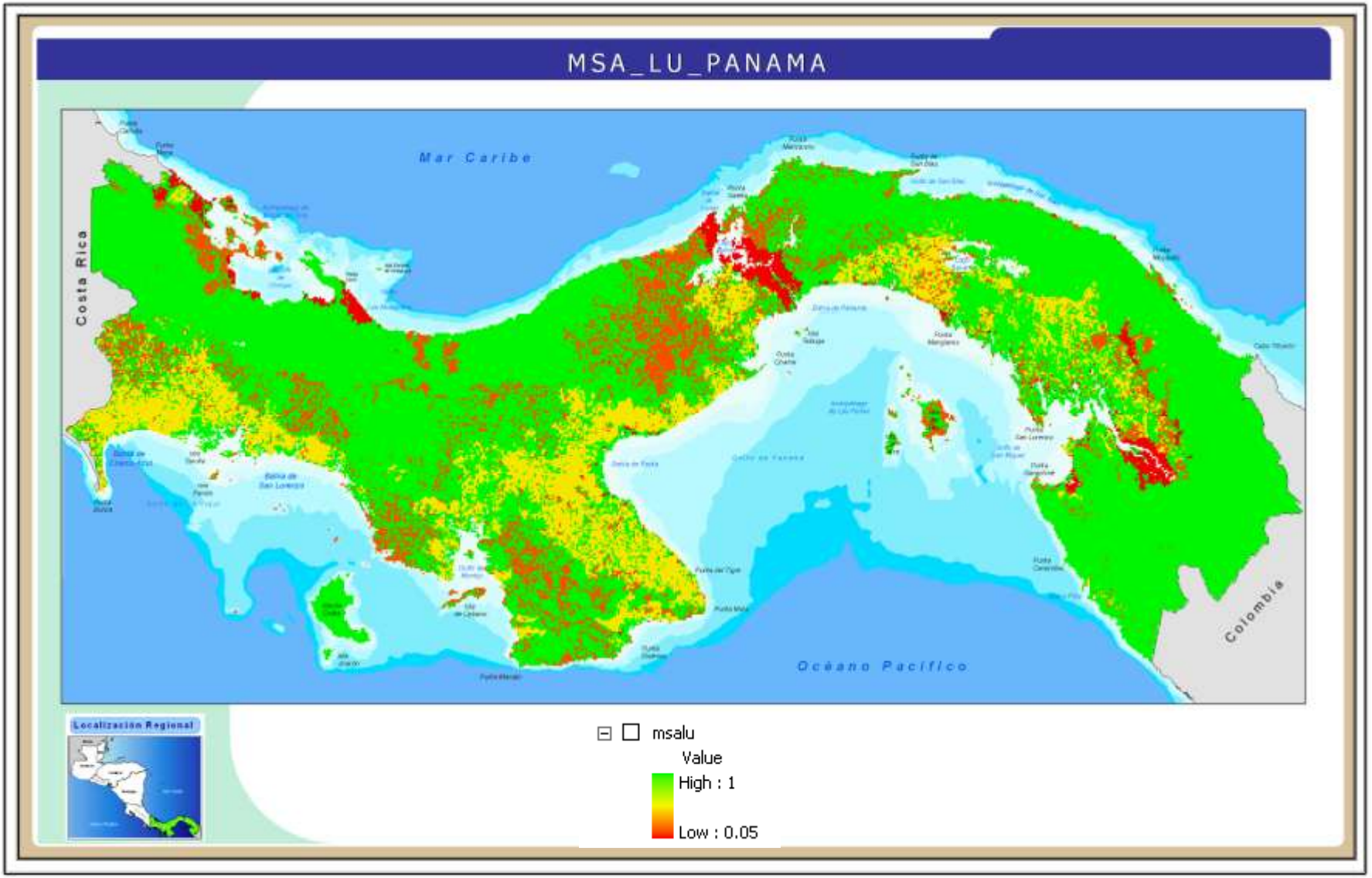


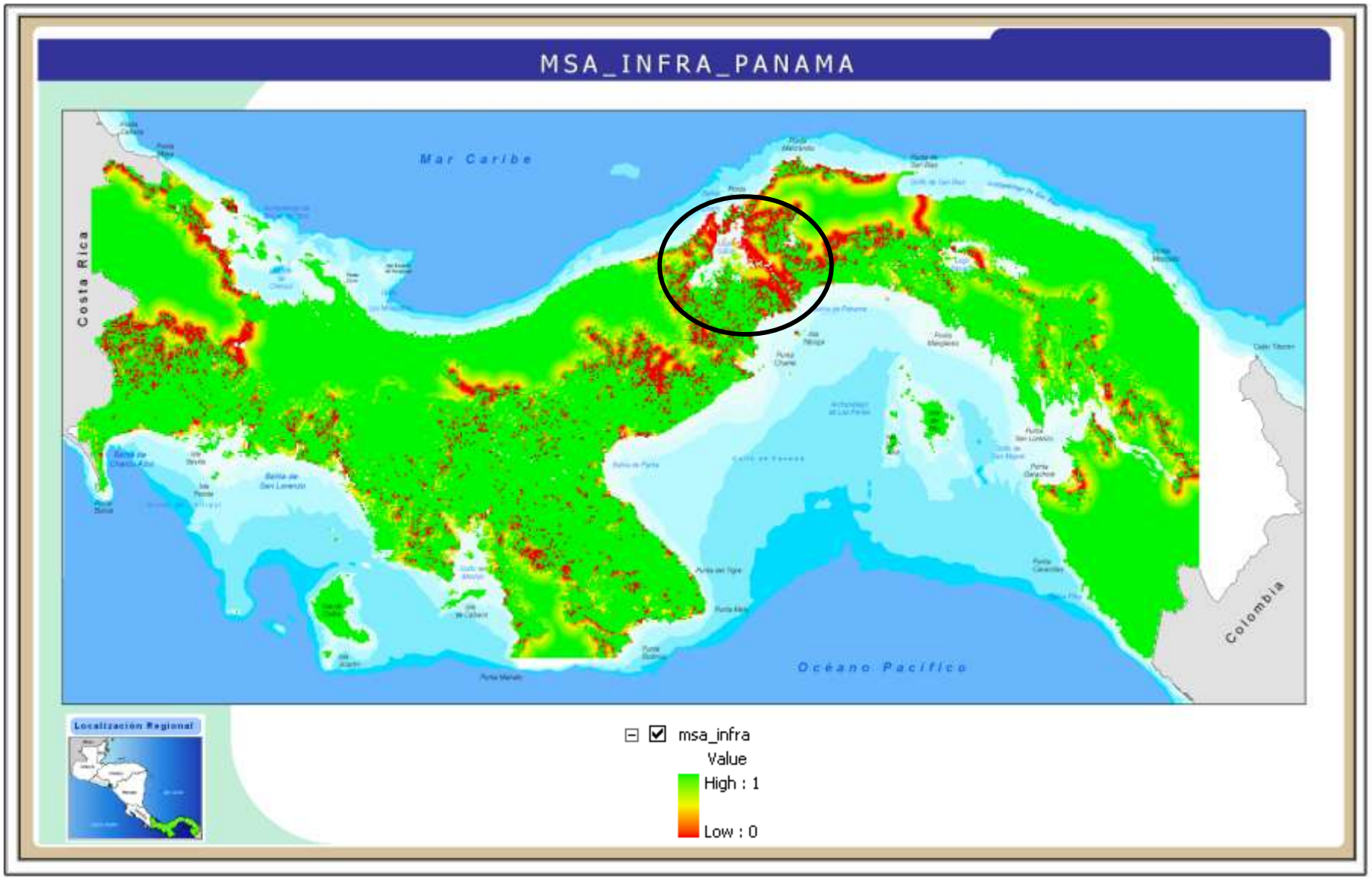

MSA SNAP ES. Contribución por Presión
3%
14%
2%
7%
2%
13%
20%
39%
MSA remaining
Infrastructure
Fragmentation
Climate
Agriculture
Agro forestry
Forest
Grassland

