Evaluation and Assessment of Forest Landscapes: The Challenge to Adaptive Management Strategies

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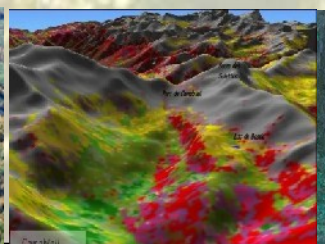
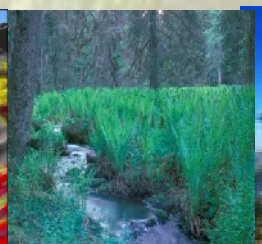
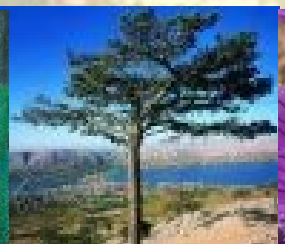
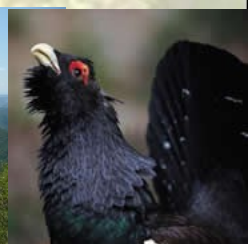






Outline

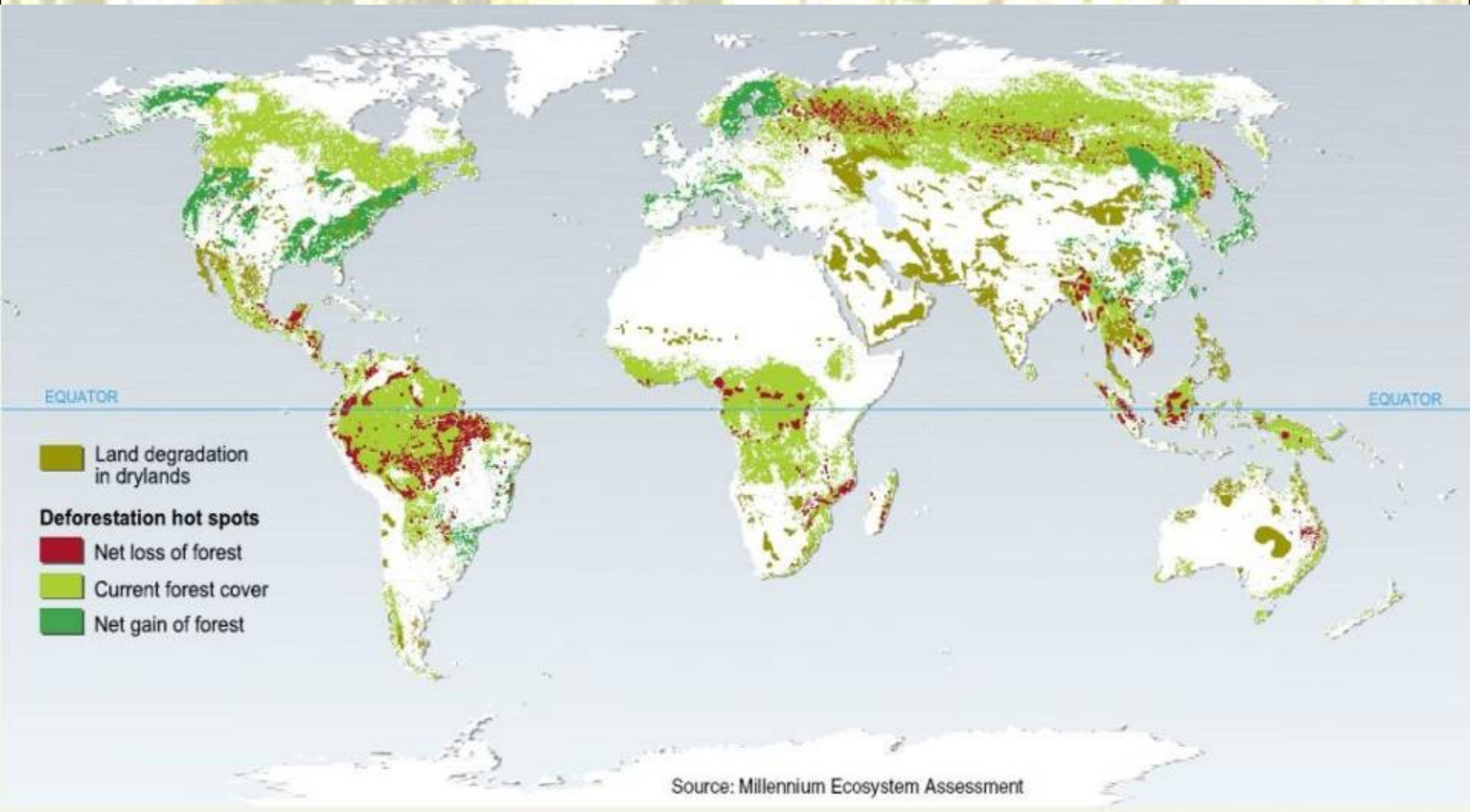
- Introduction

A call for landscape ecology: The role of landscape ecology in adapting landscapes

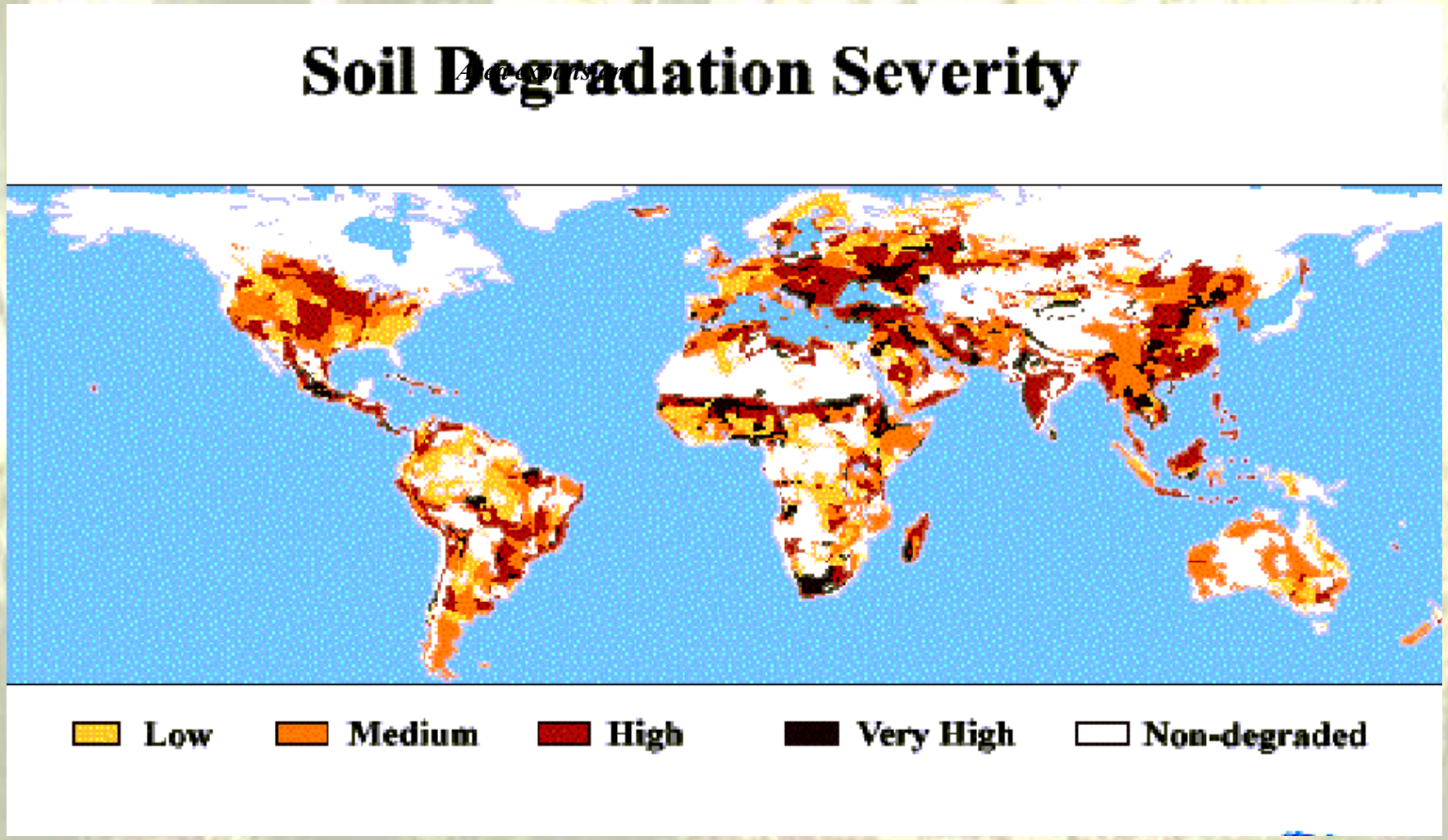
- **An adaptive forest management approach: Where and how to protect forest biodiversity**

The Global Context

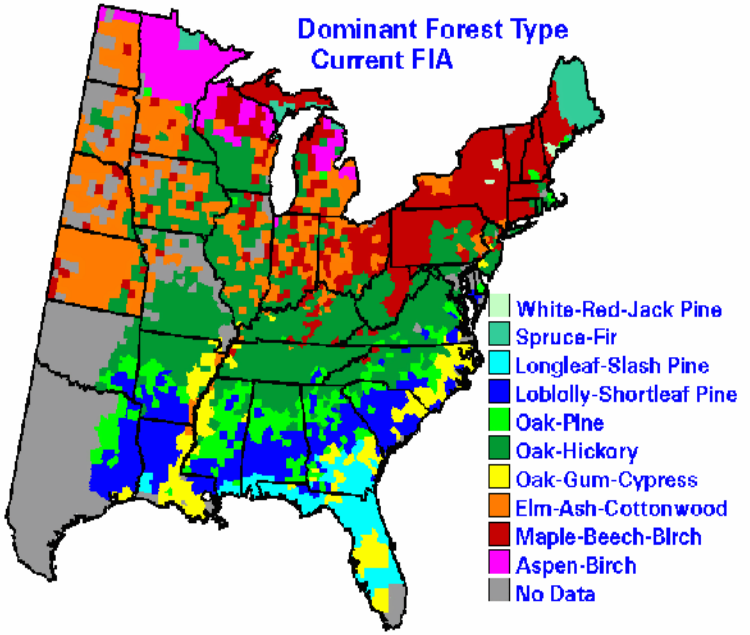
- Land-Use Change

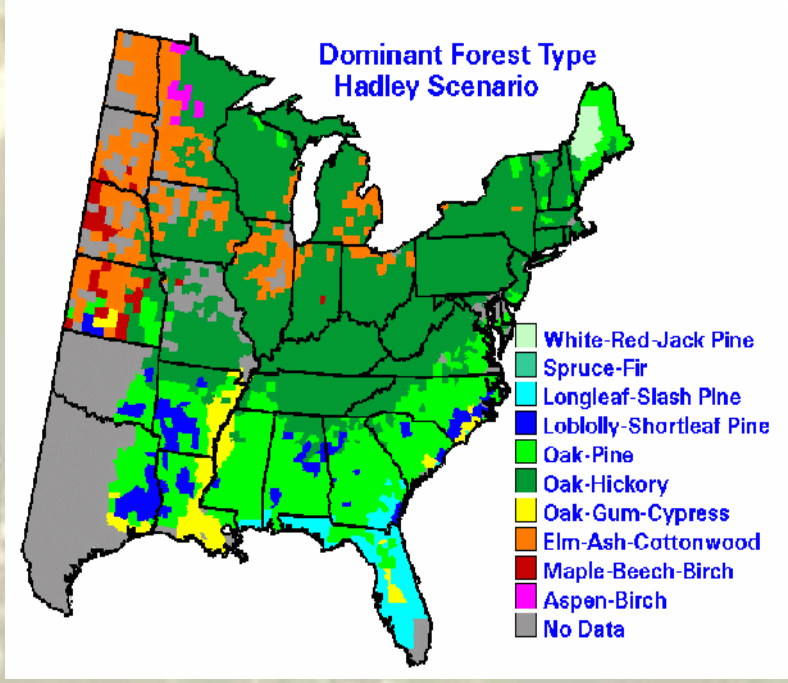


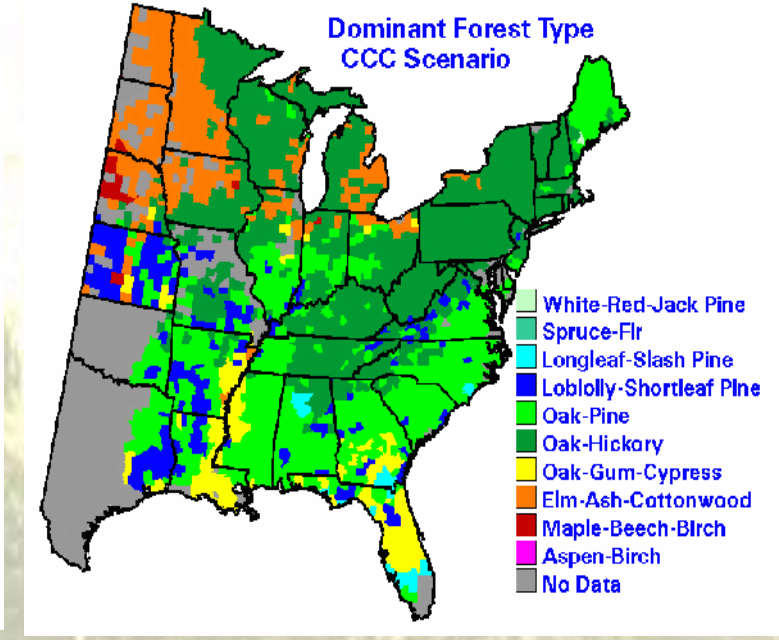
Current technologies?



Potential changes in tree species following climate change







Iverson and Prasad 2003 Ecosystems

Climate change impacts on landscapes are a fact

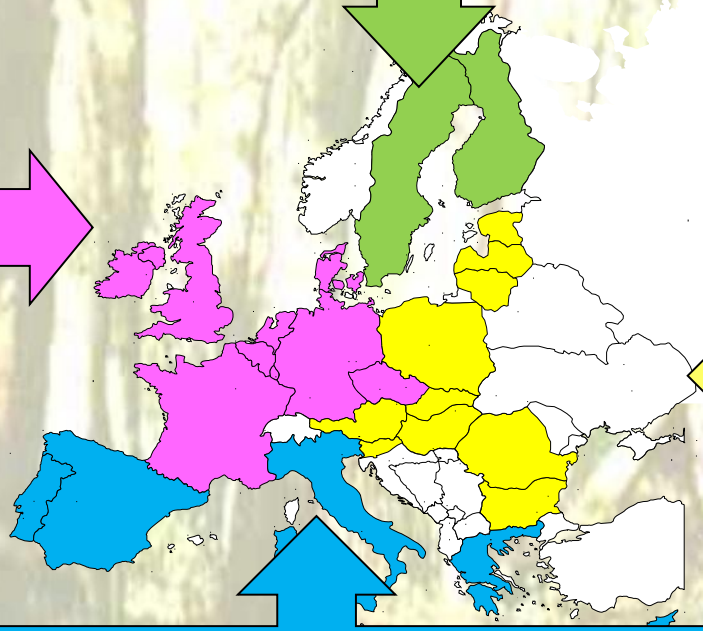
- Species are moving
- Water systems more variable
- Floods cause damage
- Droughts cause damage
- Cities are getting warmer

Impacts of climate change on forest

Impacts:
+ Positive
- Negative
? Unknown

+ forest growth
- abiotic and biotic disturbances
- difficult winter harvesting

+/- forest growth
- wind and fire disturbances
? Shifting species composition



+/- forest growth
- wind and fire disturbances
? Shifting species composition

- forest growth
- fire disturbances
- erosion risk

Facing Climate Change Impacts

Increased growth rates in the North

Higher risk of storm and insect damages

Shifting species suitability

More intense and frequent forest fires

Adaptive capacity

- Ability of a system to adapt to changes
- Adaptive capacity has two components:

1. Inherent adaptive capacity of trees and forest ecosystems

2. Socioeconomic factors determining the ability to implement adaptation measures

UNEMPLOYMENT
OFFICE
FARM
ECONOMY

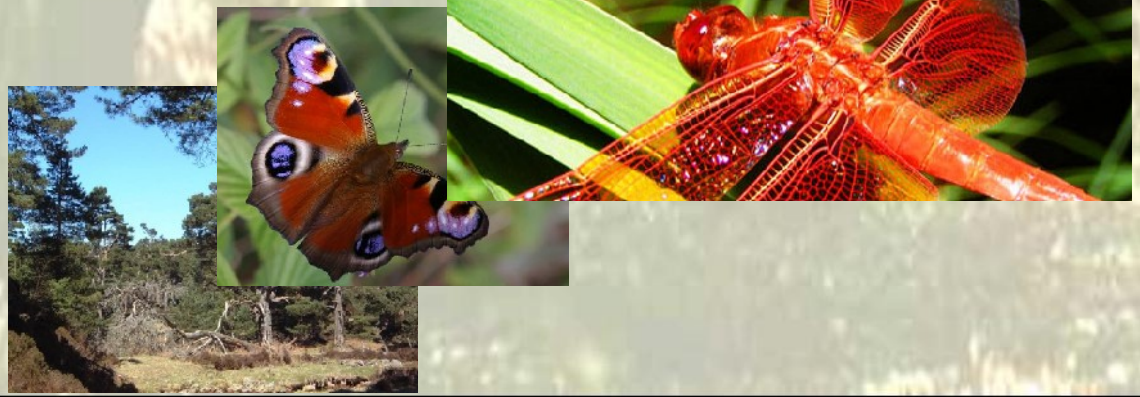
“..how .. manage ecosystems in a way that promotes ecological sustainability ?

⇒Need proper incentives ….
⇒Participative actions
⇒Need good data for proper planning

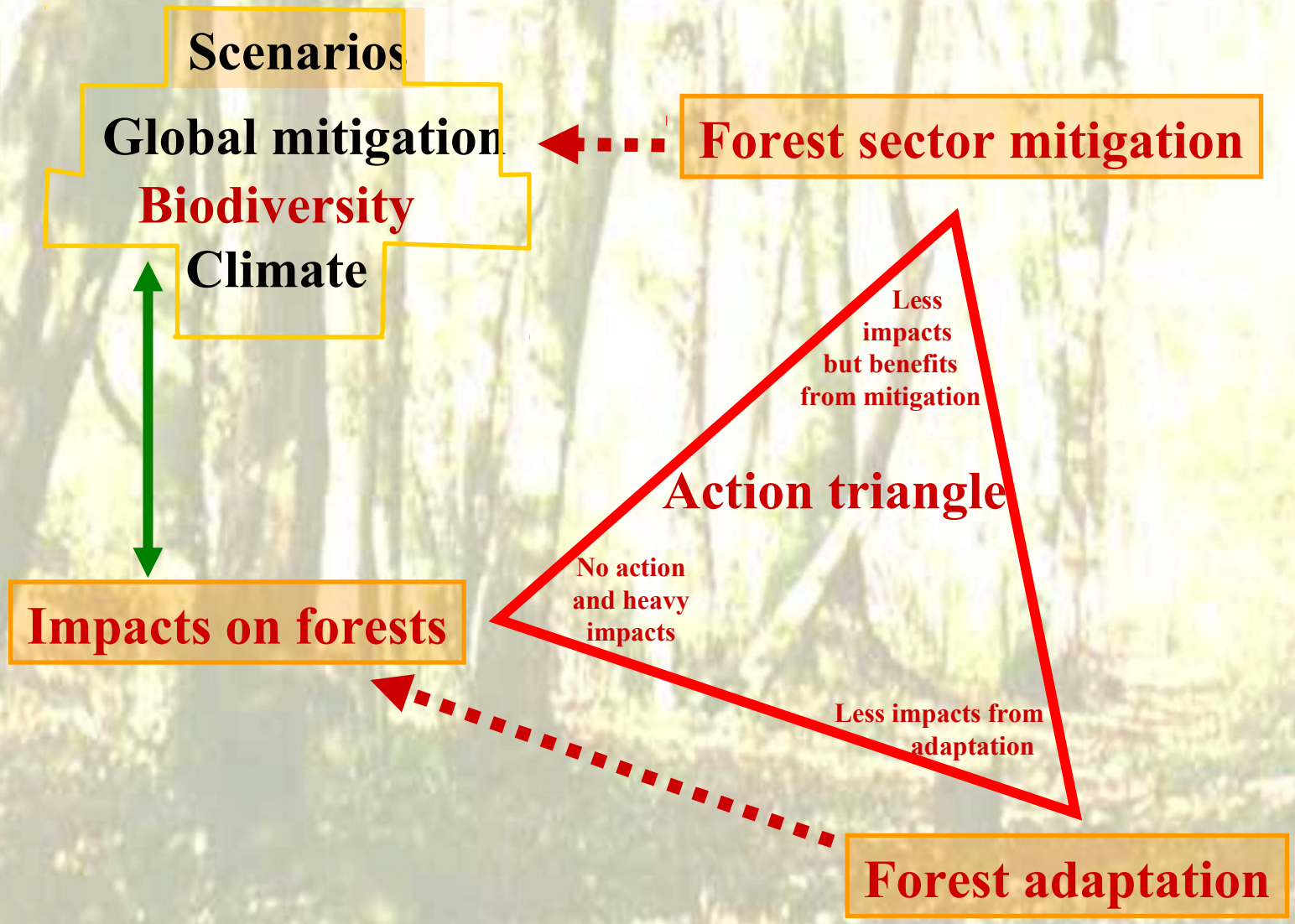
How to improve sustainable use of biodiversity in a landscape perspective?

