



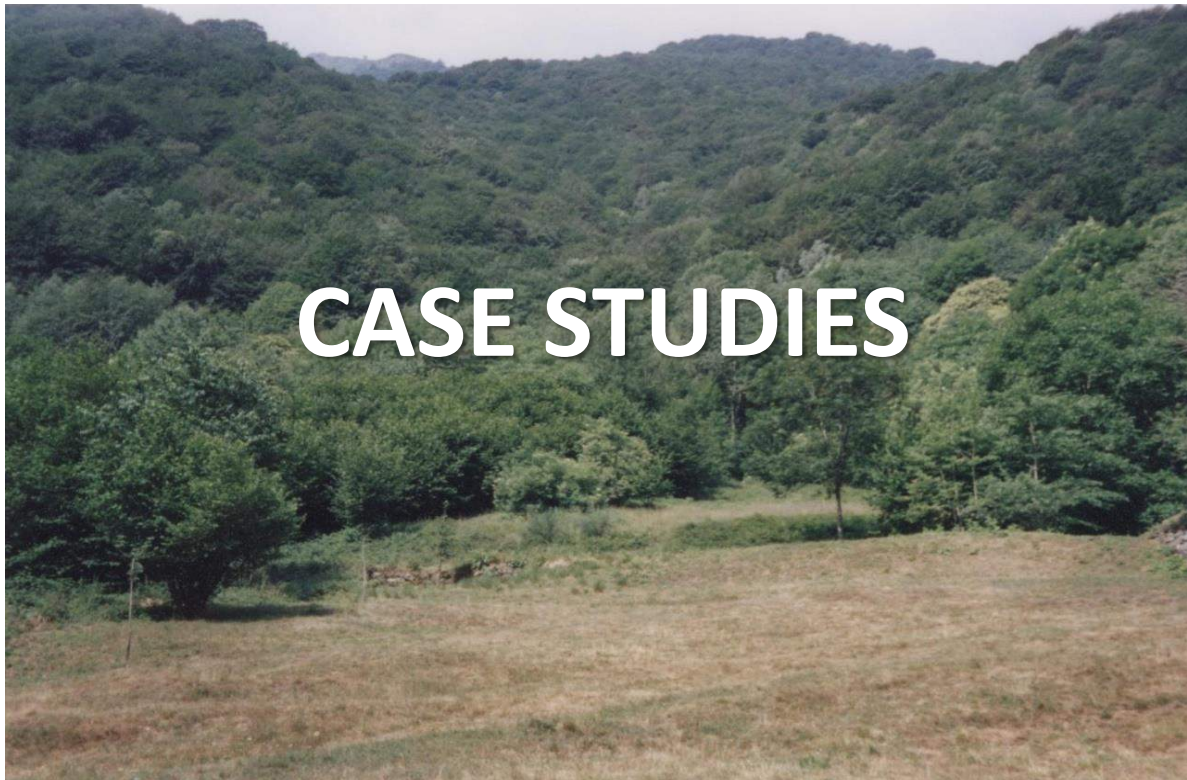
IPROMO



Landscape approach for enhancing mountain resilience

Landscape ecology to assess forest dynamics in mountain ecosystems

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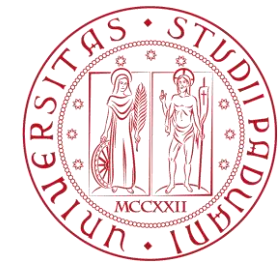
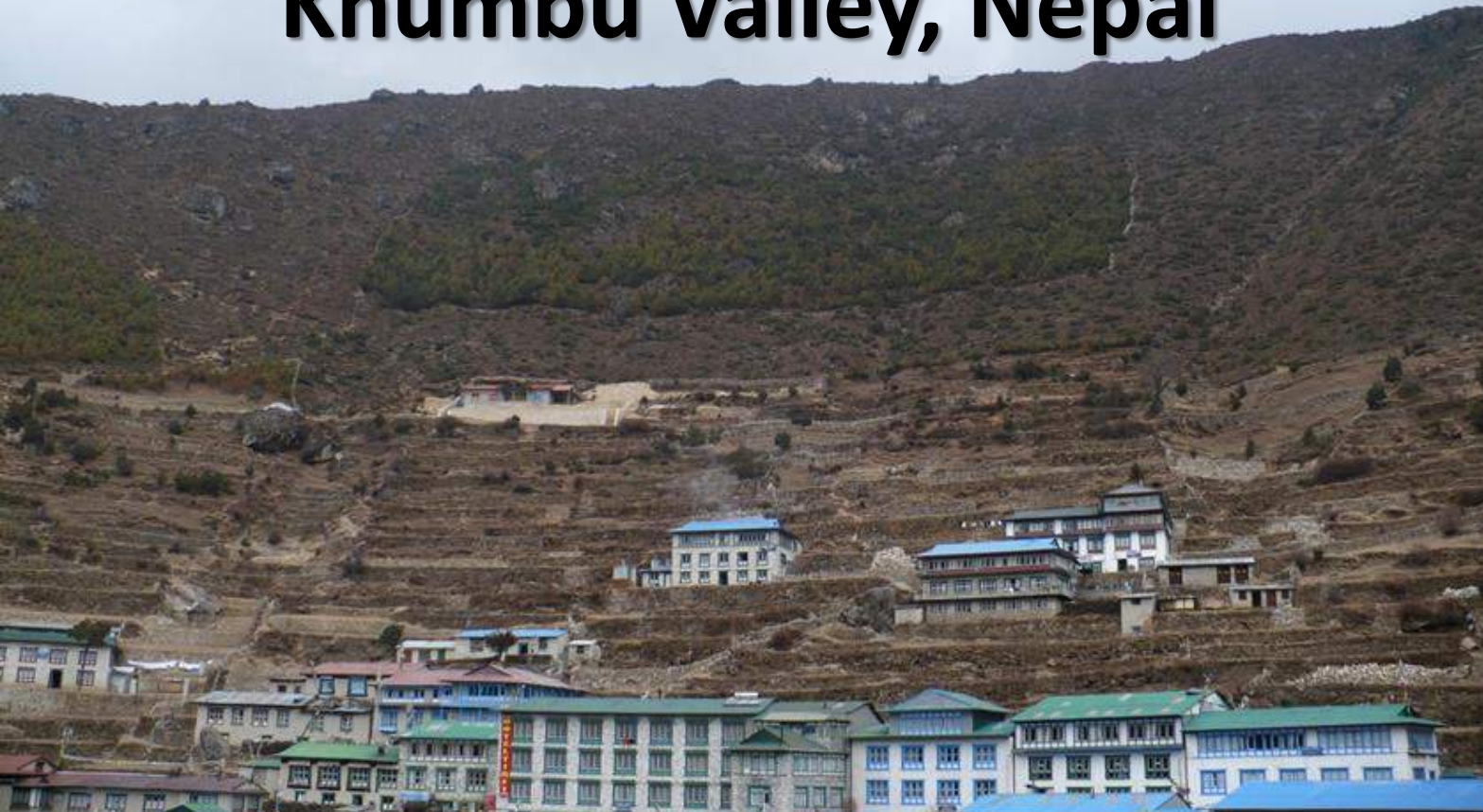


Case studies:

- Land use legacy on forest landscapes of Nepal
- Land Use / Land Cover change in the Italian Mountains
- Forest-line dynamics in the Apennines
- Old-growth forests of the Balkans
- Post-disturbance forest recovery dynamics (Donato Morresi)



Effects of anthropogenic activities on forest landscape in the Khumbu Valley, Nepal