Resultados de MSA para las Áreas Protegidas de El Salvador

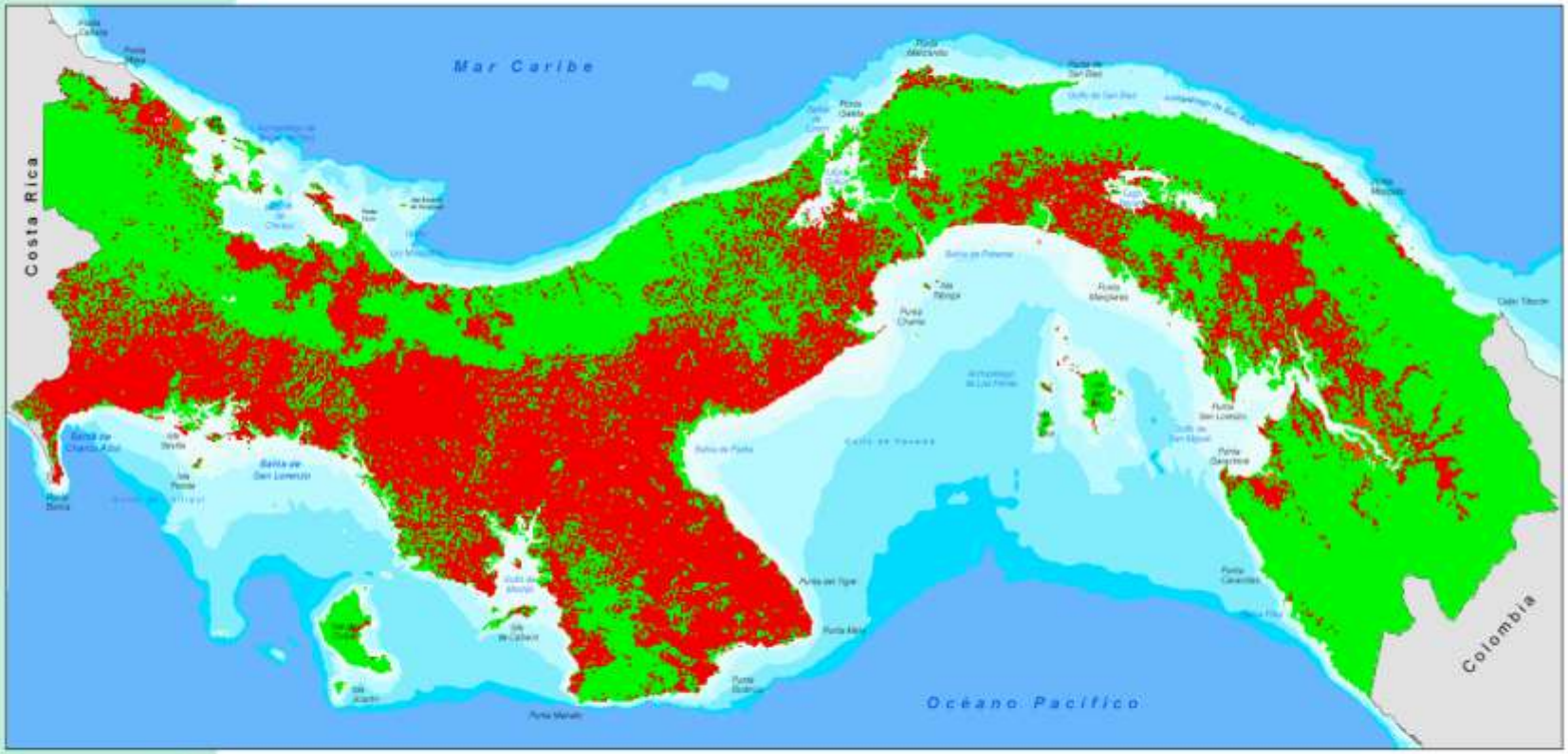



LANDUSE_PANAMA VS SINAP
Mar Caribe
Costa Rica
Colombia
Océano Pacífico
Localización Regional
1 Bosque Maduro
2 Uso Agropecuario de Subsistencia
3 Bosque Intervenido
4 Rastrojos (Bosque Pionero)
5 Manglar
6 Uso Agropecuario
7 Agua
8 Otros Usos
9 Bosque de Orey Homogéneo
10 Bosque Inundable Mixto
11 Bosque Secundario Maduro
12 Vegetación Baja Inundable
13 Cativo Mixto/Homogeneo
14 Albinas
15 Plantaciones