CBD request within the International Year of Forests 2011

- A call for landscape ecology?
- An adaptive forest management approach



The Action Triangle



Evaluation criteria

Biodiversity

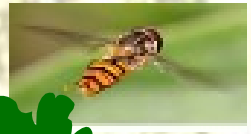
Production
(wood & carbon)

Multifunctionality

Forest status:
recreation and tourism
soil & water protection

Management

- **Forest (→ & Natural Ecosystem) Management**



Management – *Organisation Level*

Organism
Plant (tree)

Patch
Parcel / Stand
Community
Ecosystem

Borders
Ditches
Embankments

Farm
Forest Estate
Watershed

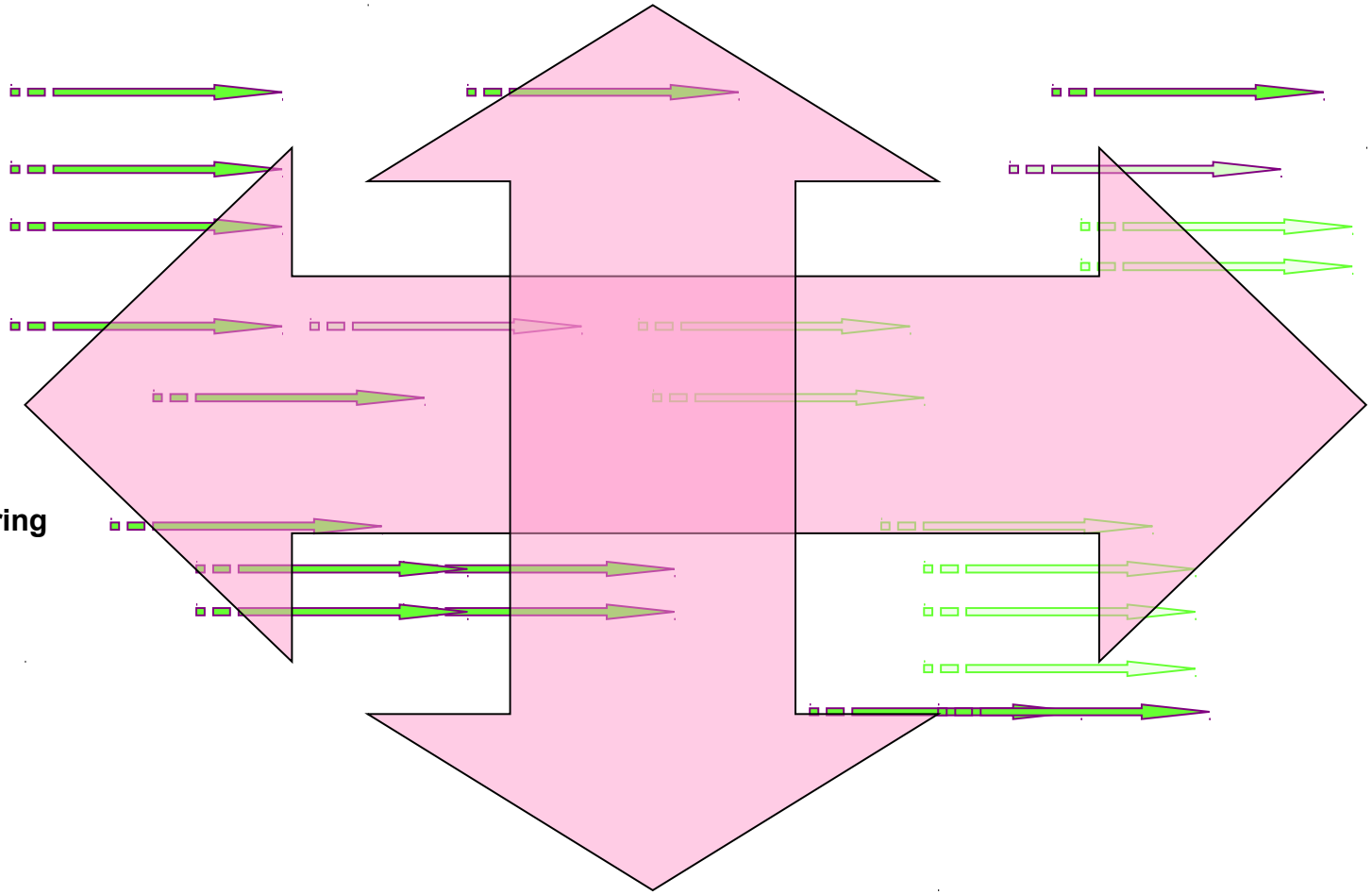
Landscape

Region

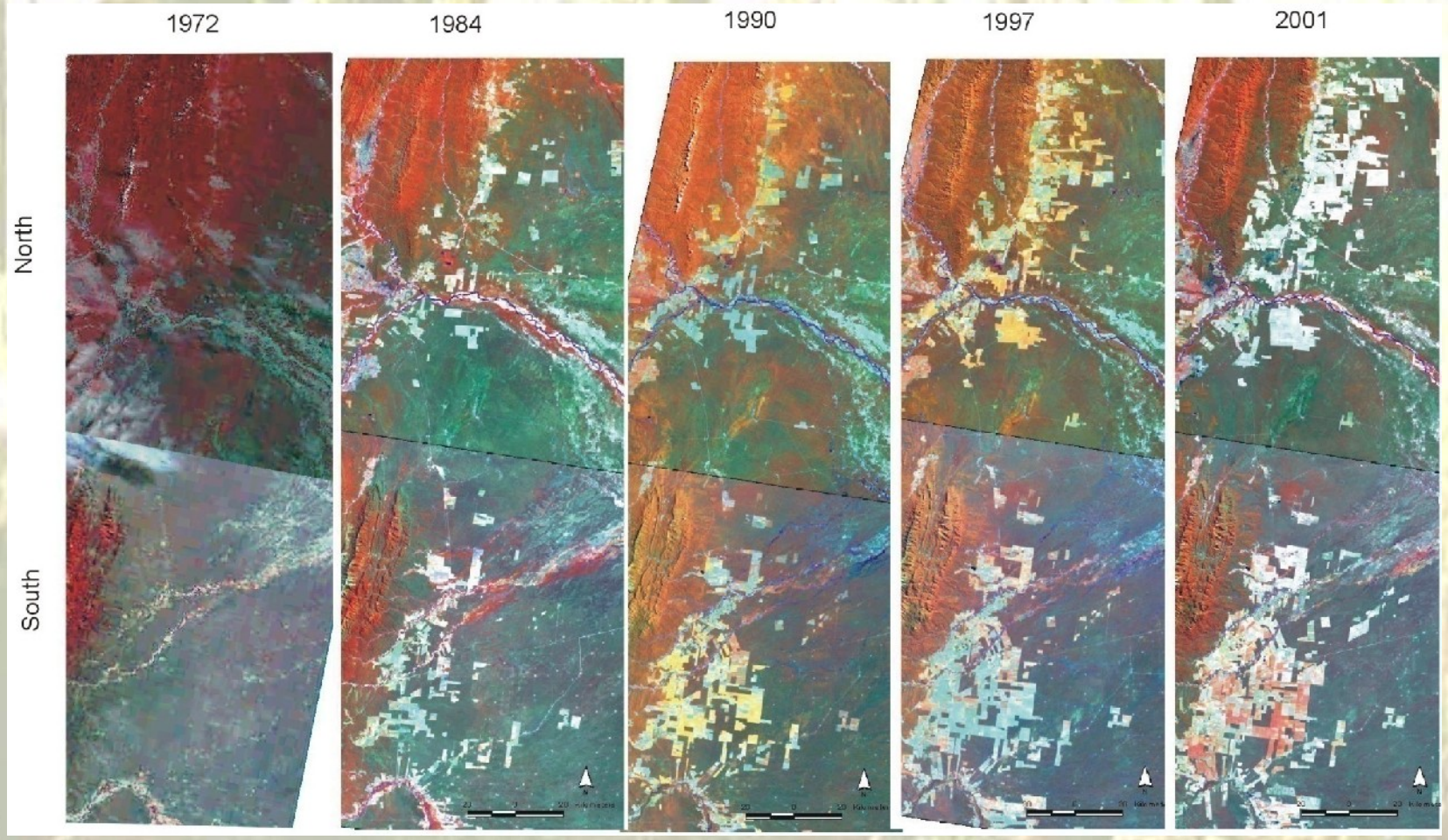
Multi-scale

Multi-criteria

- Timber / Crop
  NTFP / $ / €
- Biomass
- Carbon
- Other GHG
- Adaptation to CC
- Pollution,
  Agrochemicals
- Disturbance,
  Ecological engineering
- Conservation
- Biodiversity
- Socio-Cultural
- Recreation, amenity

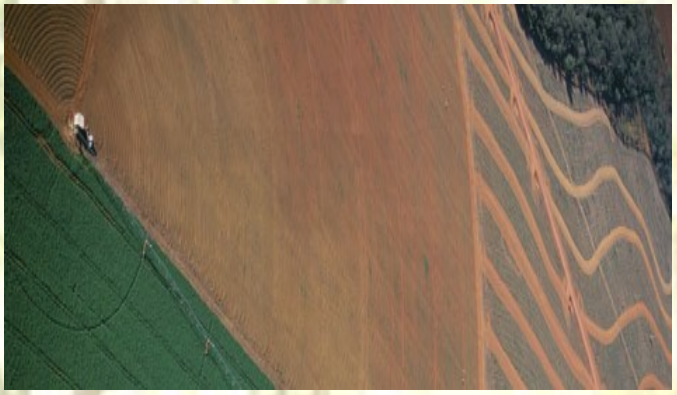


Agriculture expansion into dry forests (800,000 Ha/30 y)



Grau et al. 2005. *Environmental Conservation* 32, 140

- 2007, Argentina exported 200 millions litres of oil, in 2010 exported 800 millions litres of SOYA oil



Native Forests in 1914 covered 35%
2010 only 10% of native forests within total forest land

Increase in Soya area culture

In 2007 2,5 millions hectares in Paraguay.
CAPECO increased the plantation into 3,5 millions hectares in 2008

Plantations de forêts

Valdivia, Chile

Small scale logging of native forests, livestock and agriculture have been replaced by large scale timber production

- 1975-2001: Show changes in land use during the last 30 years

1975 → 1990 → 2000

A reduction in forest area of 67% between 1975 and 2000

Annual forest loss rate of 4.5%

Agricultural land

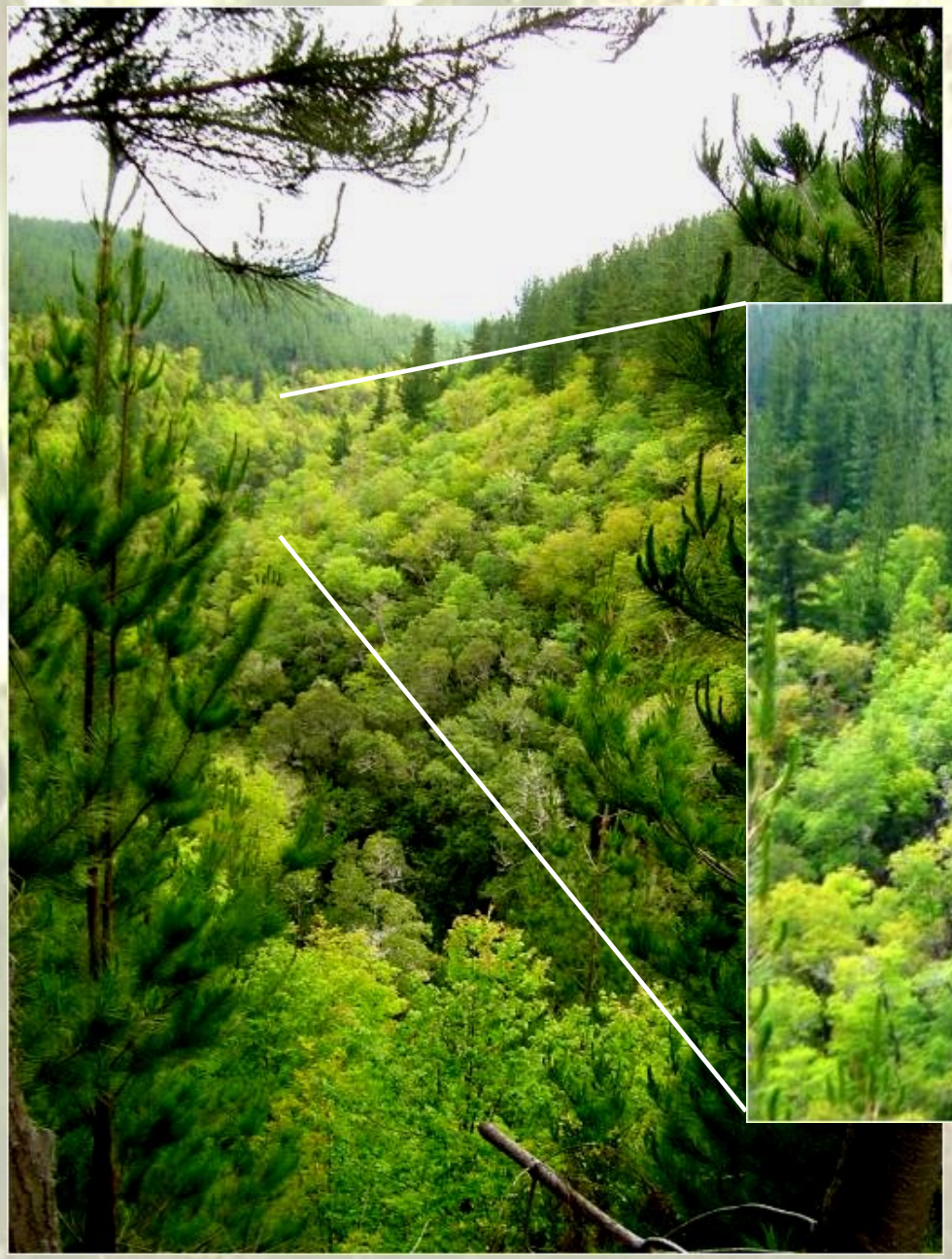
Shrublands

Native forests

Exotic-species plantation

0 20 40 km

Echeverría, et al. 2007. Impacts of forest fragmentation on species composition and forest structure in the temperate landscape in southern Chile. Global Ecology and Biogeography 16: 426-439



Nothofagus alessandrii* (a critically endangered tree) forest surrounded by industrial plantations of *Pinus radiata

A Forest Landscape Perspective

- It is difficult for managers to:
  - understand the effects of proposed management actions in the presence of **complex interactions**
  - estimate the range of **natural variability** of ecosystem properties
  - objectively predict the consequences of **management alternatives**

Adaptation is emerging topic

- Double strategy:

- Accelerating mitigation measures
- Adaptation of landscapes

Questions to landscape science

- Determine effects on landscape functioning
- Determine if people care (e.g. loss of value and safety)
- Provide options to adapt landscapes to prevent or diminish impacts
- How to organize landscape adaptation in a multilevel complex society?
- How to integrate landscape adaptation in land change planning and design?

Opdam, Luque B. Jones. Landscape Ecol (2009)

Imperfectness of state of the art

- Impact studies often focus on change in functioning without considering **spatial variation** of landscapes.
- Impact indicators not linked to values, costs, benefits, they do not have a meaning to stakeholders & policy makers
- Impact studies often are at large scale, but change will be noticed first at the local level,

  ⇨ a **multilevel approach** is needed

Patterns into Processes

Processes

Local

Regional

Continental

Pattern

Holistic approach to forestry

upscale

downscale

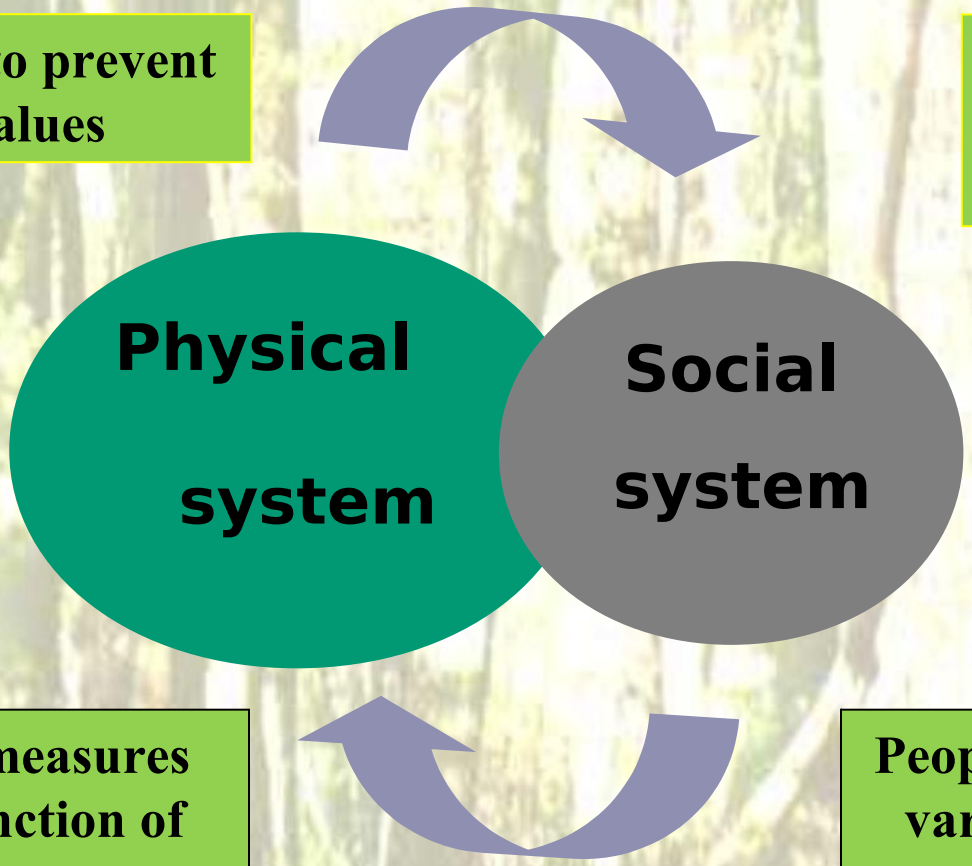
Complex & more realistic models

Scaling
Dynamics
Interactions

Landscape adaptation as a cyclic process

Adaptation to prevent loss of values

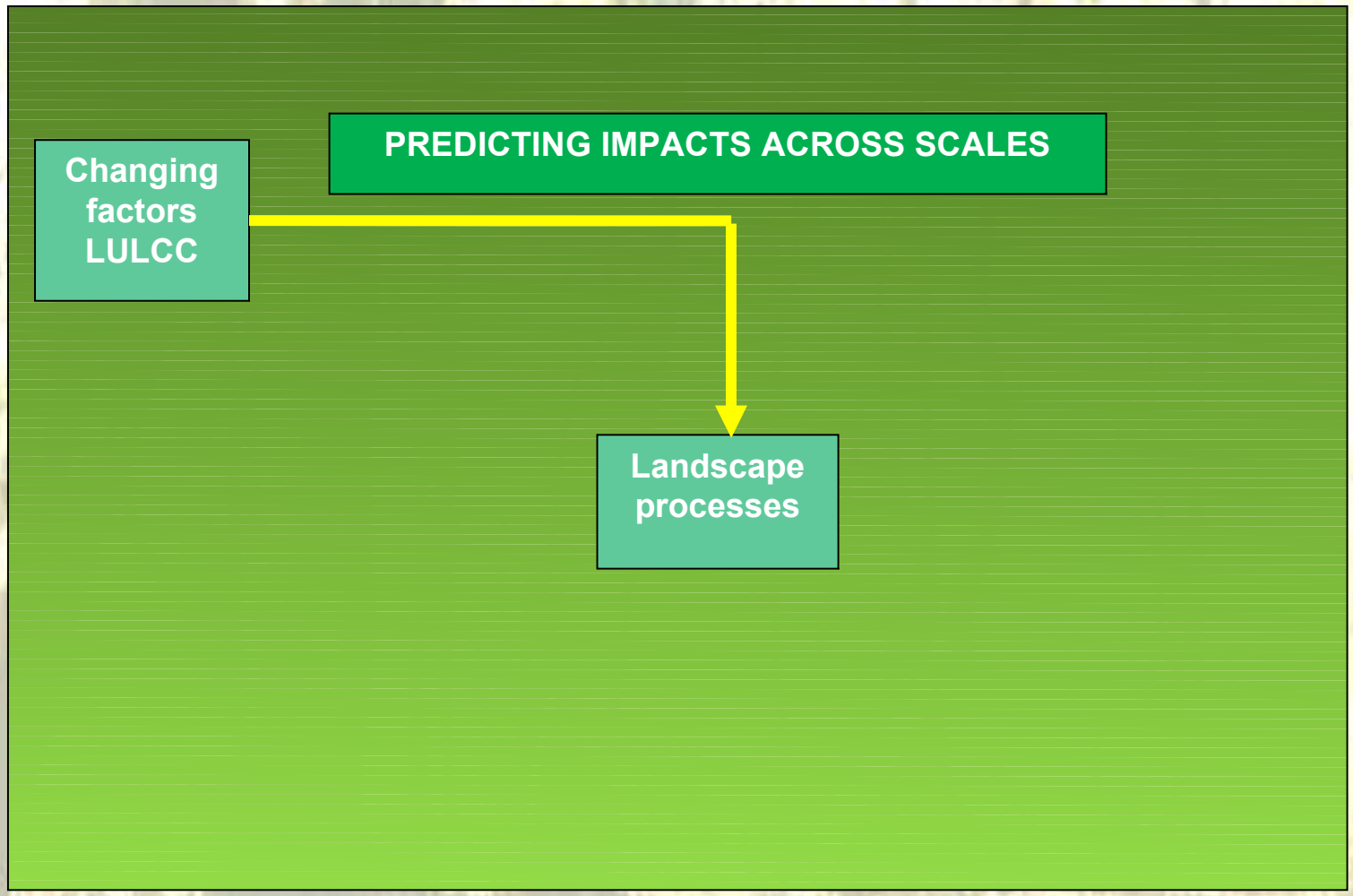
To improve benefits or lower costs of land use