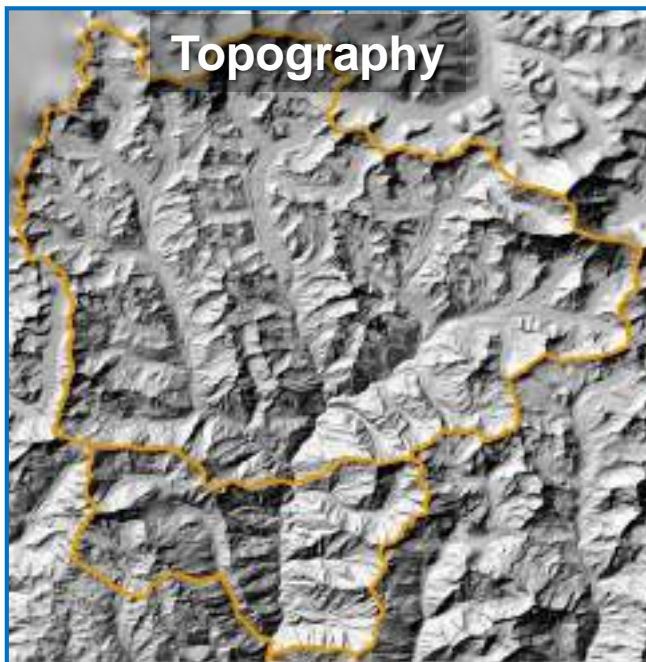


M. GARBARINO¹, E. LINGUA², R. MARZANO³, C. URBINATI¹, D. BHUJU⁴, M. CARRER²

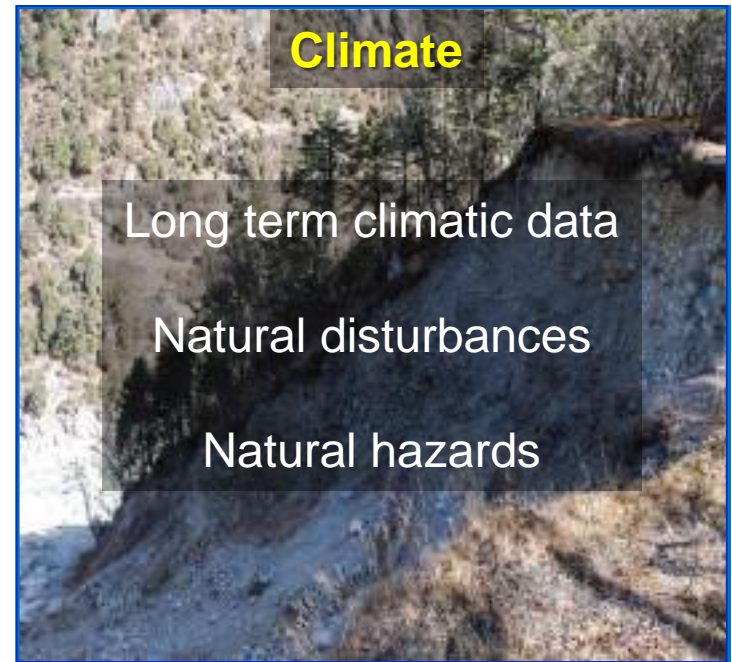
1 – Università Politecnica delle Marche, IT ; 2 – University of Padova, IT ; 3 – University of Torino, IT ; 4 – Nepal Academy of Science and Technology, NP

What influences the structure of vegetation in mountain landscapes?

Traditional approach → **PHYSICAL TEMPLATE**



&



However, for most regions of the world **ANTHROPOGENIC INFLUENCES** play a critical role

Anthropogenic influence on forest structure can be:

Destructive and abrupt → deforestation Gradual and shaping → thinning, etc...



- **TOURISM IN MOUNTAIN AREAS → INCREASING**
- **MOUNTAIN AREAS IN DEVELOPING REGIONS → VULNERABLE** due to:
 - Environmental fragility
 - Seasonality of human activities
- **TOURISM IS A CRITICAL ENVIRONMENTAL ISSUE** (*Geneletti & Dawa, 2009*)

This is particularly evident in Nepal...

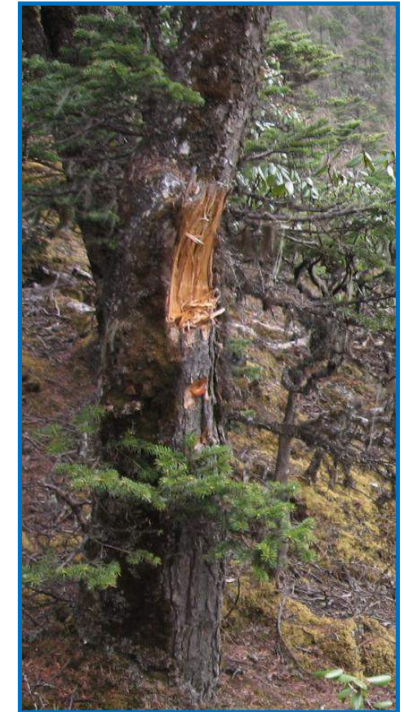
Sagarmatha region is very sensitive to natural and anthropogenic disturbances due to its steep slopes, variations of precipitations with elevation and short growing periods.