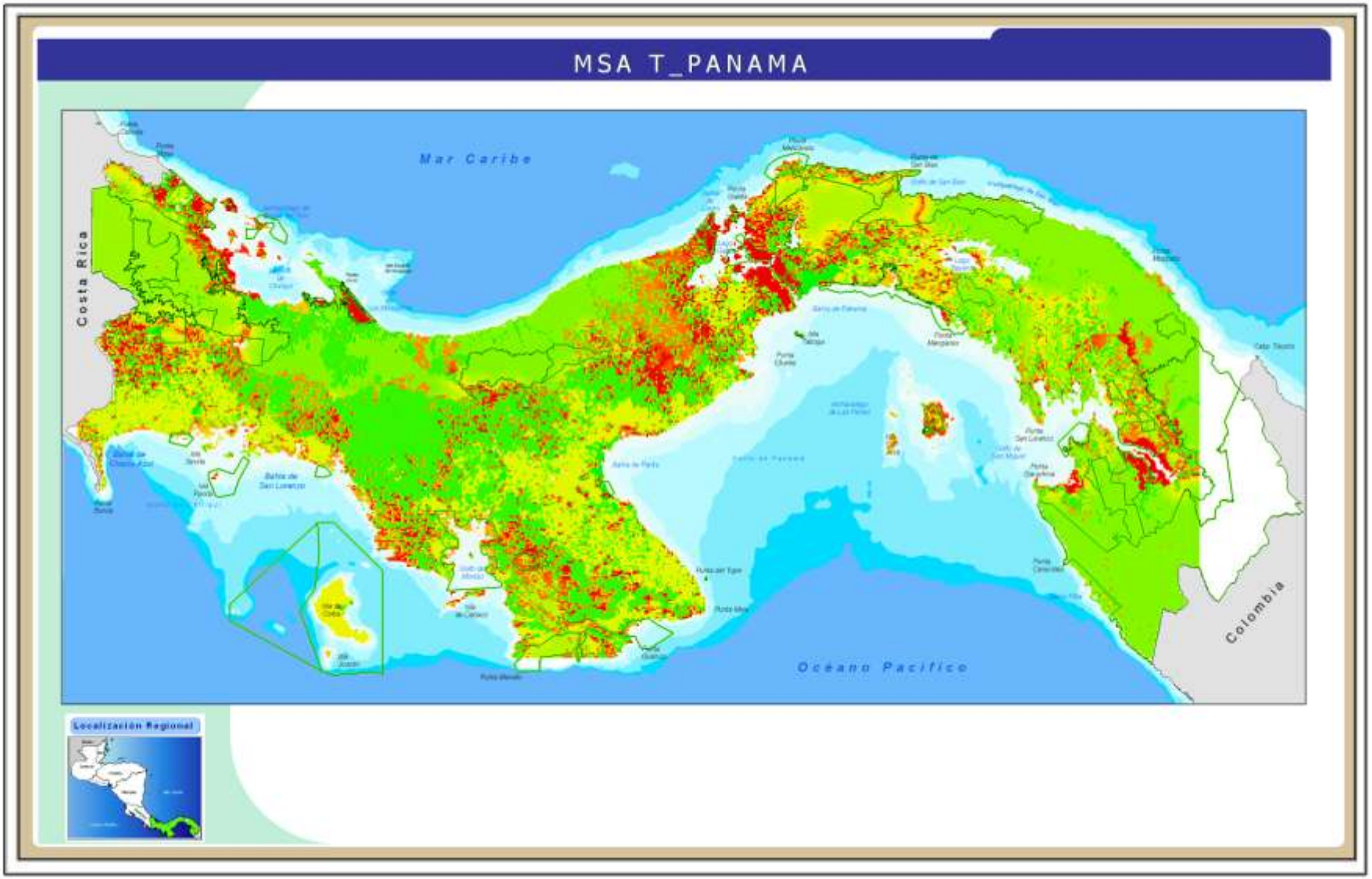

MSA_LU_PANAMA
Mar Caribe
Costa Rica
Colombia
Océano Pacífico
Localizacion Regional
msalu
Value
High : 1
Low : 0.05


MSA_INFRA_PANAMA
Mar Caribe
Costa Rica
Colombia
Océano Pacífico
Localización Regional
msa_infra
Value
High : 1
Low : 0

MSA_CLIMA_PANAMA



msa_clim
Value
High : 0.9807
Low : 0.9442


MSA T_PANAMA
Mar Caribe
Costa Rica
Colombia
Océano Pacífico
Localización Regional