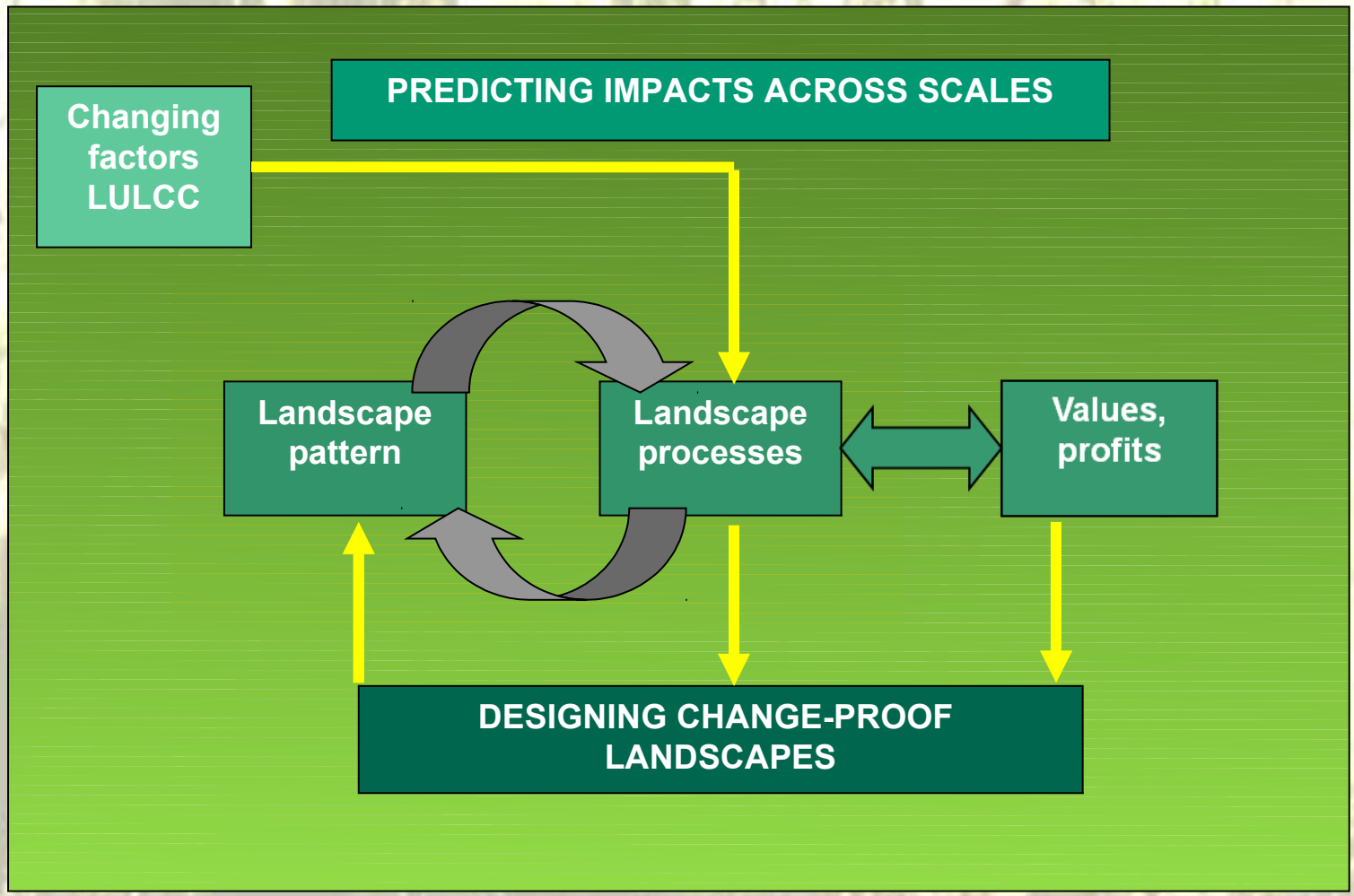
Adaptation measures affect the function of landscapes

People have different and variable perceptions of value

Why is landscape ecology in a key position?



Why is landscape ecology in a key position?



A Forest Landscape Perspective

- To reach adaptive forest management :
- There is a need for landscape ecological decision support tools
- Many ecological problems can only be understood and managed at landscape scales
  - Managing **disturbance**
  - Understanding **natural variability**
  - Assessing management plans in light of **global change**

Manage for Multifunctional Landscapes

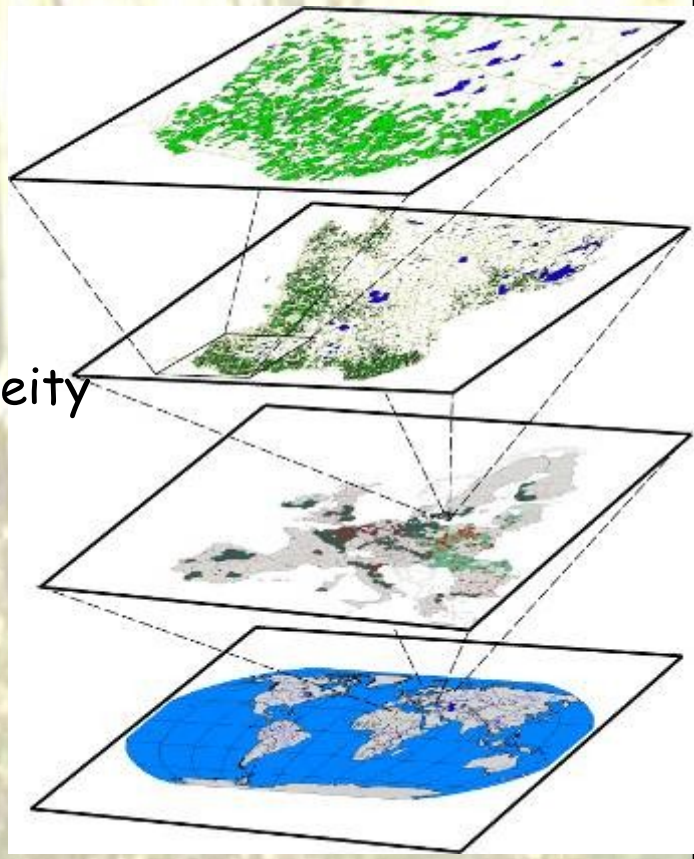
Landscapes have a number of provisioning, habitat, regulatory, and cultural/aesthetic functions (multifunctional)

Function	Description	Examples
Provisioning	Goods and services	Food, raw materials, cultivation, resource extraction, energy conversion
Regulation	Direct benefits from ecosystem processes (e.g., biogeochemical, water cycles)	Climate regulation, erosion control, air & water quality, biological control
Cultural/ Amenity	Aesthetic, recreational, spiritual, scientific or educational value	Scenery, ecotourism, heritage/cultural sites, religious sites, research & education
Habitat	**Maintenance of biodiversity**	**Persistence of rare or endemic species, refugia, breeding habitat**

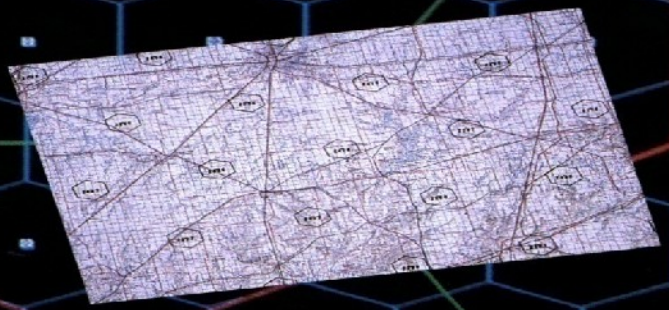
Mander et al. (Eds.). 2007. *Multifunctional Land Use*. Springer, Berlin.

Management - *Organisation Level*

- Organism - Plant (tree)
  - Selective logging & pruning / Precision agriculture
- Patch – Crop / Field / Stand / Parcel– Ecosystem – Community
  - Borders – Ditches – Embankments
- Farm - Forest Estate - Watershed
- Landscape
  - Ecological Corridors / Networks/ heterogeneity
- *Region*
- *(State – Community of States [EU] – World)*



Multi-scale Monitoring Tools



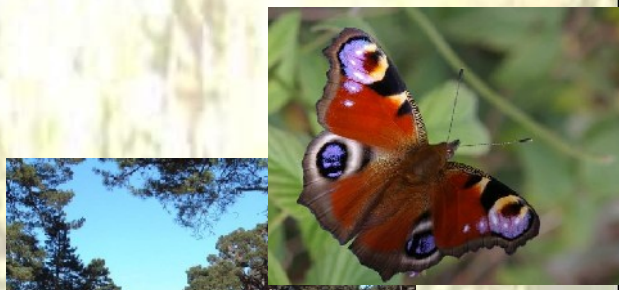
U.S. Department of the Interior
U.S. Geological Survey

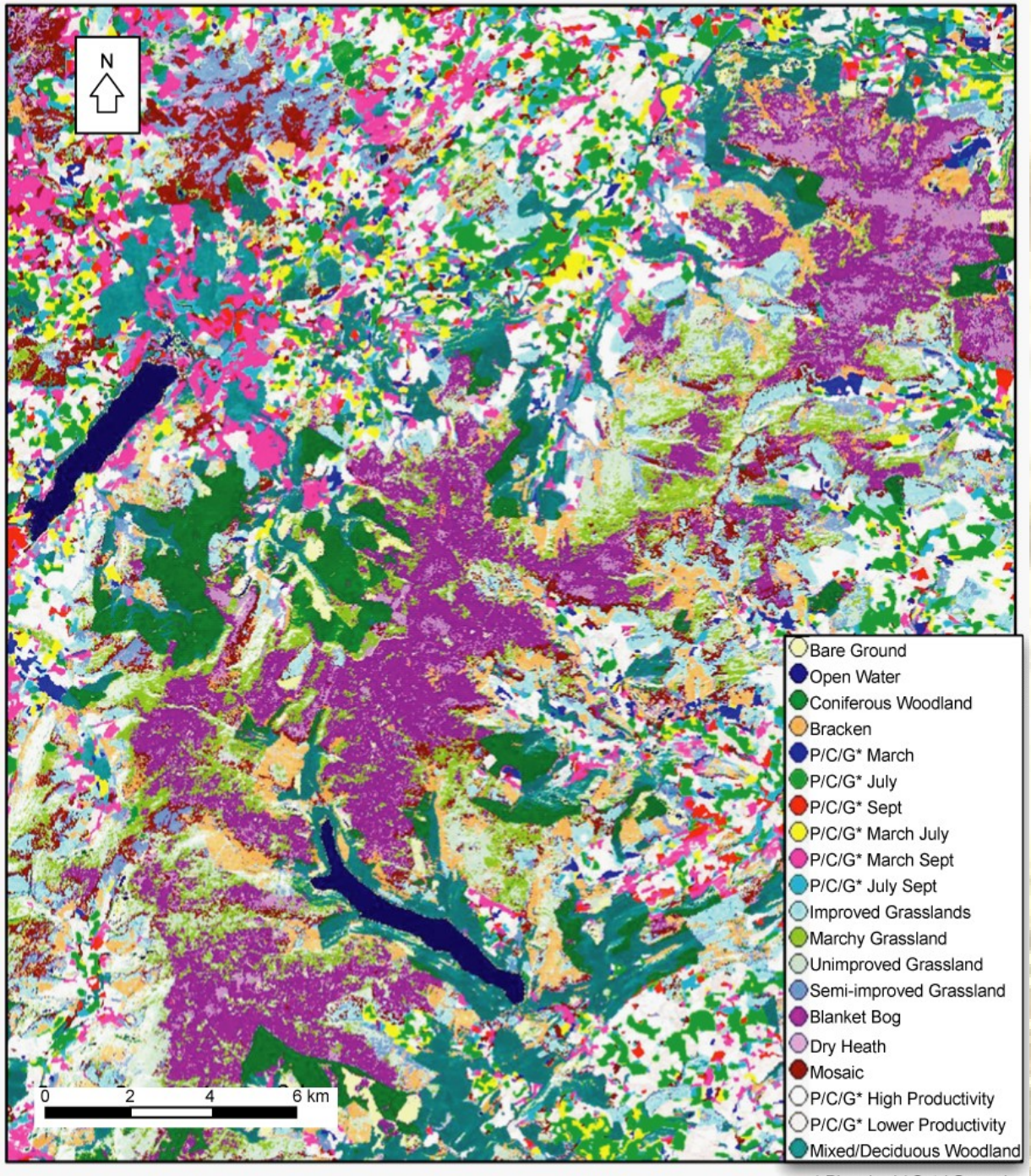
Conceptual framework

- **How to develop links between Forest habitat quality – biodiversity - management?**

INCLUDES

models that develop and explore relationships between the spatial distribution of species or/and species diversity and habitat conditions

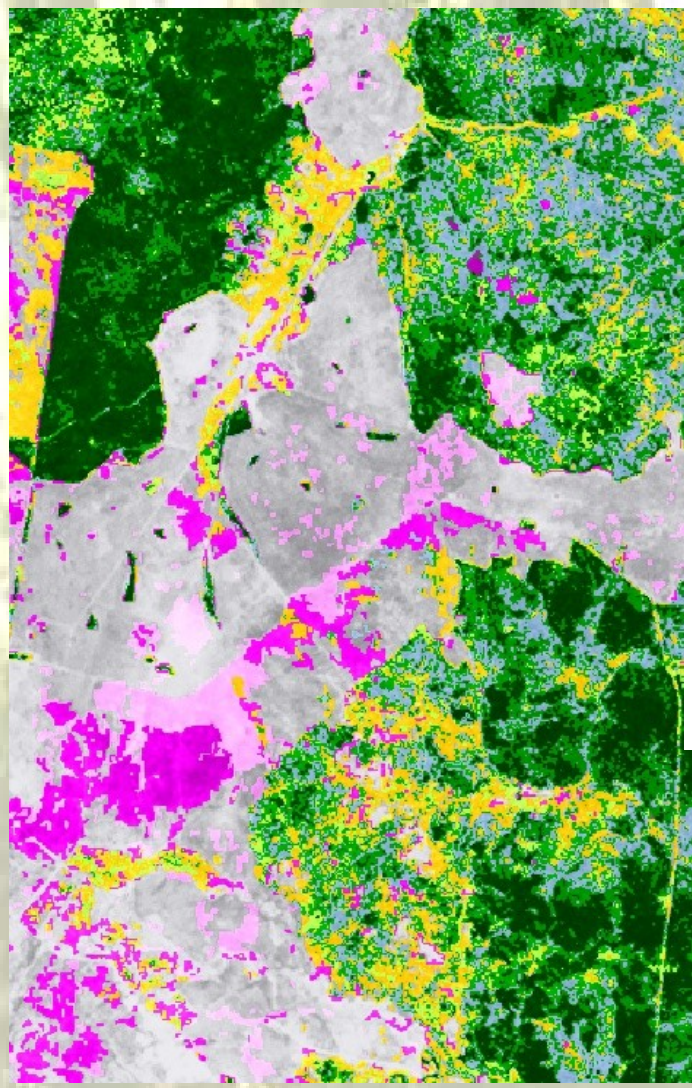


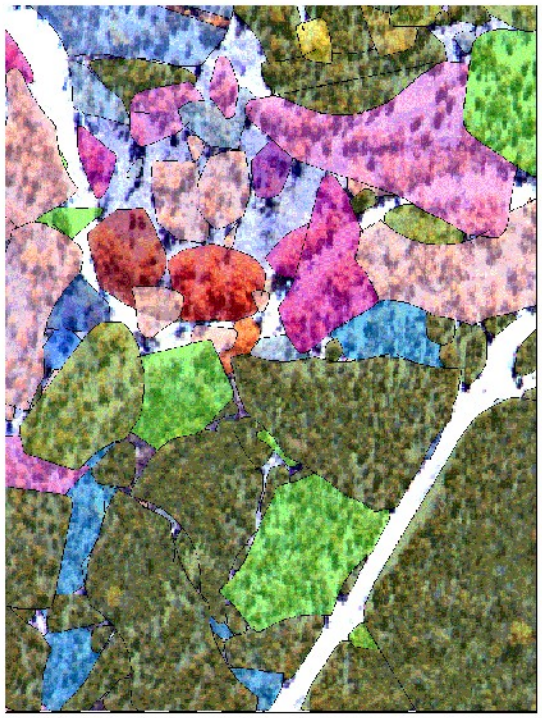


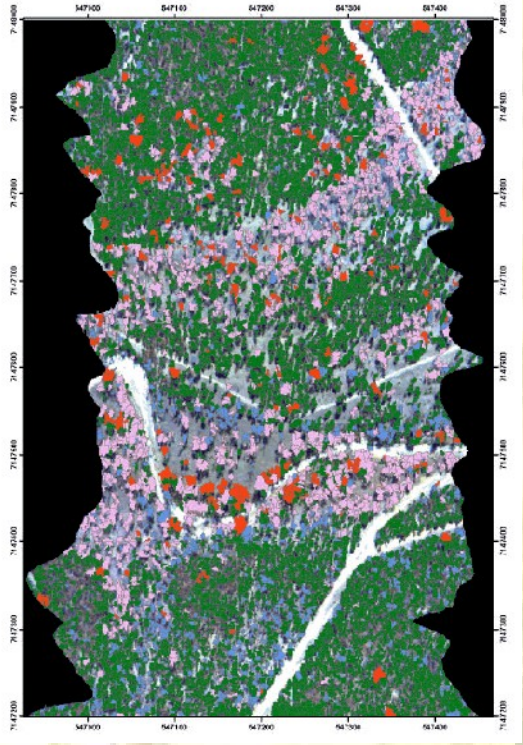
Linking with optical data

- Rule-based classification of habitats based on integration of optical/radar remote sensing and ancillary data.
- Vegetation height and structural retrieval using Synthetic Aperture Radars (SAR) interferometry
- Scale-up distributions of birds and other indicators of diversity to the wider landscape.