Last 50 yrs Sagarmatha has become a premier **international trekking destination**.

Increased anthropogenic pressure caused **deforestation, overgrazing, uncontrolled lodge building, and accelerated soil erosion**.



- < **1950**: forests in **good conditions** – village field-guards (*von Fürer-Haimendorf 1964*)
- **1957**: nationalization of forests – no more regulated, **deforestation**
- **1959**: 6000 new refugees in the whole Tibet – **increased fuel demand**
- **1976**: Sagarmatha National Park (**SNP**) **established** to preserve the protective role of forests (ecosystem service). ***Banished to cut living trees***
- **Today**: massive pruning and damages to trees because removal of ***dead wood is allowed***



THE PROJECT

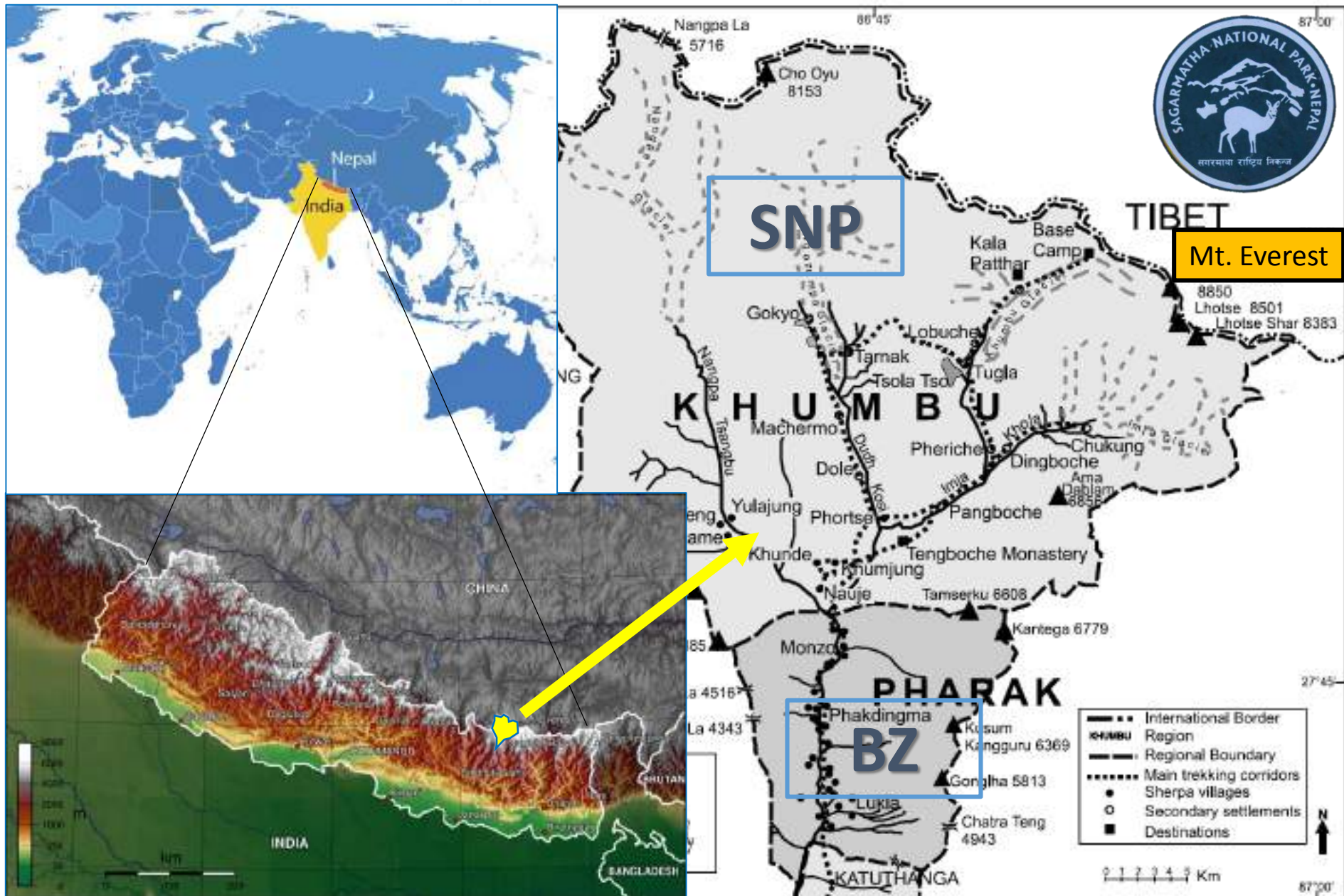


Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex

Financed by the Italian Ministry of Foreign Affairs – DGCS

RESEARCH HYPOTHESES