Outputs: Classifications of tree species at various scales



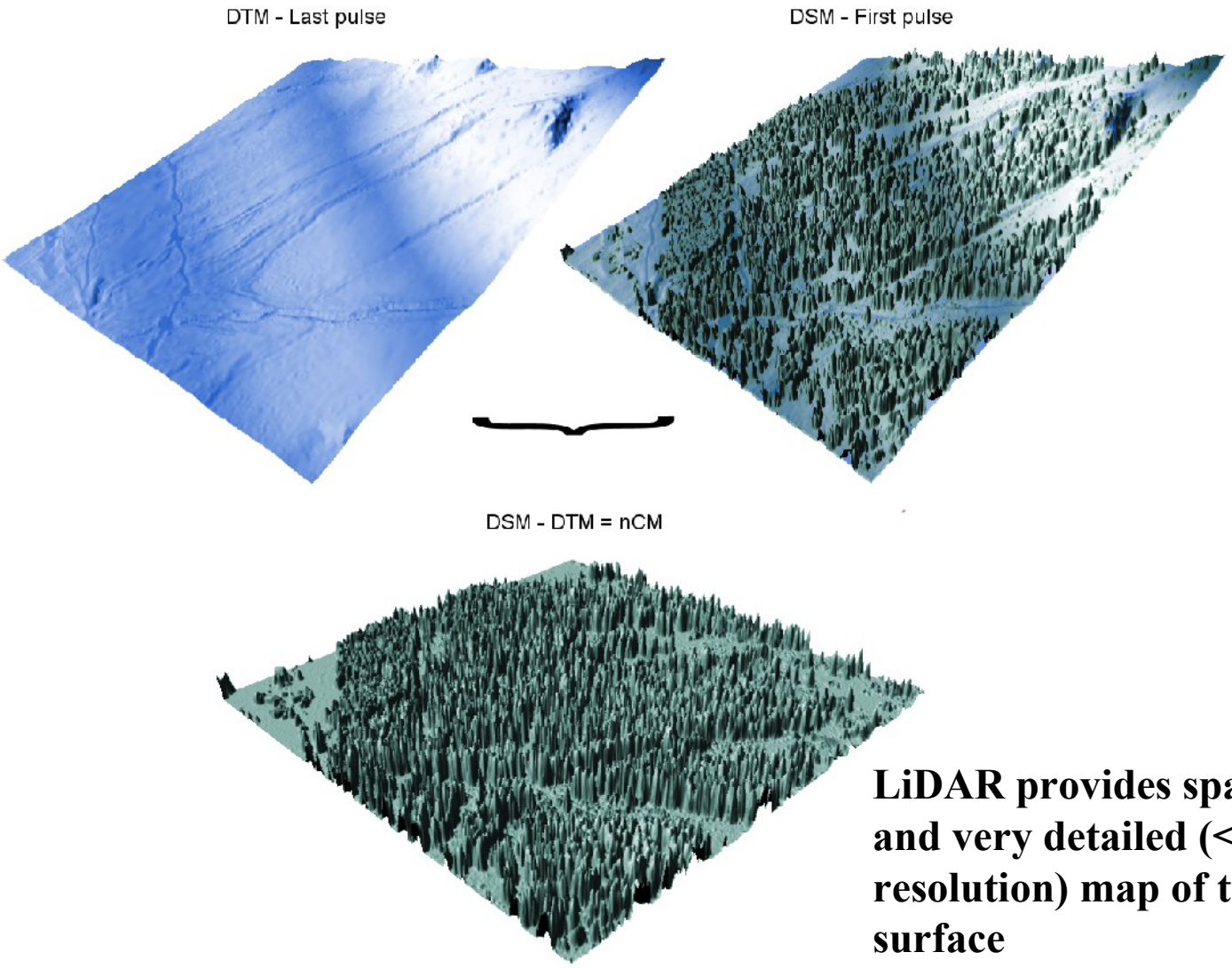




Scaling

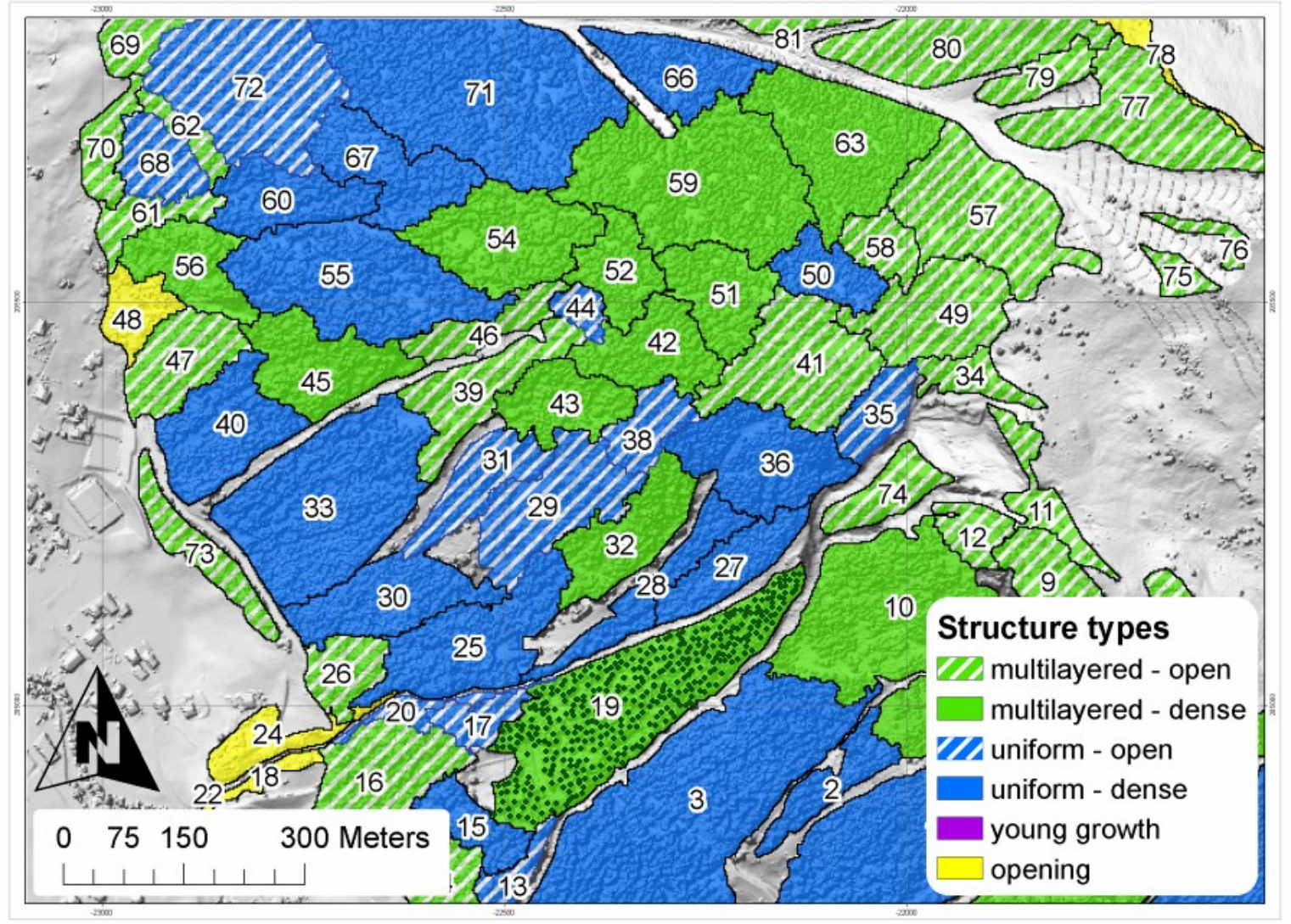
Laser scanning (LiDAR – Light Detection and Ranging)

Forest Research Applications (Natural Hazard / Protection)



LiDAR provides spatially explicit and very detailed (< 1m resolution) map of the earth surface

LiDAR based forest stand mapping



- nCM (normalised canopy model) - automatic mapping of both single-trees and forest stands.
- For forest stand mapping : use of multi-resolution segmentation.
- Landscape metrics at the stand level to characterise the structure of the stand

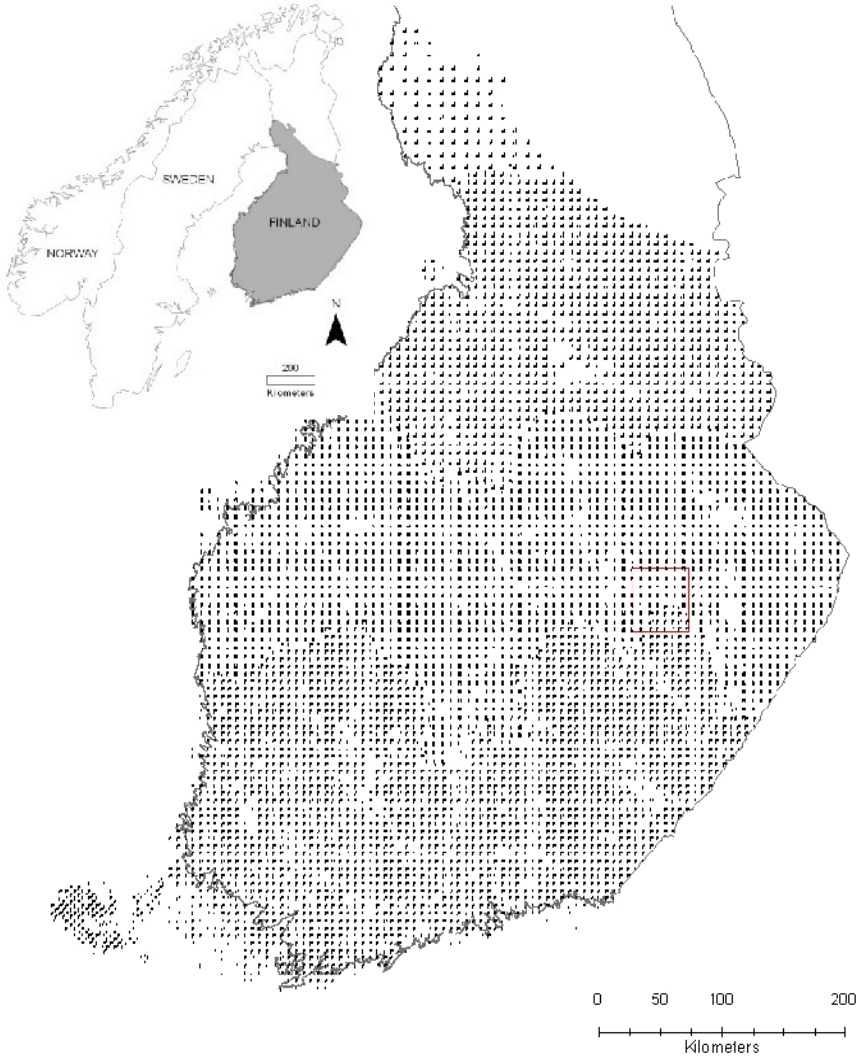
National Forest Inventory Plot data FINLAND

NFI9 (1996-2004)

- For Southern Finland we are using 53 434 plots (Forest & scrub land) within approximately 30,000 hectares
- Measured variables in the field: 150
- Additional variables derived from field measurements

Ecological Observations:

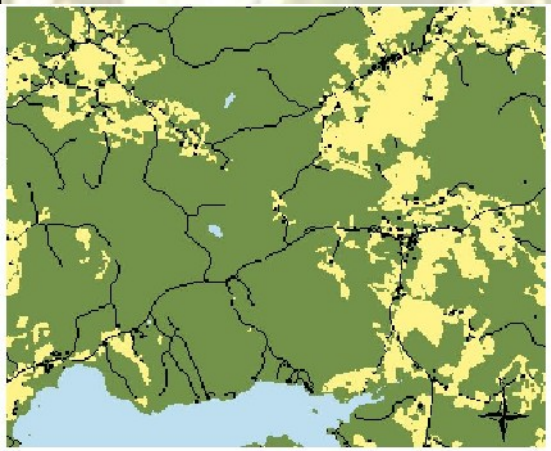
- Dead wood as measured on field plots
- Key biotopes identified based on ground and environmental conditions



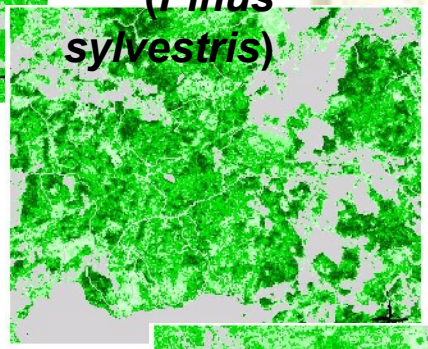
The field sample of the NFIs were measured from

NFI Multisource data

Stand Volume

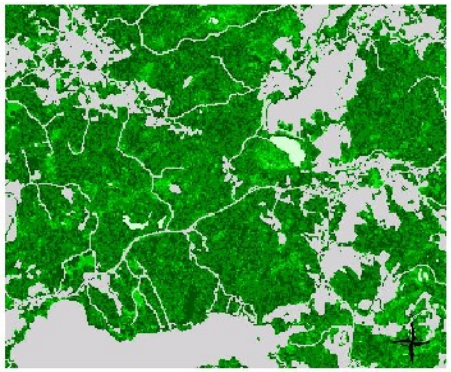


Pine
Scots pine (*Pinus sylvestris*)

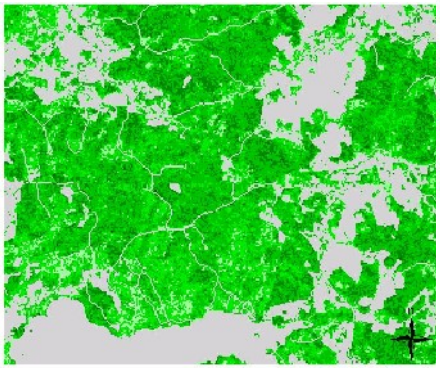


Spruce
Norway spruce (*Picea abies*)

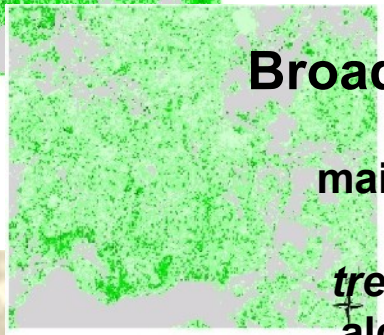
Land Cover



Birch
(*Betula spp.*)



Site fertility

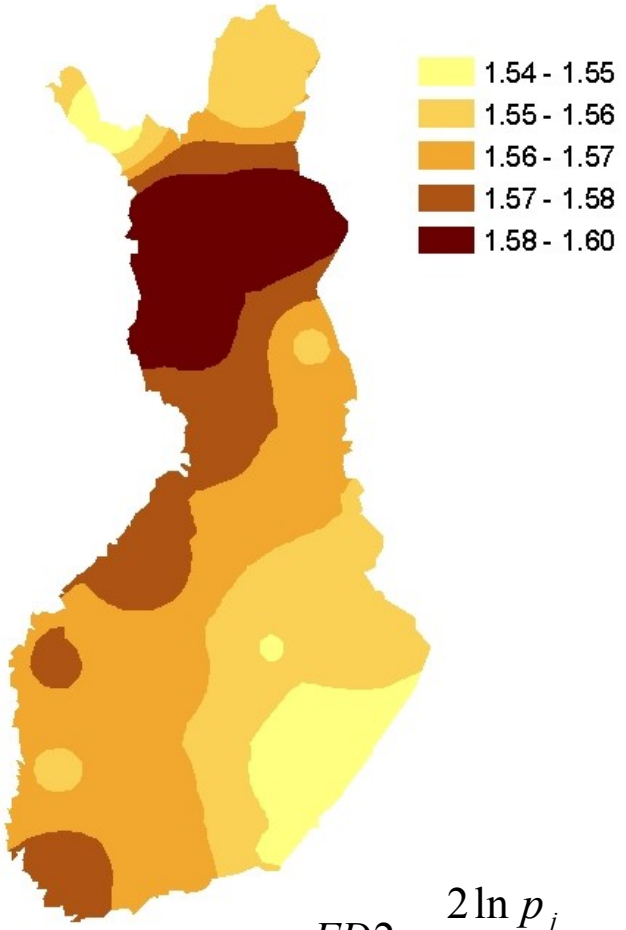


Broad-leaved

mainly aspen (*Populus tremula*) and alder (*Alnus spp*)

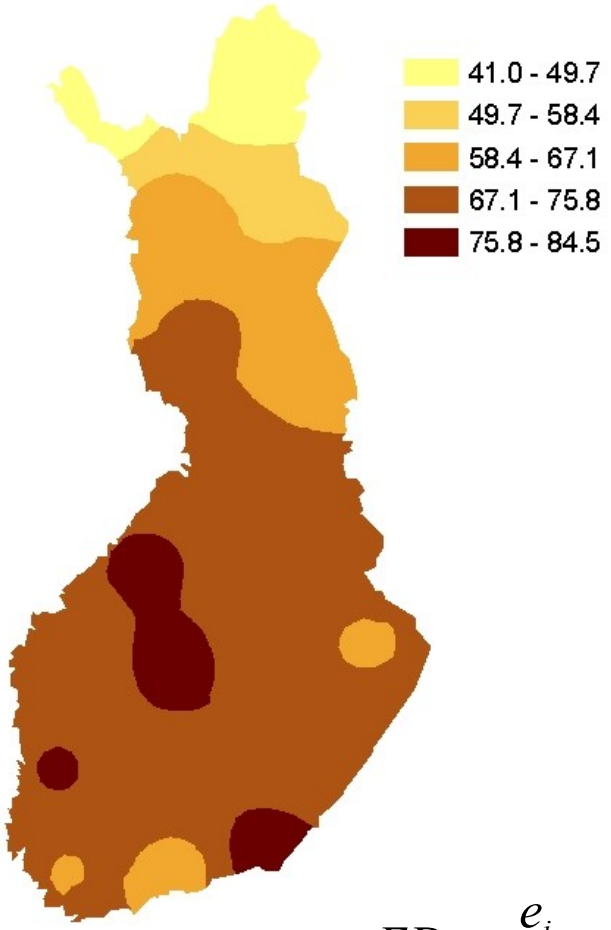
Stand Age

Fractal dimension for forest classes based on age



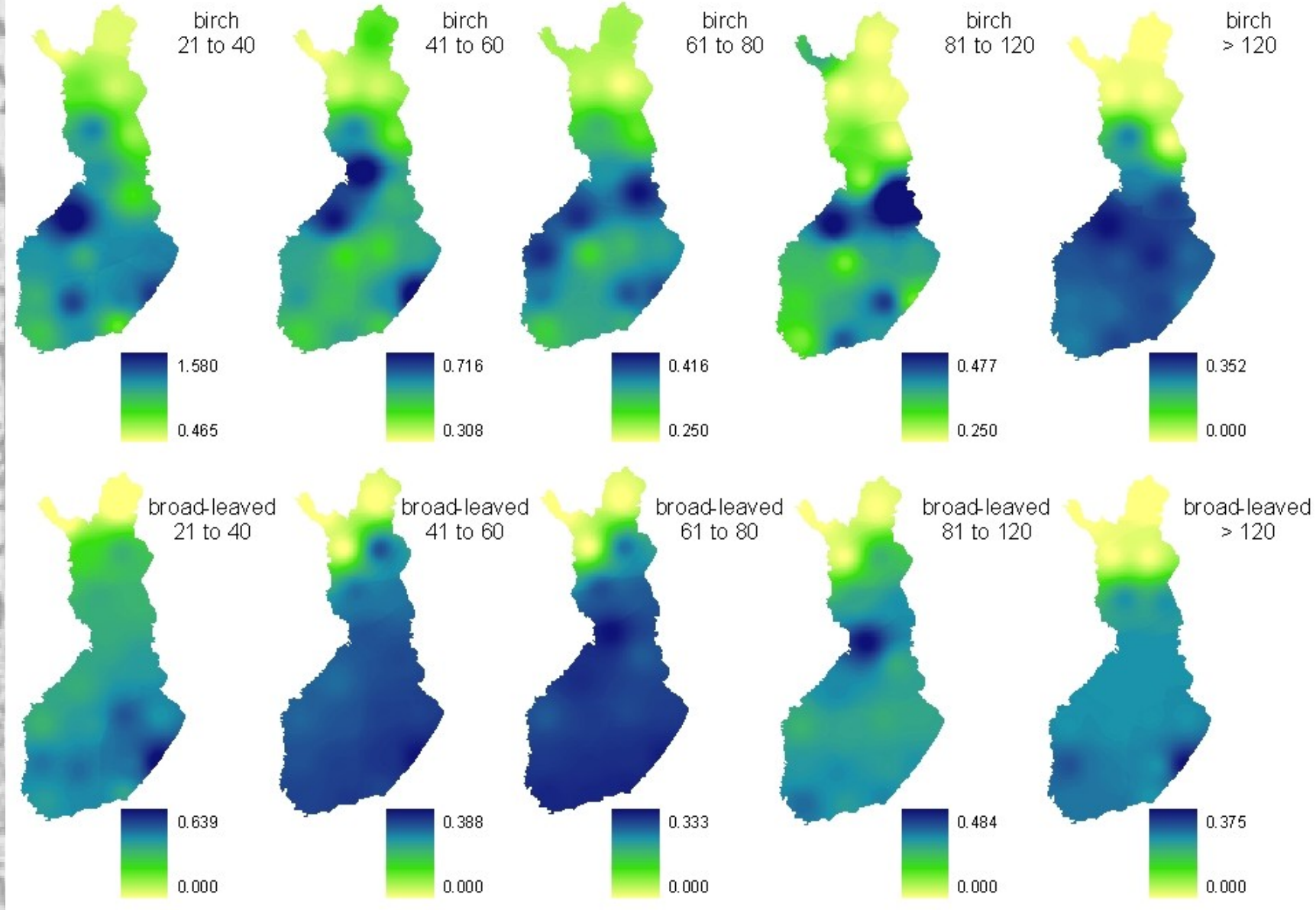
$$FD2 = \frac{2 \ln p_j}{\ln a_j}$$

Edge density (m/ha) for forest classes based on age



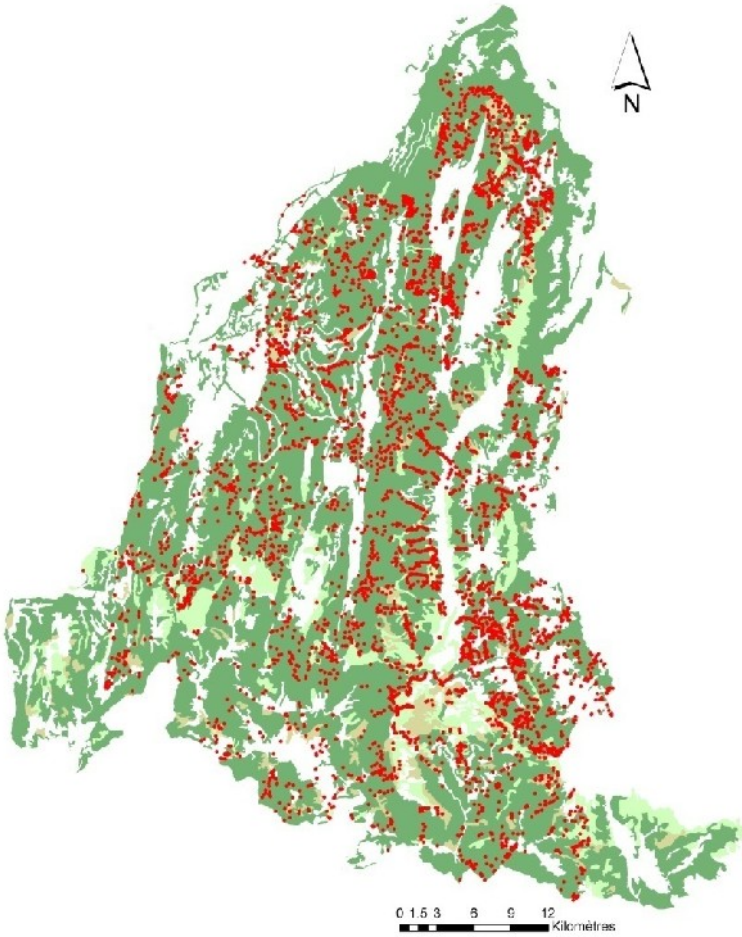
$$ED_i = \frac{e_i}{A}$$

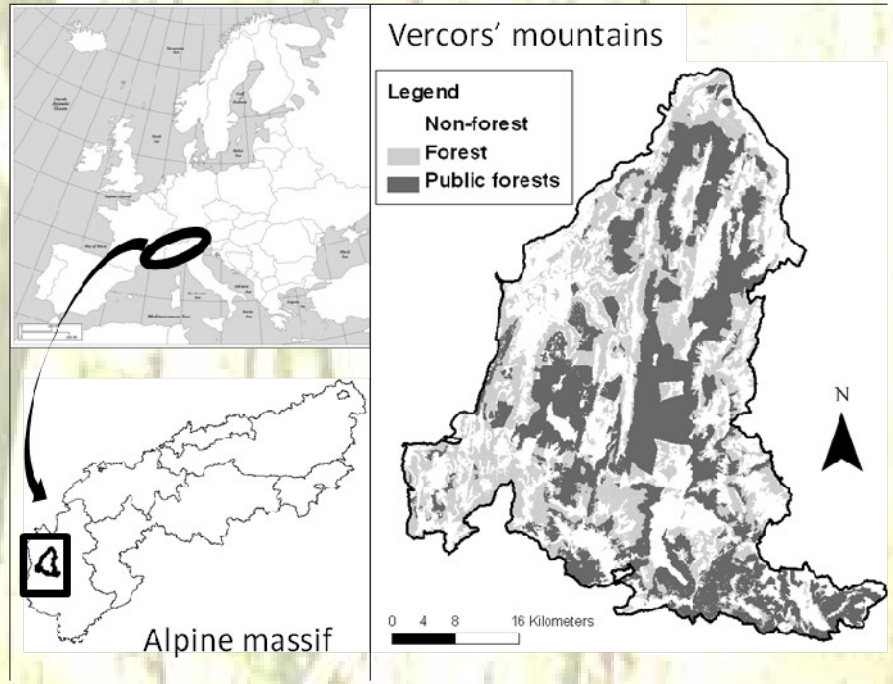
MPS (ha) for deciduos species, based on volume (m3/ha)