1. **Tourism** and other human activities cause a **reduction in diversity** of both forest **stand structures** and tree **species composition**;
2. **Topographic constraints** play a fundamental role in **shaping forest structure**;
3. The **establishment of a protected area** such as the SNP has an **important role for the conservation** of forest resources in the Khumbu valley.



PARK (SNP)

Surface: 113'148 ha (3748 elevation mean)
69% > 5000 m a.s.l. (*rocks, glaciers, tundra, lichens*)
28% pastures
3% FORESTS

E
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V
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Lower subalpine forests (3000-3600)

Pinus wallichiana, A. spectabilis, J. Recurva

Upper subalpine forests (3600-3800)

Betula utilis, A. spectabilis, Rhododendron ssp.

Lower Alpine shrublands (3800-4500)

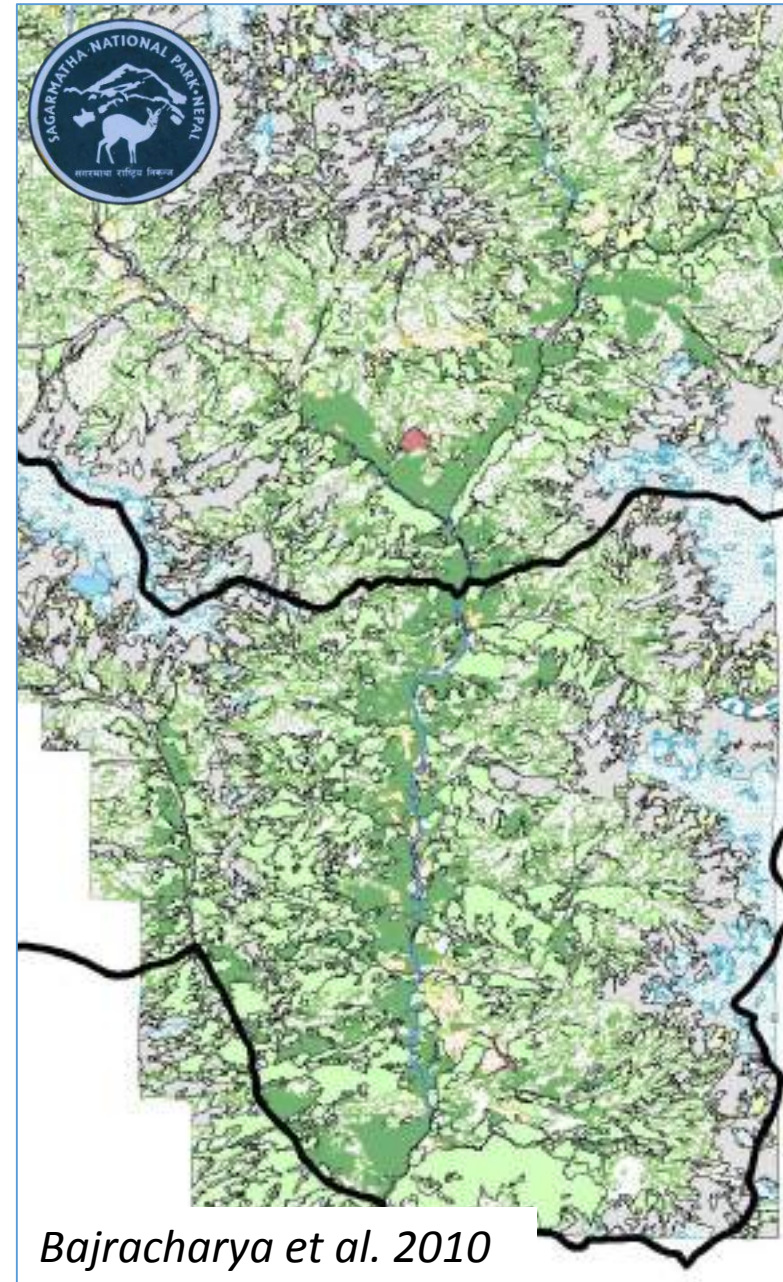
Juniperus ssp, Rhododendron ssp

Upper alpine meadows (4500-5500)

Sub-nival zone (5500-6000)

BUFFER ZONE (BZ)


Surface: 28'065 ha (2754 elevation mean)



Bajracharya et al. 2010

Field data (Forest structure and Species composition)

SAMPLING DESIGN

173 temporary plots
(SNP + BZ) 

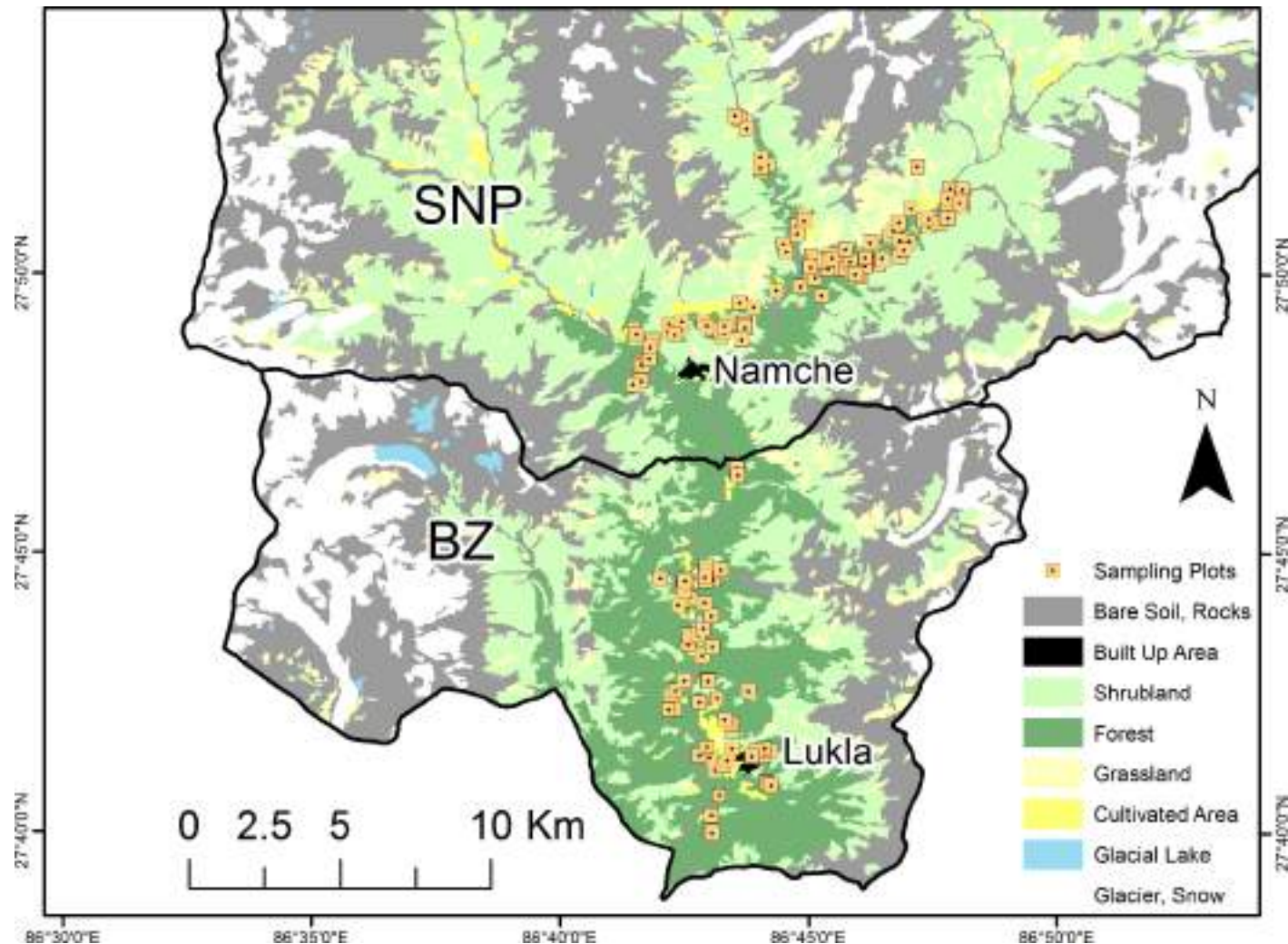
Randomly distributed
(GIS)

and Mapped
(GPS)