Data from Botanical inventory CBNA (Florisitc data)

+ de 20000 relevés phyto-sociologiques





French Alps PNR Vercors

206 000 ha

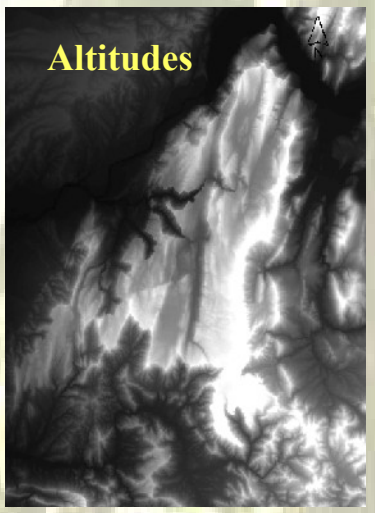
139 000ha forests

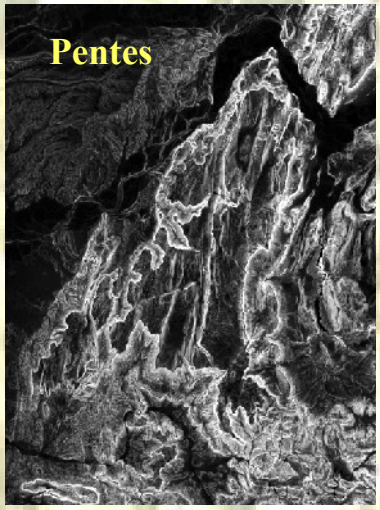
Altitude : from 180m to 2453m

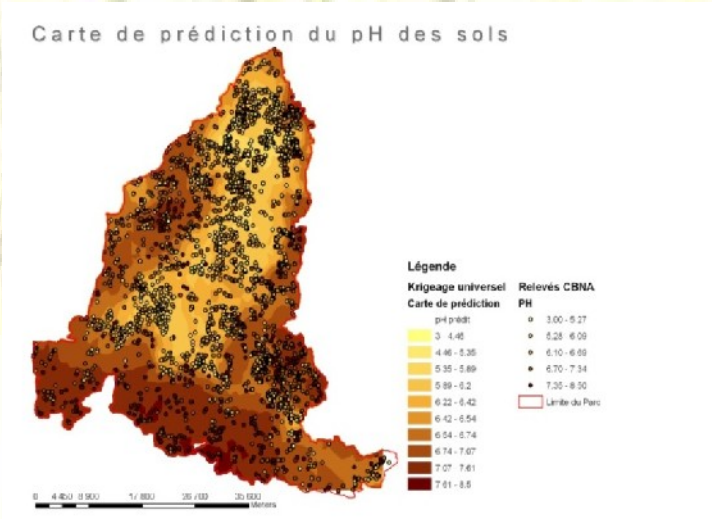
7 different natural regions

Environmental data

MNT 50m IGN

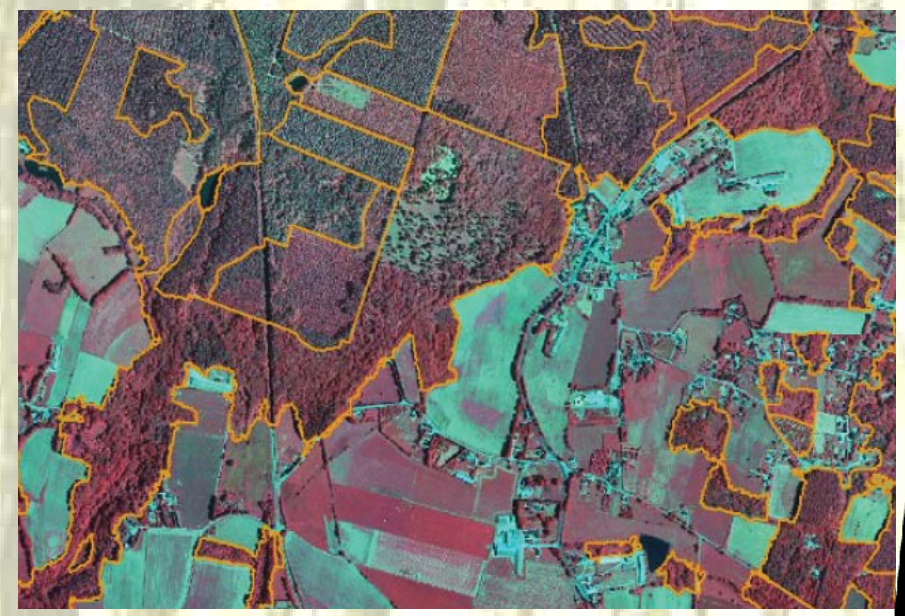




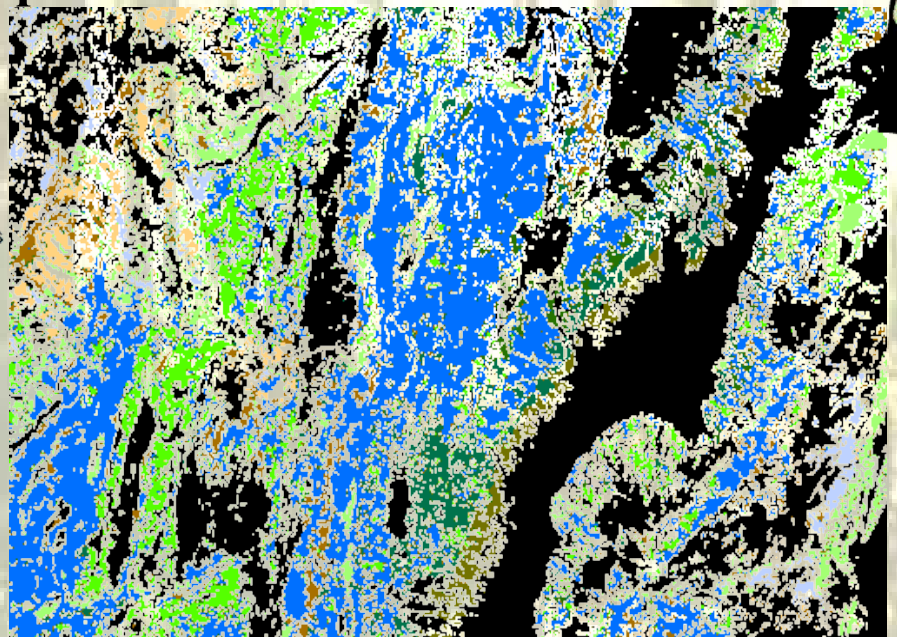


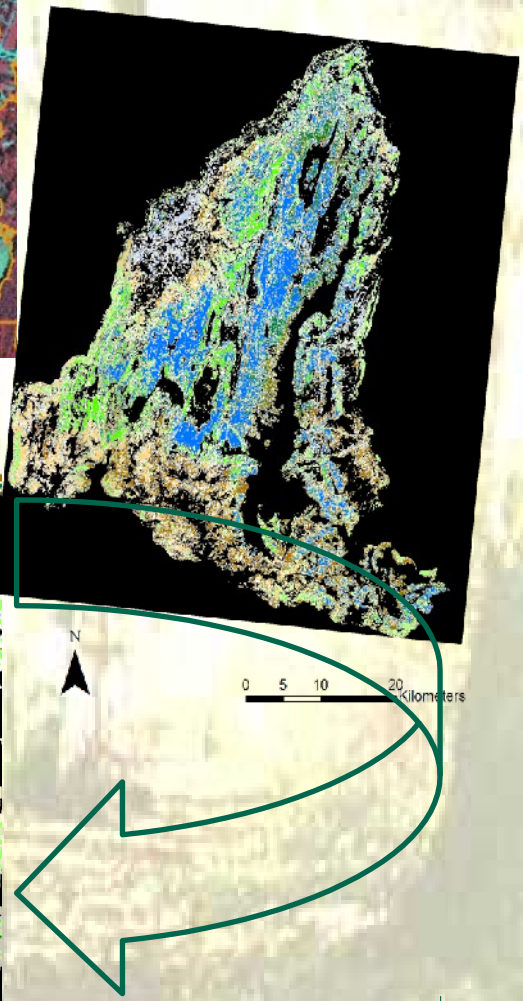
… issues des bases de données de **Météo-France (1km, méthode Aurelhy)**

Image segmentation to produce Habitat mapping



Forest Habitats maps





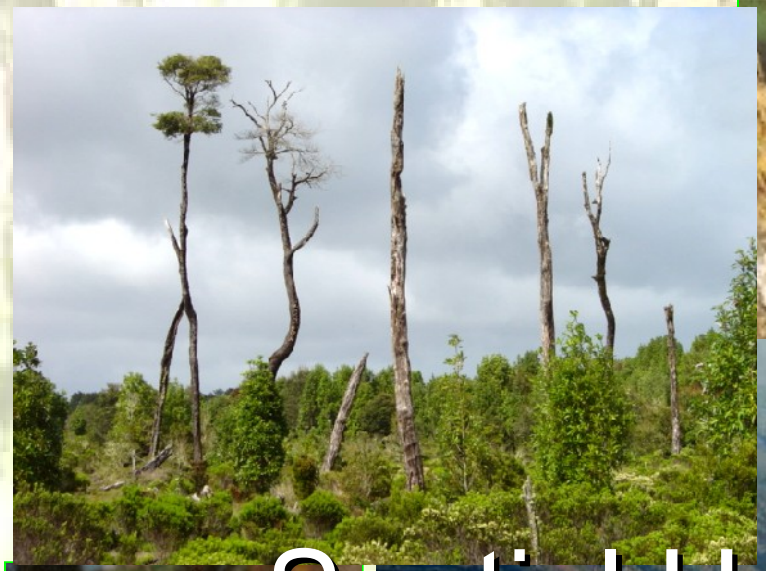
- 41.1 Hêtraies
- 41.4 Forêts mixtes de pentes et de ravins
- 41.7 Chênaies thermophiles
- 42.1 Sapinières
- 42.2 Pessières
- 42.4 Pins à crochets
- 42.5 Pins sylvestres
- 43.1 Hêtraies mixtes
- 44.3 Forêts de Frênes et d'Aulnes

The concept of “landscape services” as a common ground for knowledge production

Landscape services as a bridge between landscape ecology and sustainable development

Jolande W. Termorshuizen and Paul Opdam (2008)

Which Habitats to protect that have high level function



Araucaria araucana forest

Spatial Habitat Models

Enicognathus leptorhynchus

Pseudalopex fulvipes

Pitavia punctata

Dromiciops gliroides

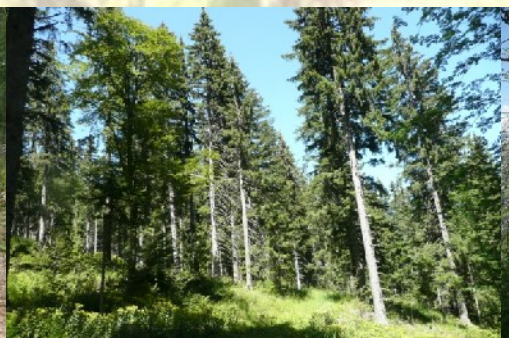
Lapageria rosea
(national flower)

How to reach an adaptive forest management to balance multiple objectives?

Where and how to protect forest biodiversity?

How can we assess forest biodiversity?

Lack of representative conservation areas for Forest Protection in terms of Biodiversity value – Geographical allocation of conservation sites is skewed



General method

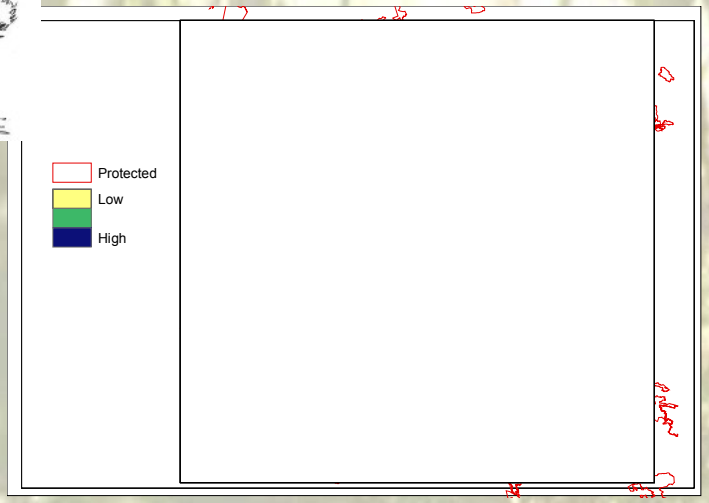
Geo-referenced species data, plot level data
dead wood data…

Indicators

Geographic Information System

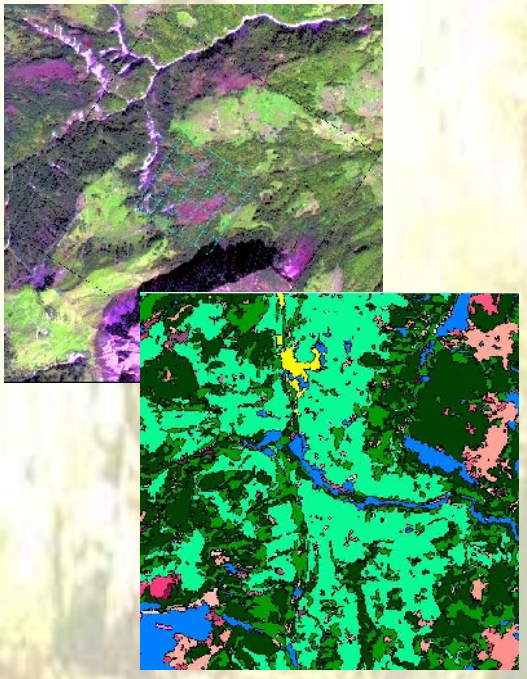
Overlapping, combining and weighting information

Modelling



Remote sensing, photo interpreteation
Digital Elevation Model , vegetation maps, ecological data, …

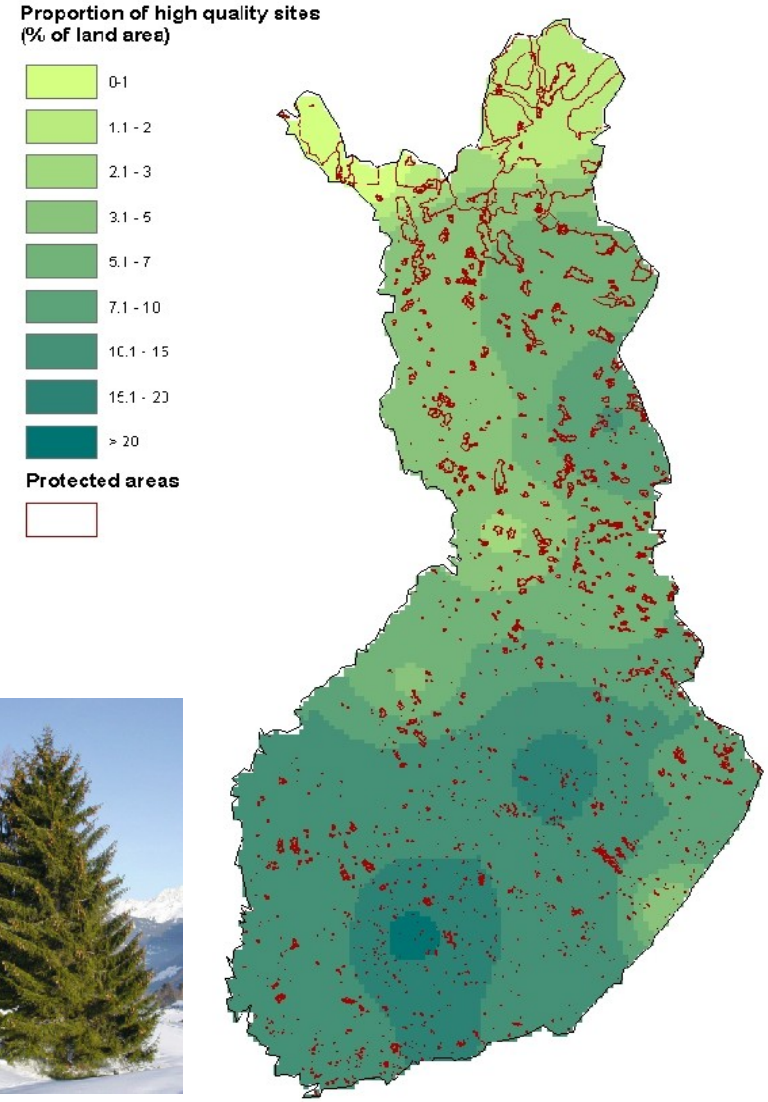
Classification



Map of forest habitats

Cemagref
Sciences, eaux & territoires

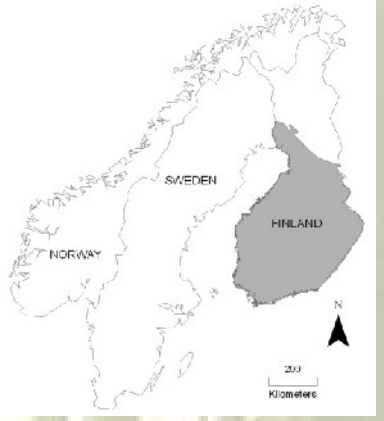
Modeled high quality sites in mature spruce (*Picea*) dominated mixed forest in relation to protected areas



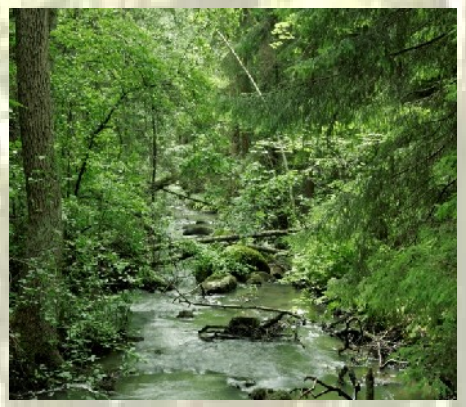
Protected areas shown in red

Rautjärvi N., Luque, S., and Tomppo, E. 2004. *GGRS Proceedings*: Göttingen GIS & Remote Sensing

Rautjärvi N., Luque, S.2005. ForestSAT Proceedings, Sweden. Håkan Olsson (editor), Life/IUFRO/ISPRS.



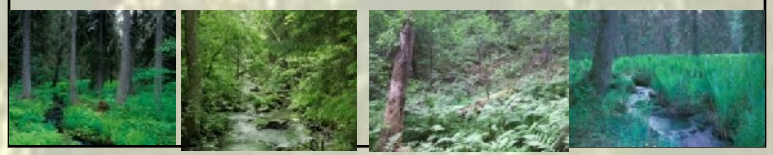
Herb-rich Habitats

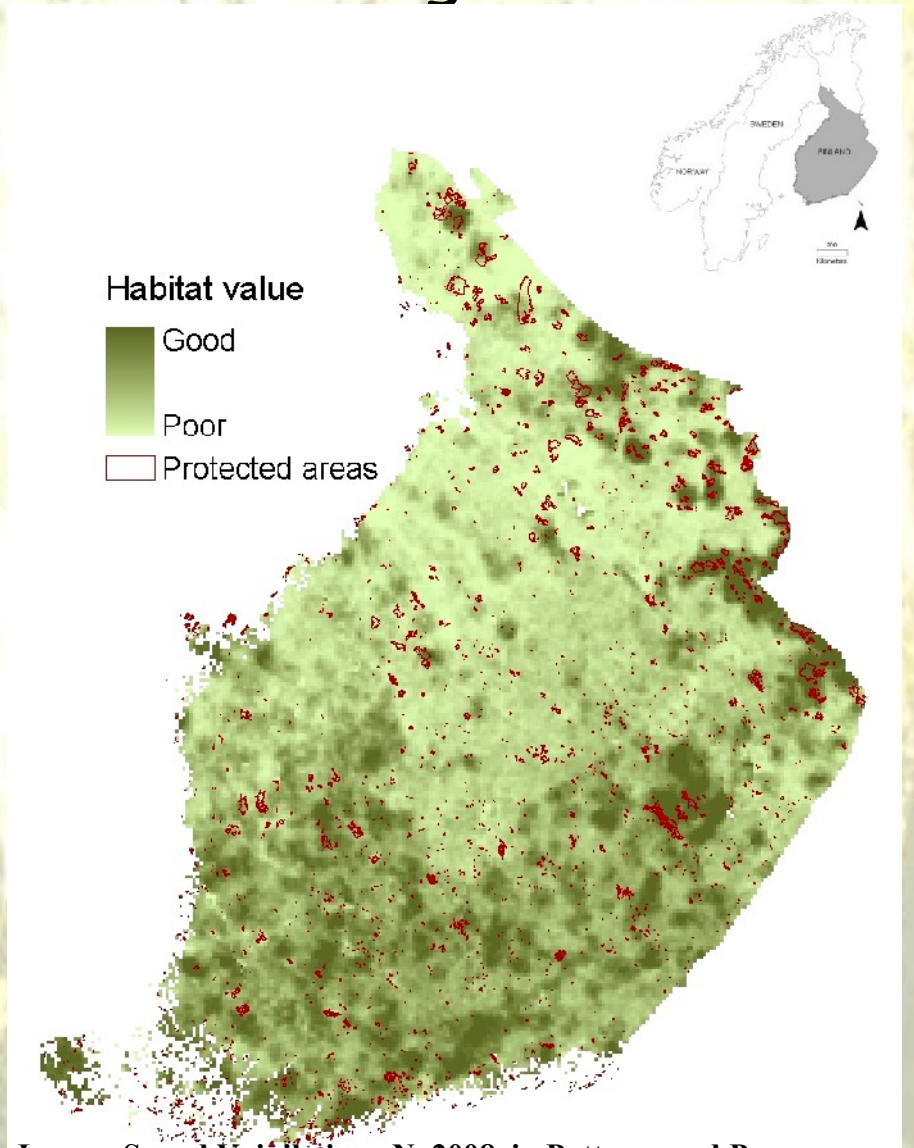


Photographs METLA/Erkki Oksanen

Habitat Quality Model & Protected Areas and Old Forest Conservation Programme

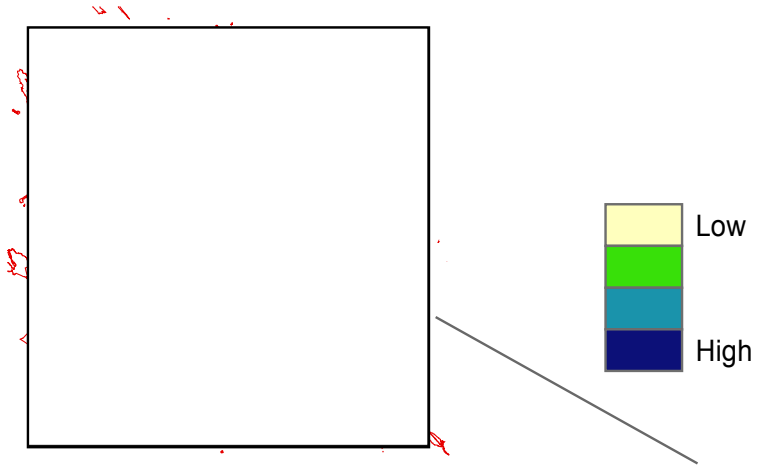
- **We proposed to base the monitoring on high quality MS-NFI data to provide measurements of forest habitat quality based on forest structure & composition**
- **This approach offers the potential to directly predict quality (in terms of physical structure and plant species composition)**

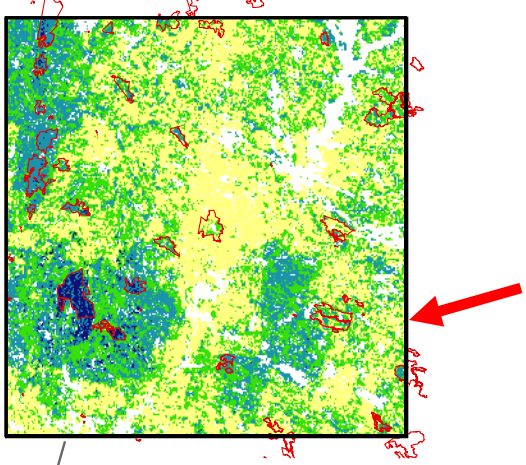


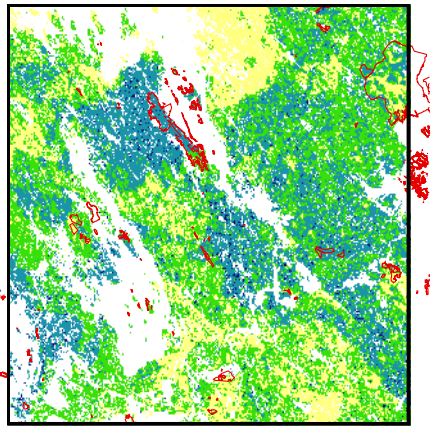


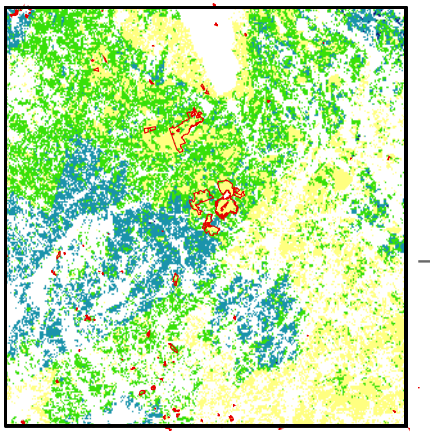
Luque, S. and Vainikainen N. 2008. in Patterns and Processes in Forest landscapes: Multiple Use and Sustainable Management. Springer publications

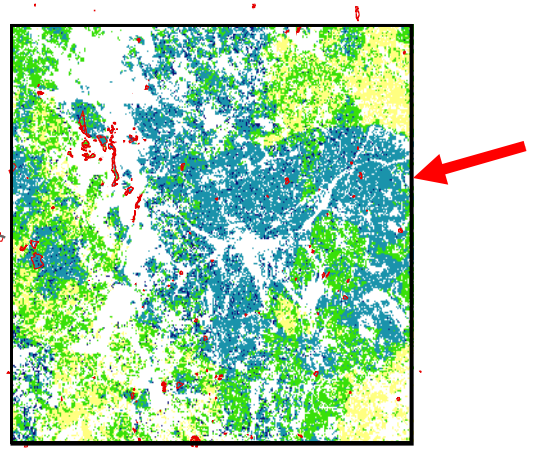
Herb Rich Habitat Quality Model



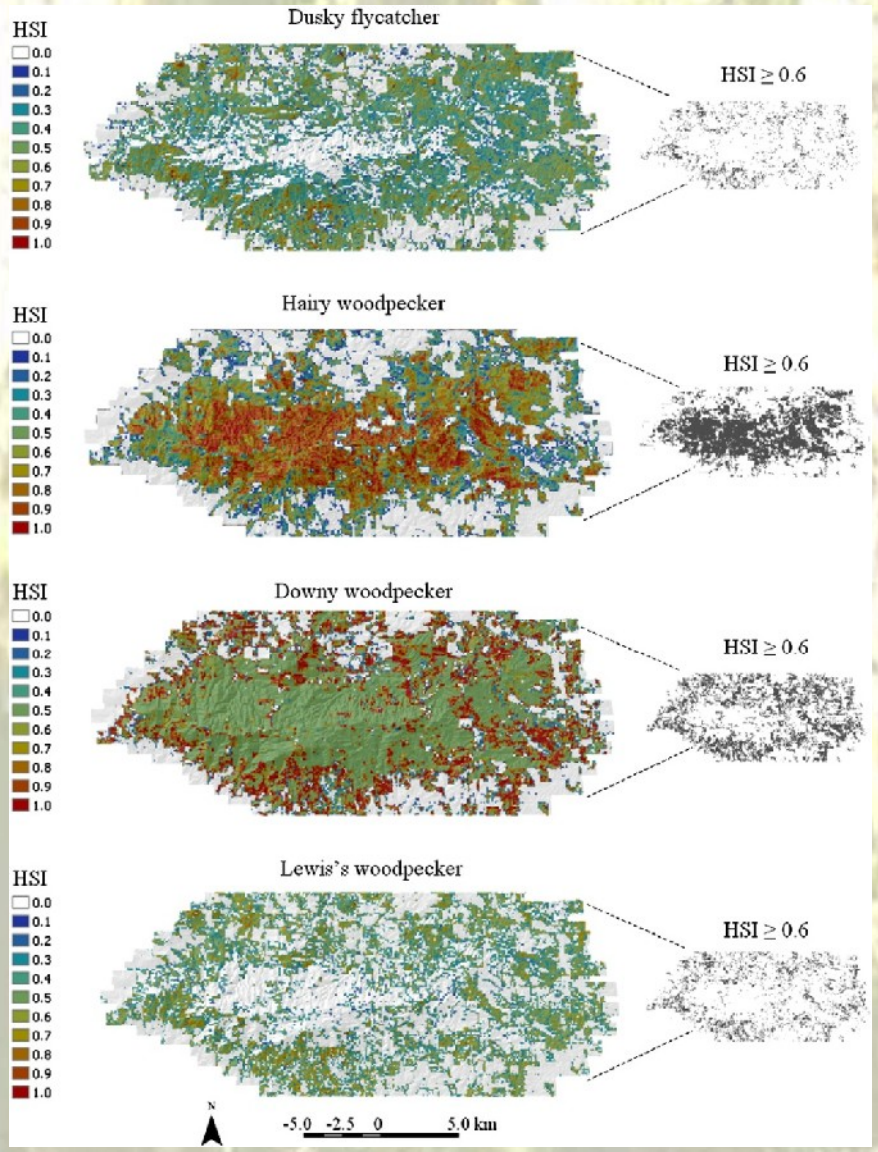








LiDAR-based assessment of wildlife habitat suitability

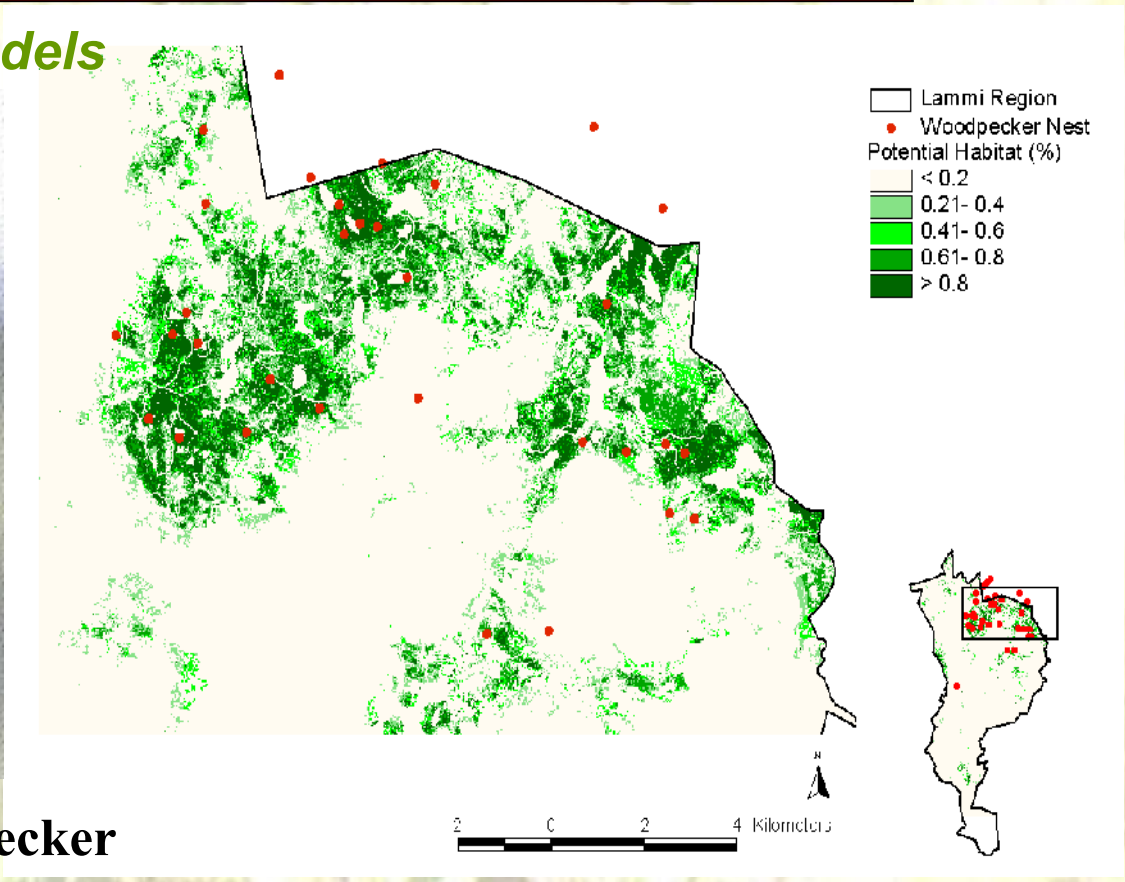


Habitat suitability maps for the different avian species. depicting areas with habitat suitability index (HSI) ≥0.6 (i.e. suitable habitats).

Martinuzzi et al 2009, Remote Sensing of Environment

HABITAT QUALITY MODELS

Weights of evidence models



Three-toed woodpecker *Picoides tridactylus* as species indicator

Romero-Calcerrada R., and Luque S. 2006. *Ecological Modelling* Luque S., et al. 2007 *Landscape and Urban Planning*

Three-toed woodpecker nesting habitat modelled for the years 1989 and 2000 using a spatial association approach among variables and nesting sites for each year

Operational Habitat modeling method to predict species distribution

Principle :

Based on Presence only data

+

Landscape Patters

+

Enviromental data

} **PREDICTORS**

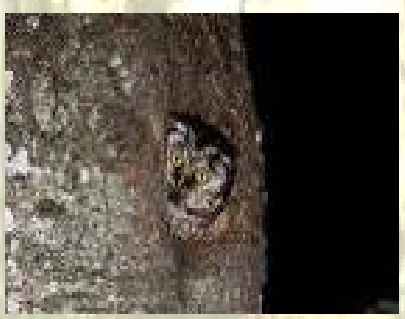
Maximum Entropy Modelling « MAXENT » (Maximum entropie)

(Phillips & al. 2004)

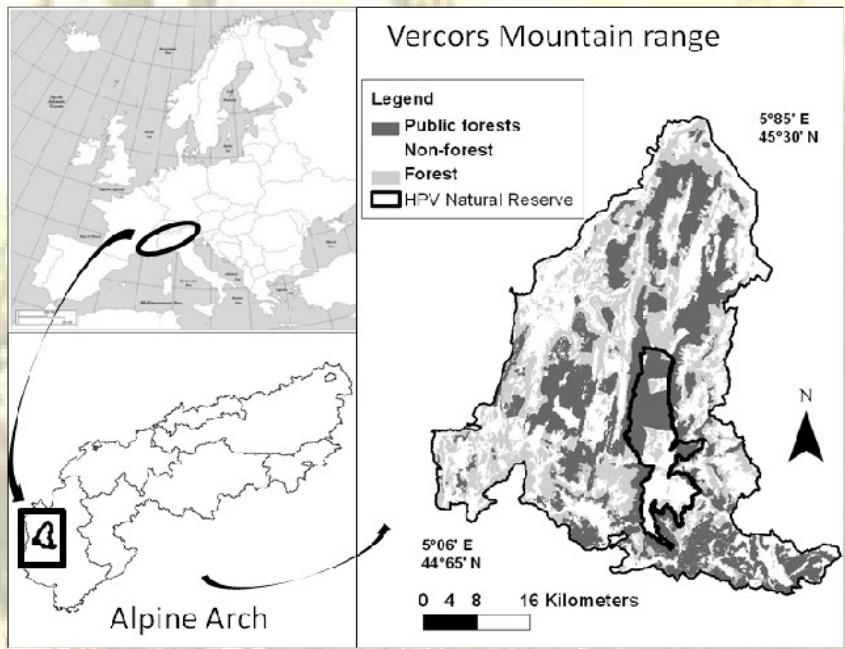
Cemagref
Science, water & land management