VEGETATION LAYERS

Trees: 20x20m plots
(sp, h, dbh)

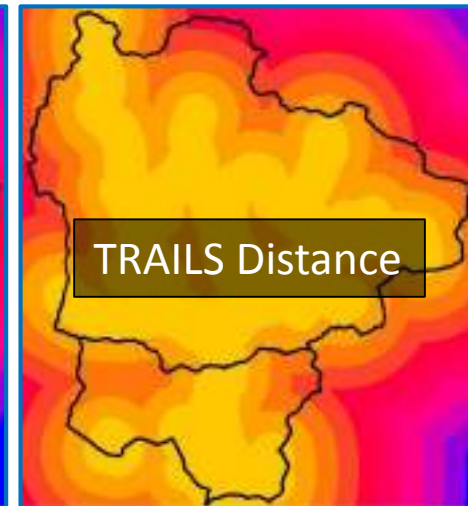
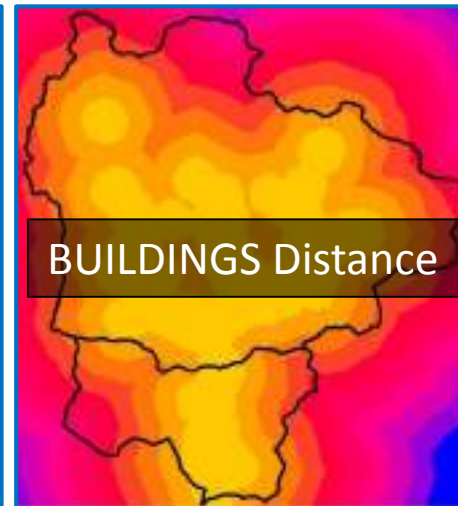
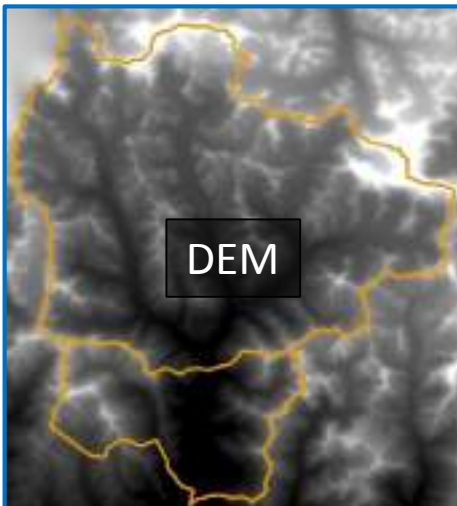
Regeneration: 5x5m
subplots (sp, density)



Geographic data (Topographic and Anthropogenic)

Topographic variables: Elevation, Slope, Heat-load index (*McCune & Grace 2000*) derived from DEM (30m res.)

Anthropogenic variables: Distance from Buildings, Trails and Touristic places derived from thematic maps by using different methods (horizontal distance, slope distance, etc....)



Environmental and forest structure variables included in the ordination analyses

Variable category	Code	Description
Forest structure	BA	Basal Area
	Dbh_av	Average diameter at the breast high (1.3 m)
	Dbh_max	Maximum diameter at the breast high (1.3 m)
	De	Tree density
	Diversity	Shannon index applied to tree species
	TDD	Shannon index applied to tree diameters
Environment	Elevation	Elevation
	Slope	Slope
	Hea	Heat load index
	Build_E	Euclidean distance from buildings
	Build_R	Slope distance from buildings
	Build_T	Accessibility time from buildings
	Road_E	Euclidean distance from roads and trails
	Road_R	Slope distance from roads and trails
	Road_T	Accessibility time from roads and trails
	Tour_E	Euclidean distance from touristic lodges
	Tour_R	Slope distance from touristic lodges
	Tour_T	Accessibility time from touristic lodges

Summary Stats on:

Touristic activities (*Stevens 2003*)

Fuel wood consumption (*Stevens 2003, Salerno et al. 2010*)