Glaucidium passerinum - Eurasian Pygmy Owl

Aegolius funereus Tengmalm Owl



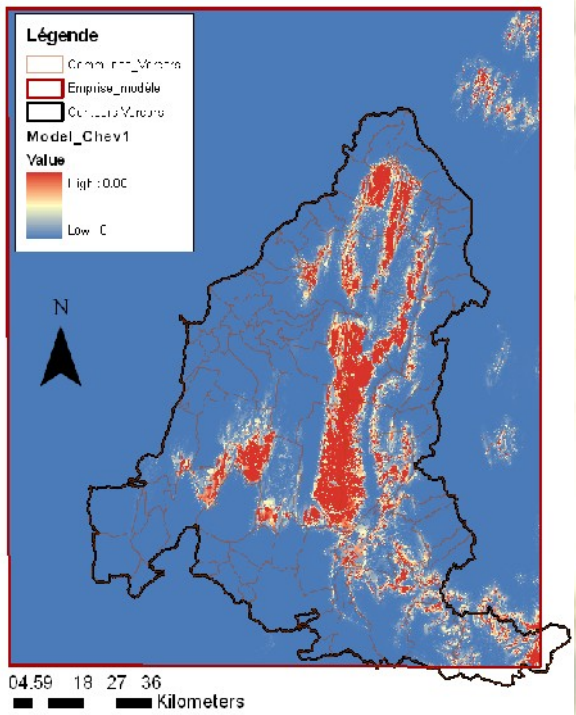
139 000ha forest area



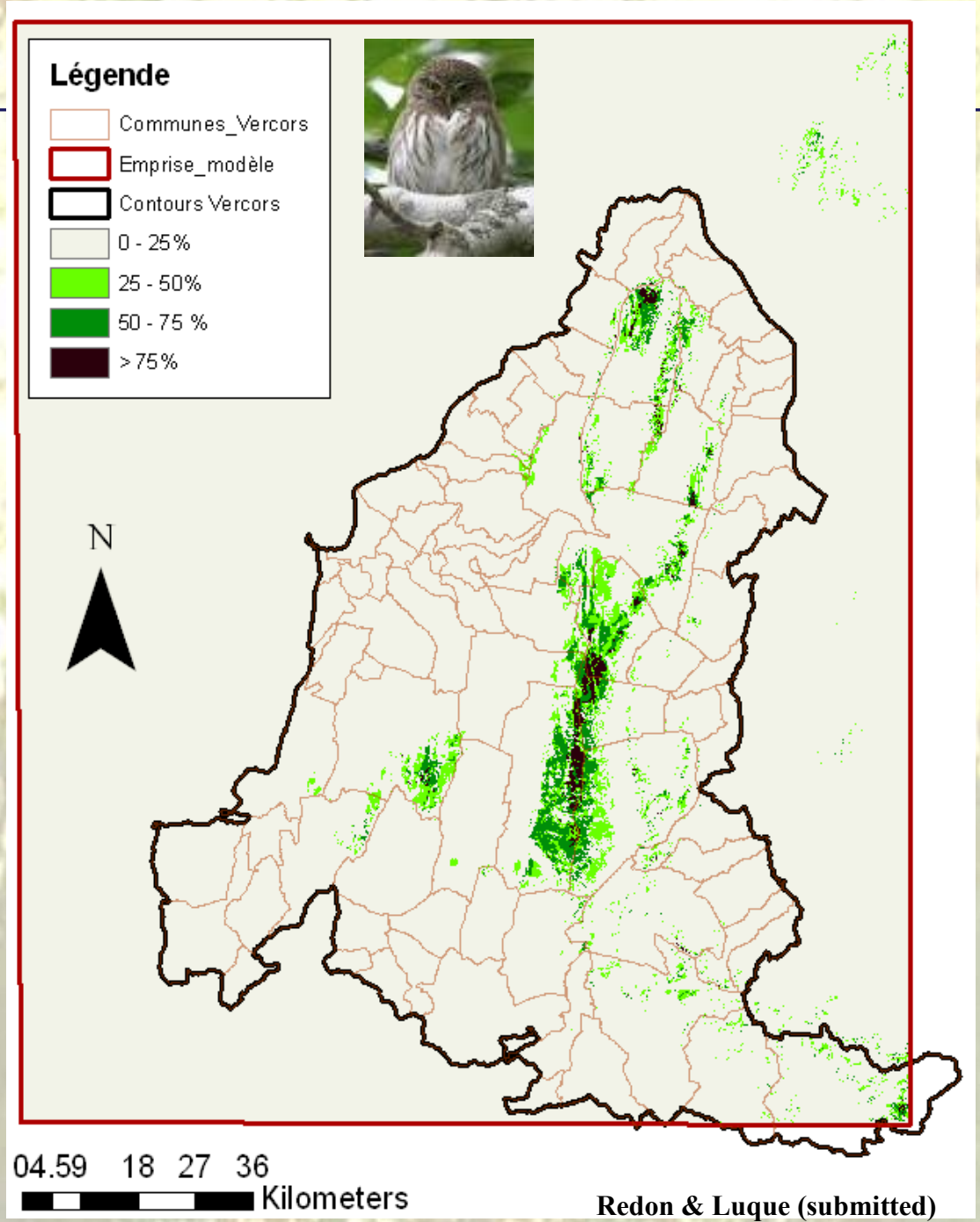
PhD Thesis Mathilde Redon

Results

Eurasian Pygmy-Owl
Potential presence distribution



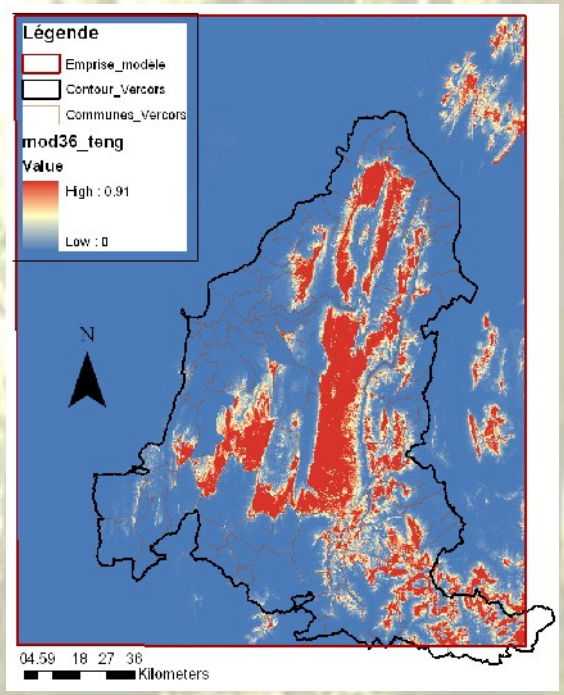
Seuils de présence



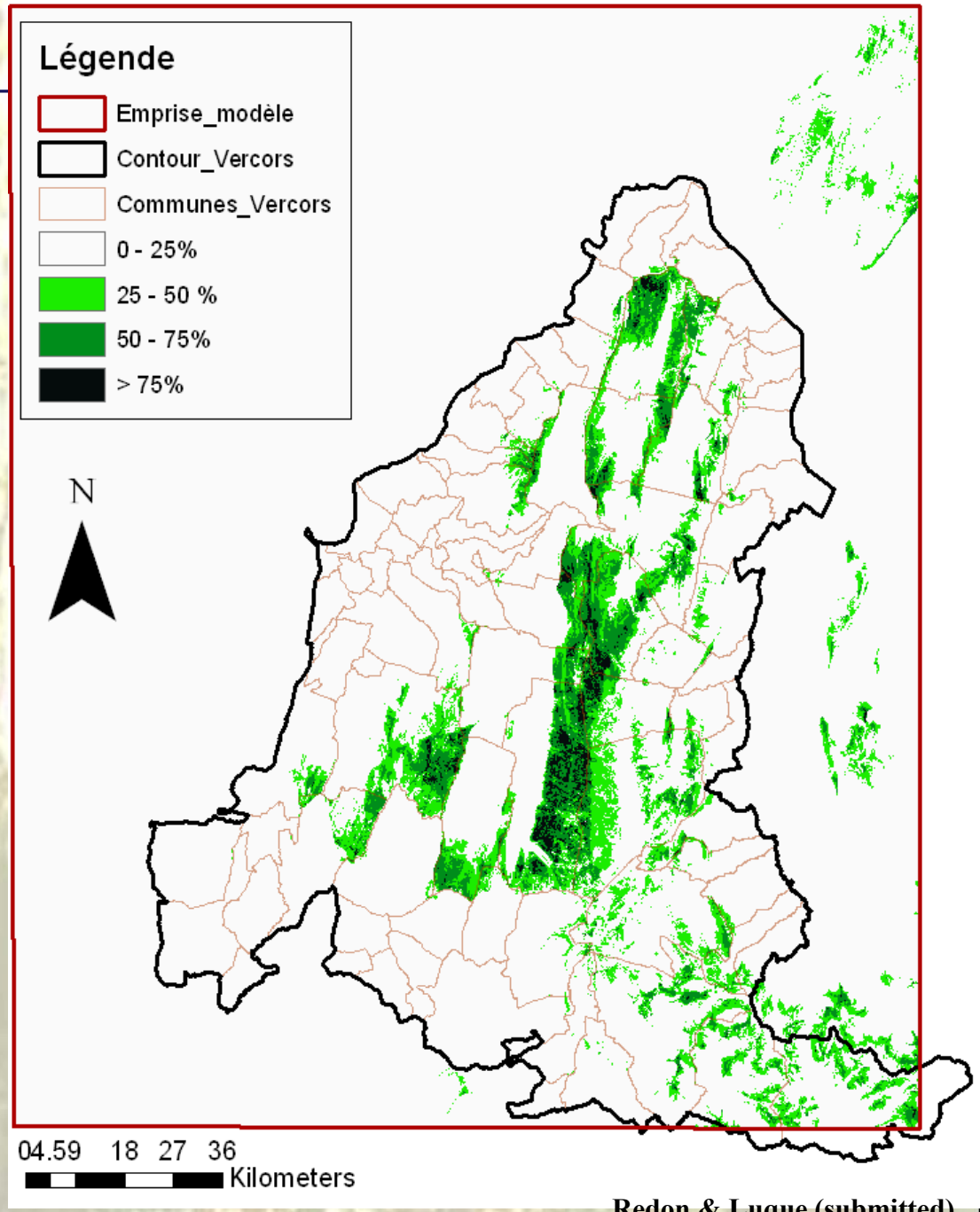
Redon & Luque (submitted)

Results

Potential presence distributi
Tengmalm's Owl (Europe)
(*Aegolius funereus*)
within the Vercors region

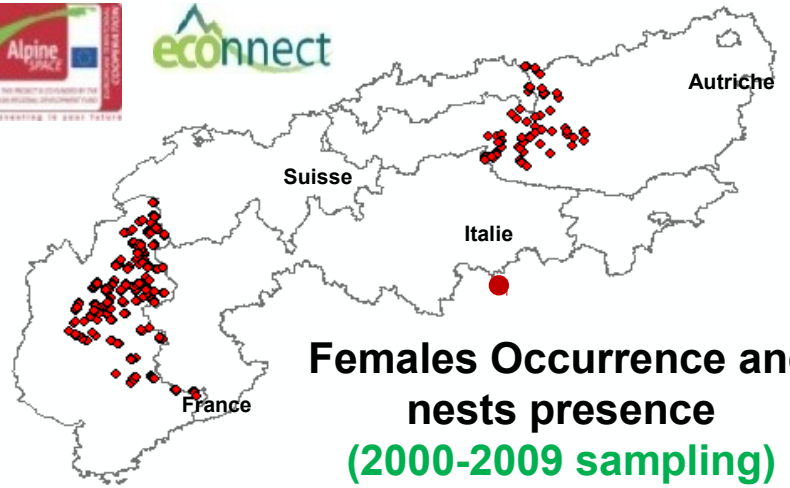


Seuils de présence

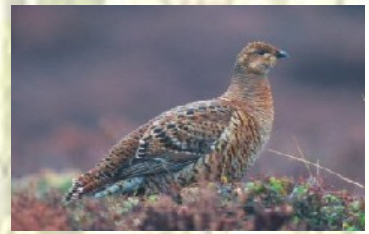


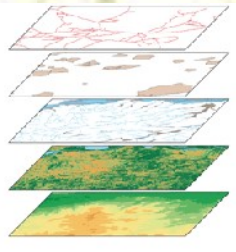
Redon & Luque (submitted)

Habitat distribution model for the reproduction of black grouse (*Tetrao tetrix*)



Females Occurrence and nests presence
(2000-2009 sampling)





Environmental Variables Criteria:

- Grasslands / km² *(CLC)*
- Forest edge density / km²
- Forest proportion / km² *(CLC)*
- Heterogeneous transitional zones *(CLC)*
- Forest – prairies Edge extension / km²
- Altitude / km² *(MNT SRTM)*
- Proportion of slopes / km² *(topographic index)*

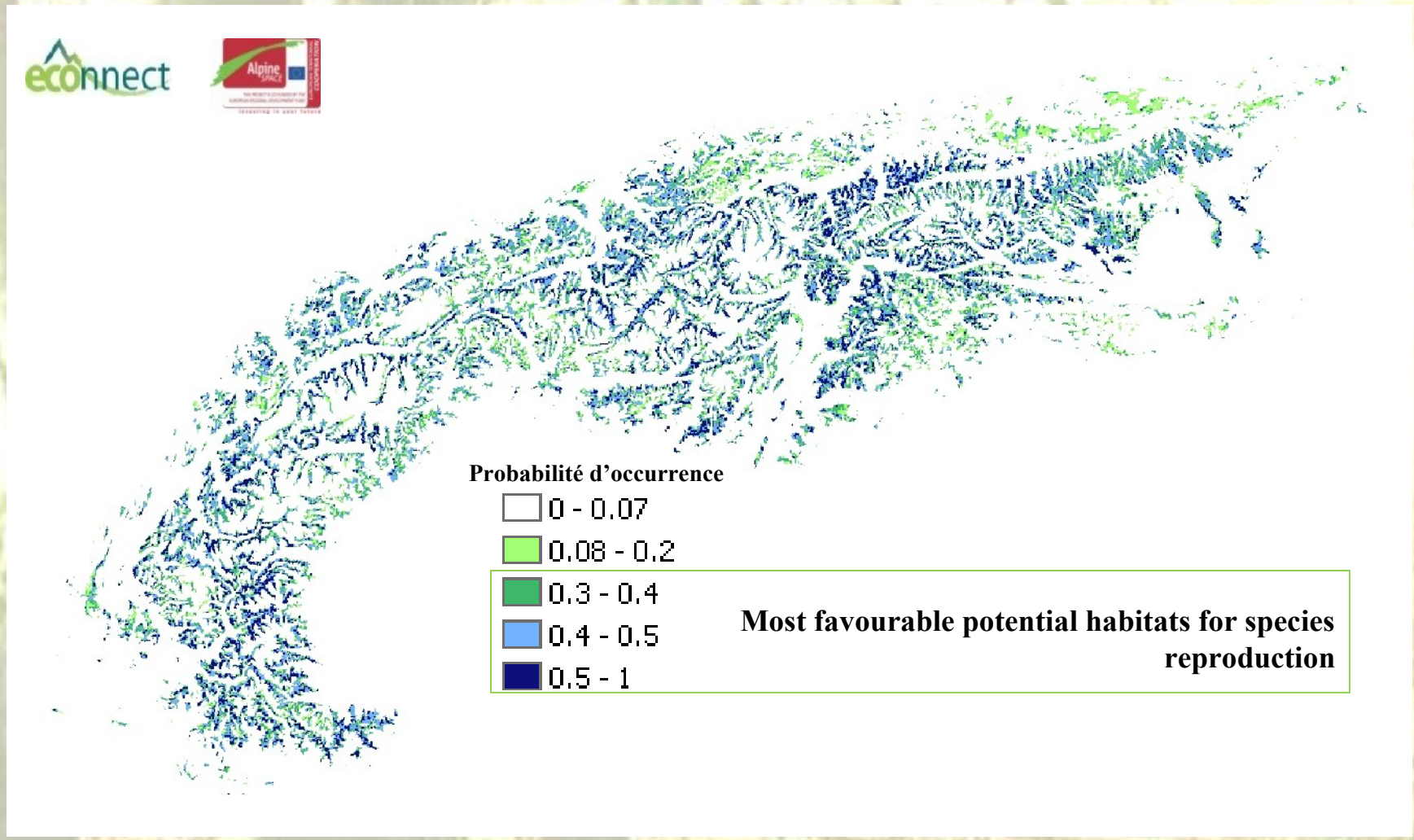
Maximum Entropy Modelling

MaxEnt *(Phillips & al. 2004)*

Predictive model for the occurrence of females and nests of black grouse

Decout, Signer, Luque (in prep.)

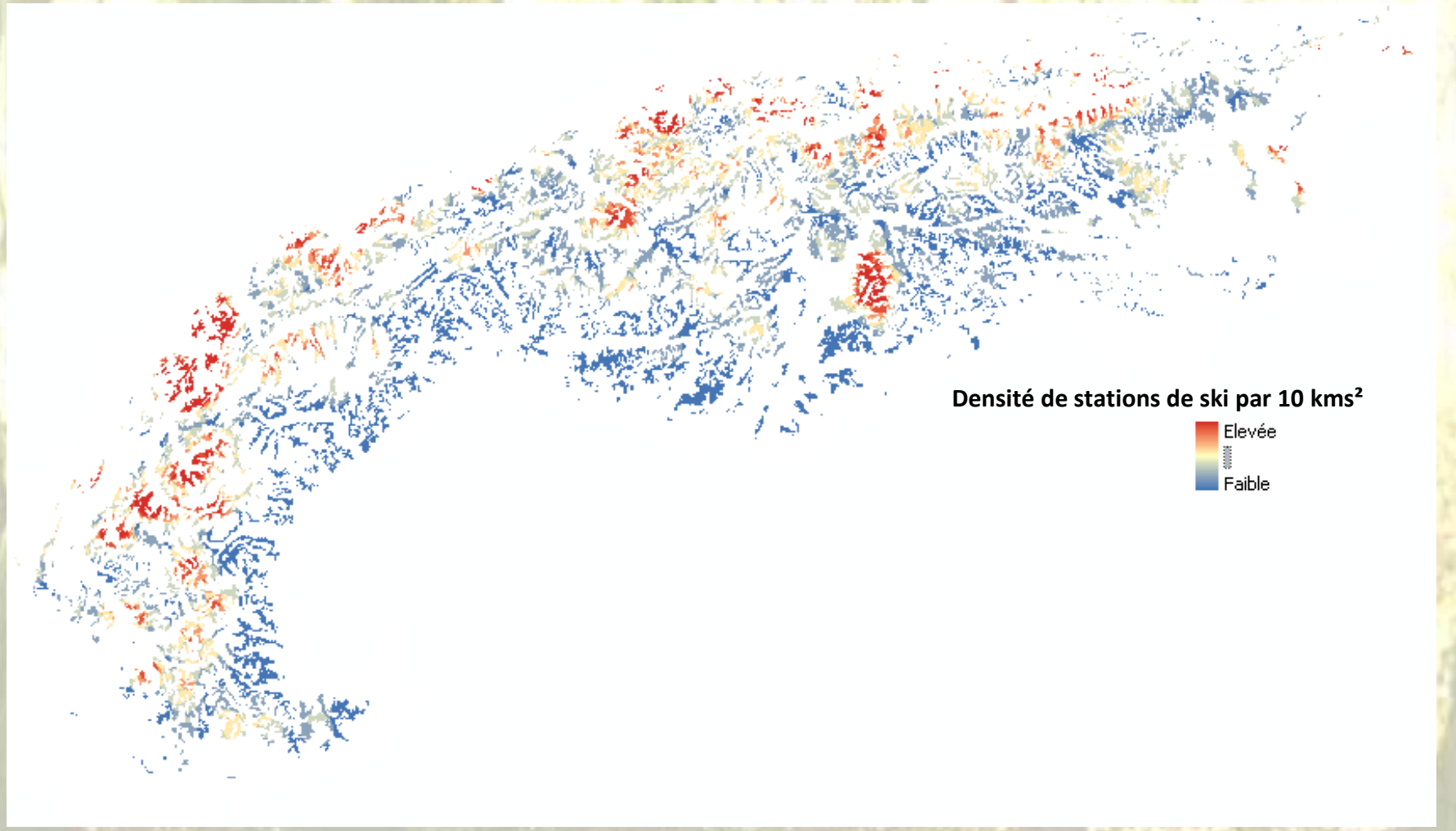
Probability of Occurrence for Black Grouse' females and nesting sites in the Alps



Statistical validation: predictive capacity 90% (AUC), omission rate: 6%

Decout et al (in prep.)

Potential perturbation of Black Grouse habitat by ski resorts in the Alps



Decout et al

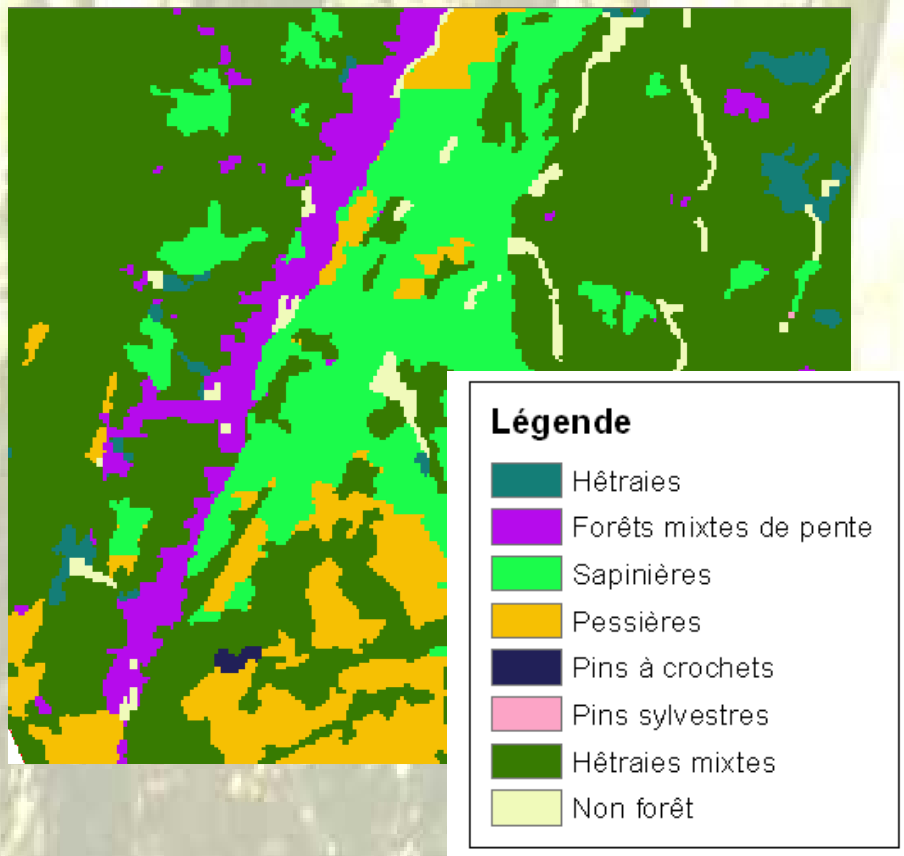
Value of the Results

- Habitat modelling at different scales, provides the potential amount of valuable forest sites that may have an interest for conservation and planning

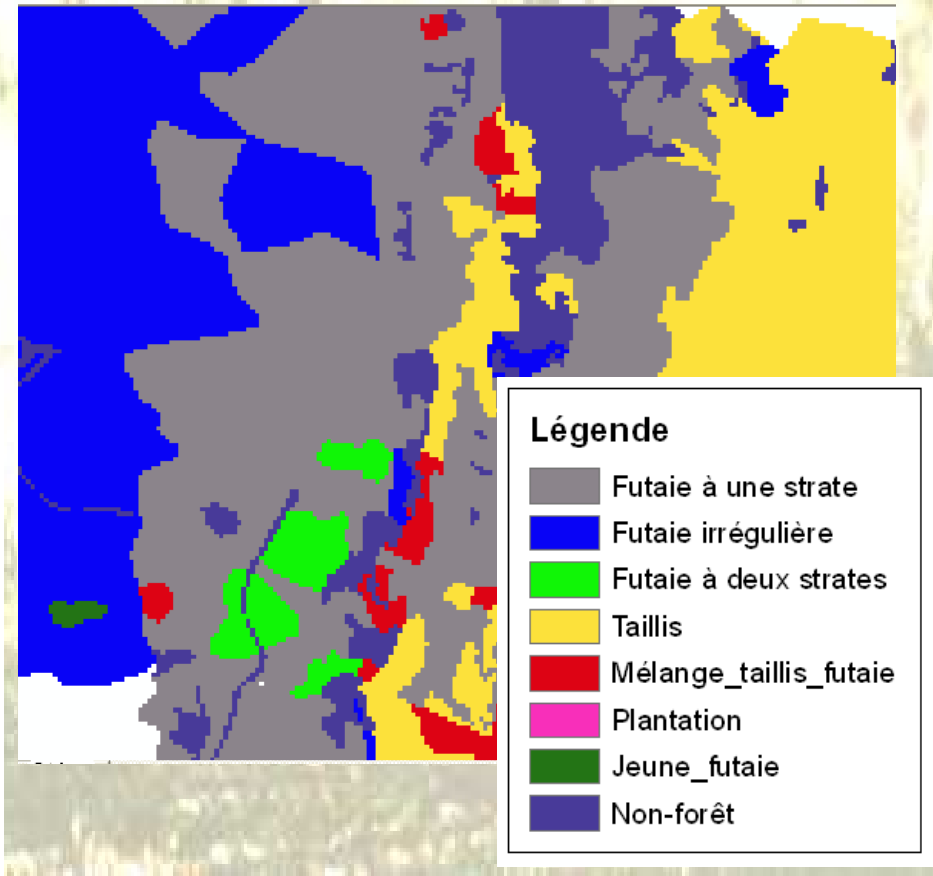
- Competition, adaptation, human disturbances not adequately included

Two Typologies for the analysis

- **Natural Habitats from Botanical inventories and Remote Sensing**

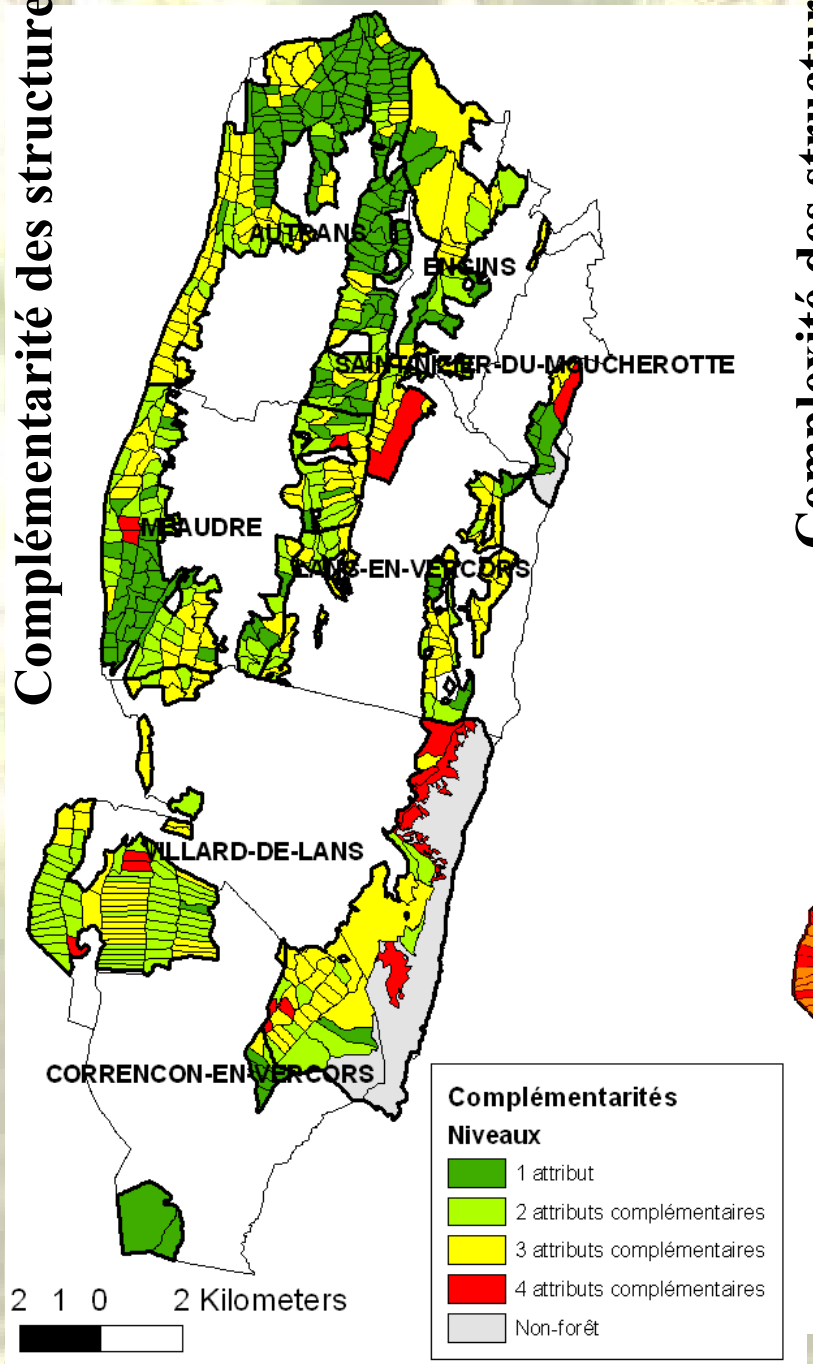


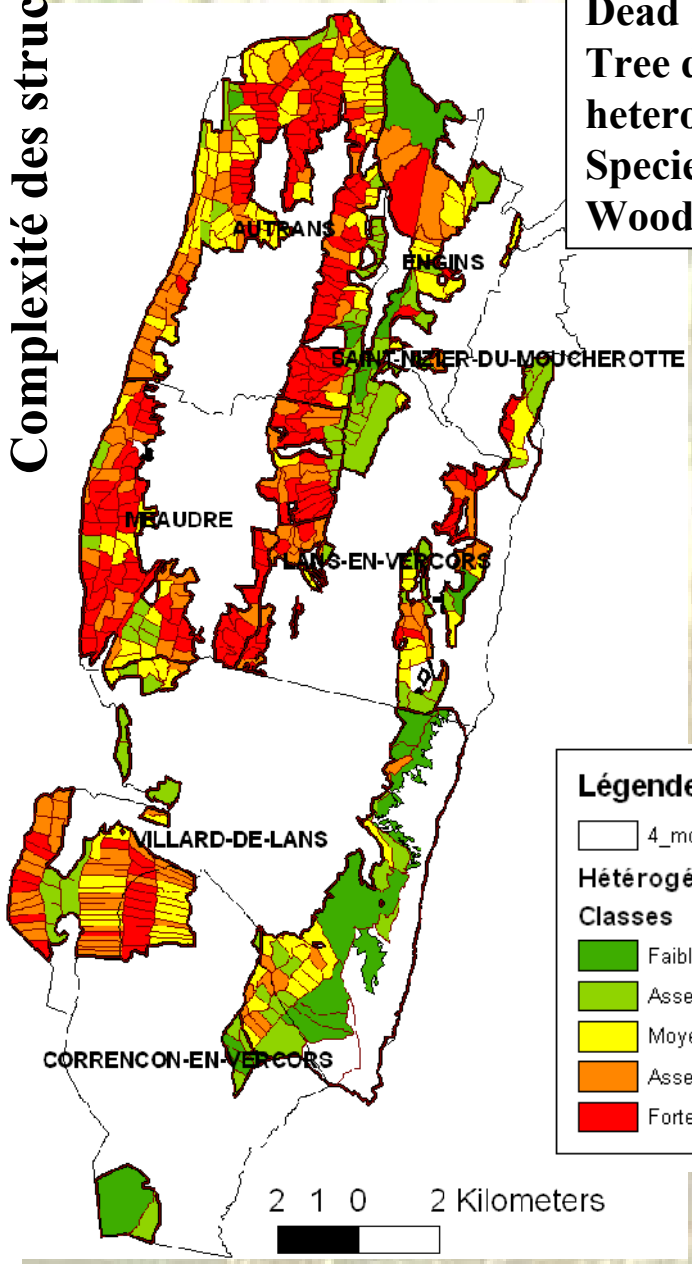
- **Forest Structure from Inventories and photo-interpretation**



Four Forest Structure Descriptors:

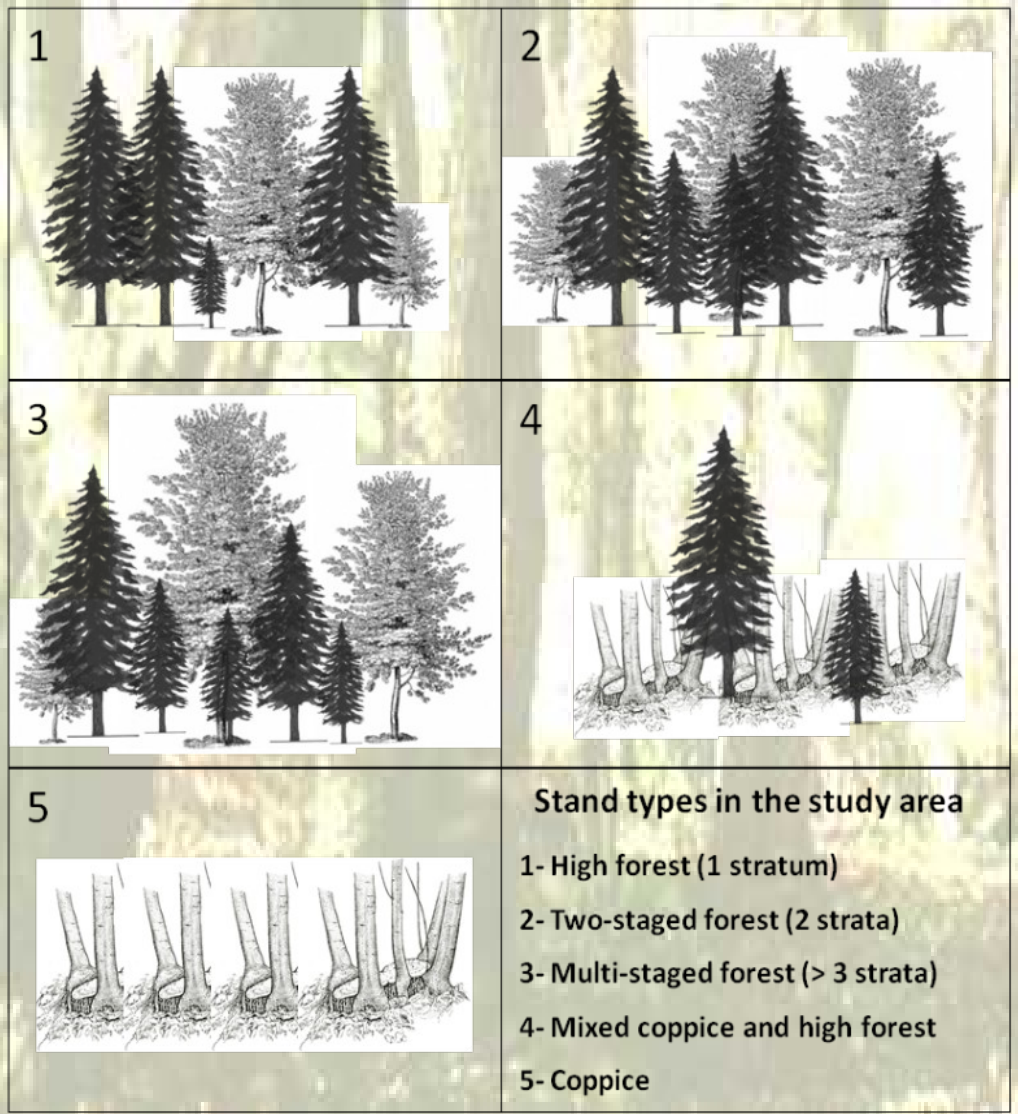
- Dead Wood Volume
- Tree diameter heterogeneity
- Species richness
- Wood Density





Structural attributes beneficial to biodiversity within a forest landscape mosaic: what are the relative contributions of different stand types?

Mathilde REDON, Sandra LUQUE Frédéric GOSSELIN & Thomas CORDONNIER



Differences in structural diversity between five different stand types

- To test the possible advantages of a combination of different stand types
- We demonstrated that structural diversity differs qualitatively and quantitatively between stand types,
- We stress the importance of a Landscape level diversification of silvicultural treatments in order to improve biodiversity conservation.
- In all, the results found, provide an important vision on how to improve sustainable use of biodiversity within a landscape level perspective.

Centro Austral de Investigaciones Científicas (CADIC-CONICET)

Tierra del Fuego Argentina

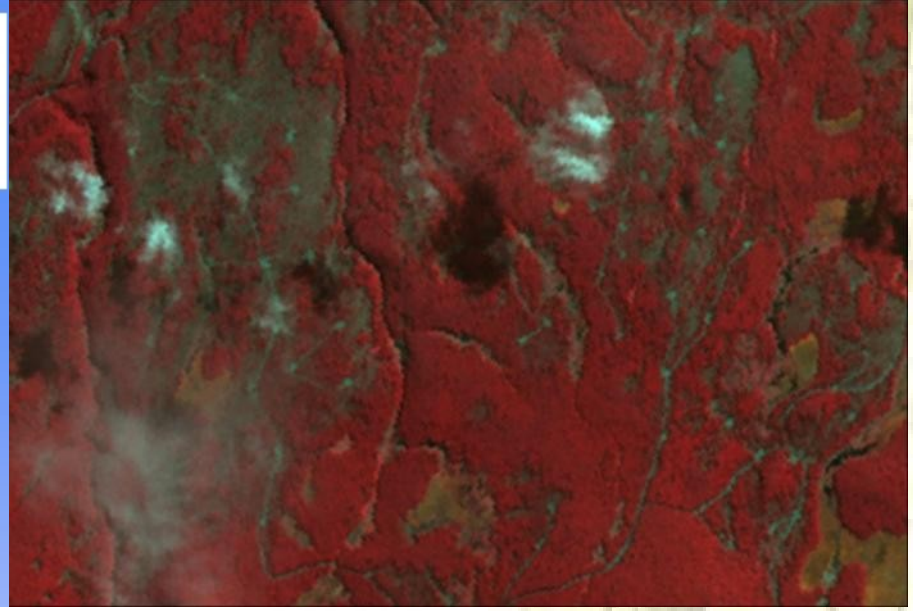
483 thousand ha of *Nothofagus pumilio* forests

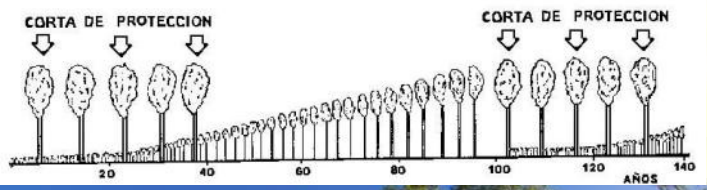
Public and Private lands

Lack in long-term forest policie

Harvesting

30 m².ha^{-1} for 20 years





Shelterwood cuts vs. variable retention

Aggregate retention 30% area Dispersed retention 15 m².ha^{-1} for more than one forest term

Martínez Pastur et al. 2002. J For Res 7(3): 165-174

Diversity begets diversity

Managed forest summary

- Diversity of forests → insurance
- Natural patterns still represent relevant goals
- Undertake salvage harvesting carefully and do not allow in natural forests

TAKE HOME MESSAGE (1)

Pattern-process levels and scale dependency mechanisms needs to be study at different spatio-temporal scales.

Future research should aim at establishing methods to determine the sustainability of various intensities of use of components of biodiversity and of ecosystems. **We should be able to evaluate different habitat types in terms of disturbance frequency and intensity that can be imitated in the management and use of such ecosystem.**

A novel **integrative approach considering different scales levels** should help **to detect when ecosystems are approaching the limits of their natural functioning or productive capacity**

TAKE HOME MESSAGE (2)

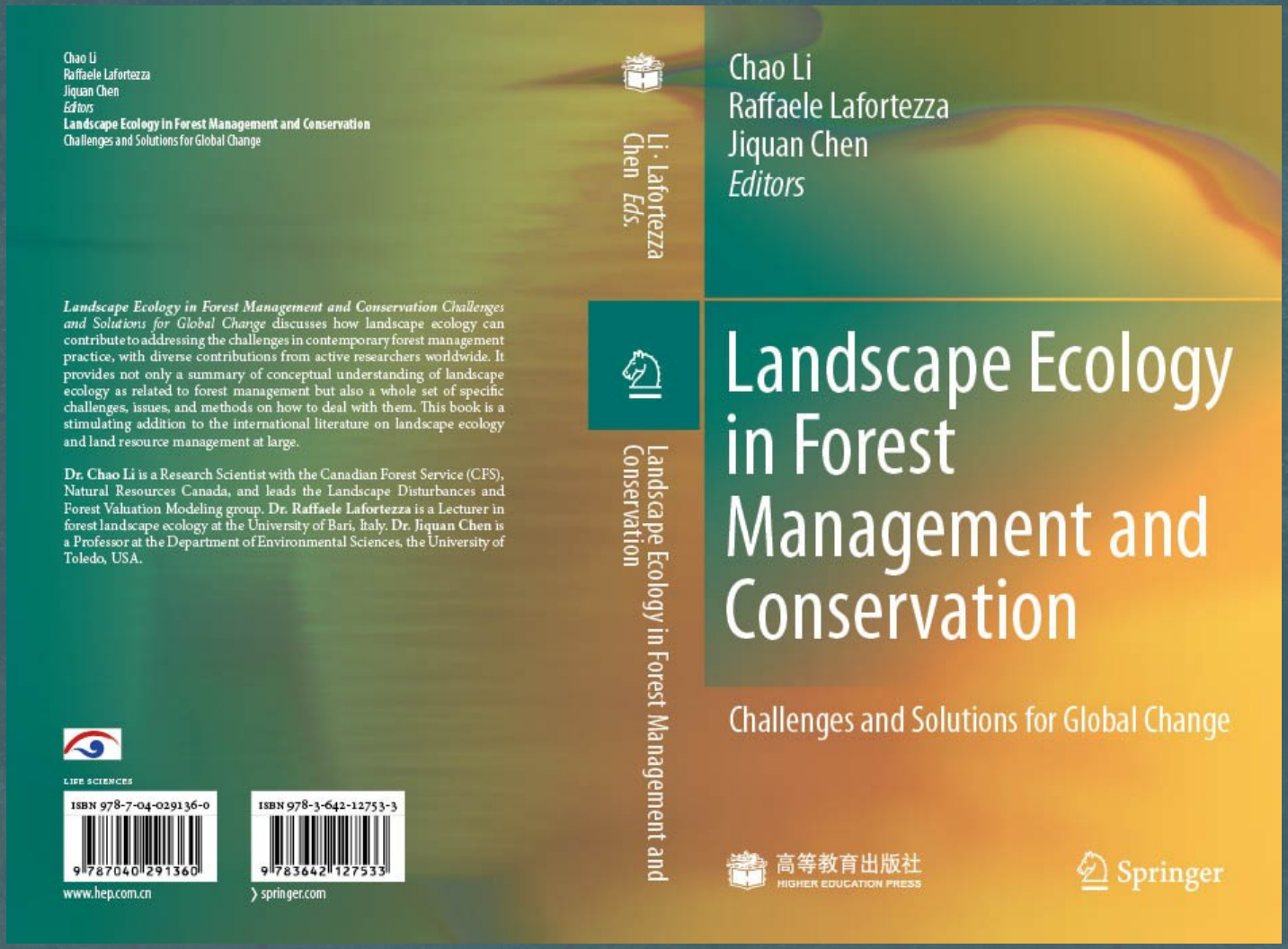
One of the most important challenges for future research will be to integrate research across different scales, including spatio-temporal scales within an interdisciplinary and multidisciplinary framework.

If we manage to follow this route, science will be able to move from analytical to actionable knowledge.

IUFRO 8.01.02 Working Group

Forest Landscape Ecology

Publications IUFRO Forest Landscape Ecology



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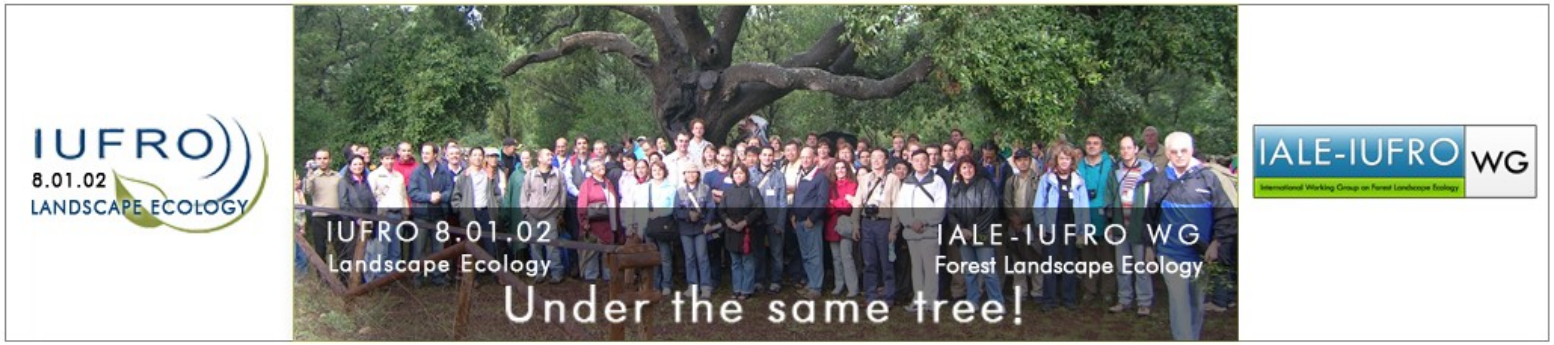

Online Registration Form for the Landscape Ecology Working Party (IUFRO8.01.02) and the IALE-IUFRO Working Group on Forest Landscape Ecology

Please provide us with the following information about yourself: (*required information)

First name*		Middle Initial		Last name*	
Highest Degree (Ph.D., M.S., or B.S.)		Title			
Postal Mailing Address*					
City*		State or Province*		Zip Code*	
Country	Select Country	Email*			
Phone		Fax			
Webpage					
Expertise (up to 5 keywords)					

Done

Thanks for your attention

Sandra.luque@cemagref.fr