Land cover change (*Bajracharya et al. 2010*)

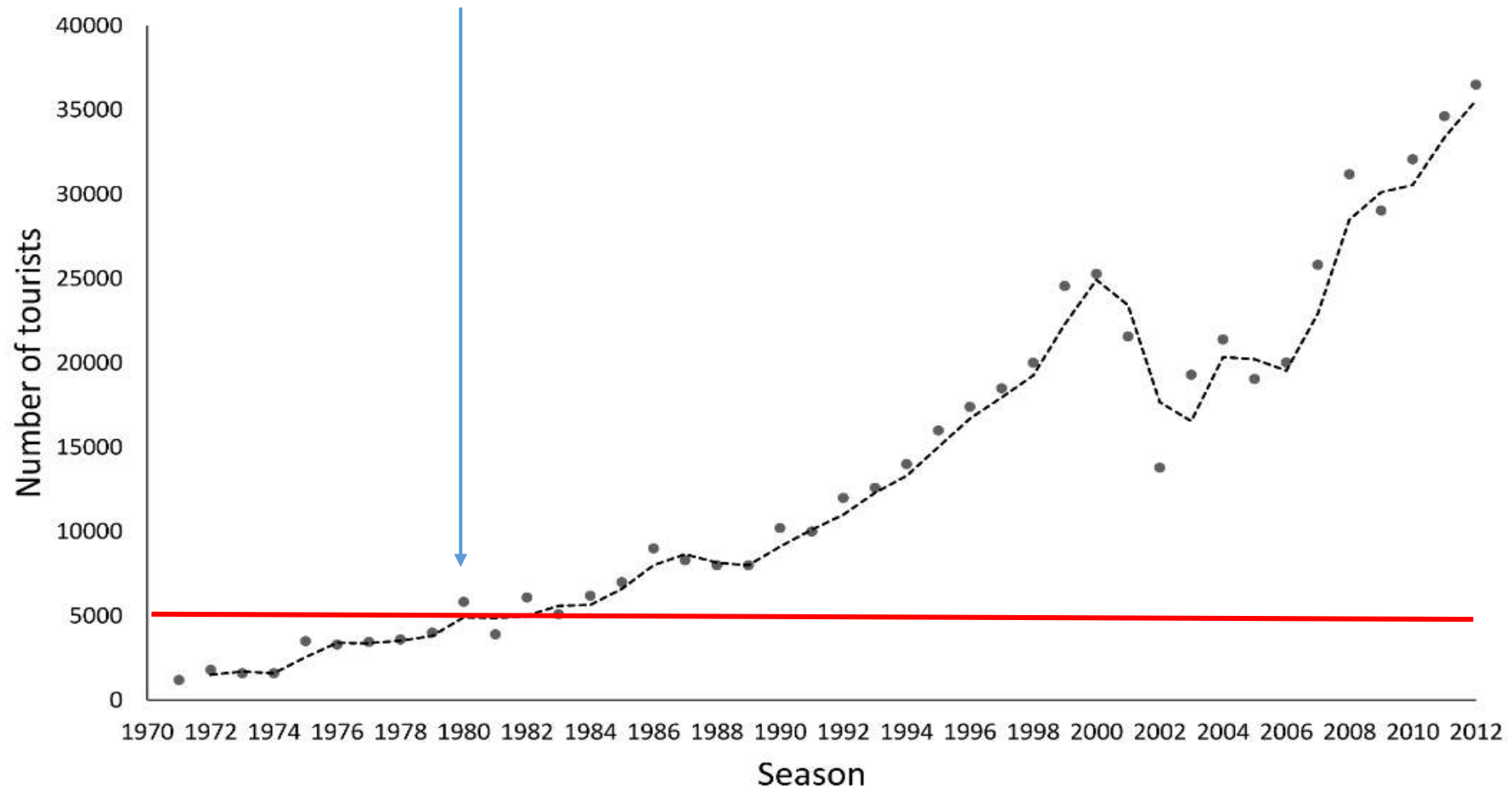
Multivariate statistical analyses on field plot data

Forest Structure VS Environment → *Principal Component Analysis (PCA)*

Species Composition VS Environment → *Canonical Correspondence Analysis (CCA)*

Annual trekking tourism to the Mt Everest region

Local people circa 5000 (2002)

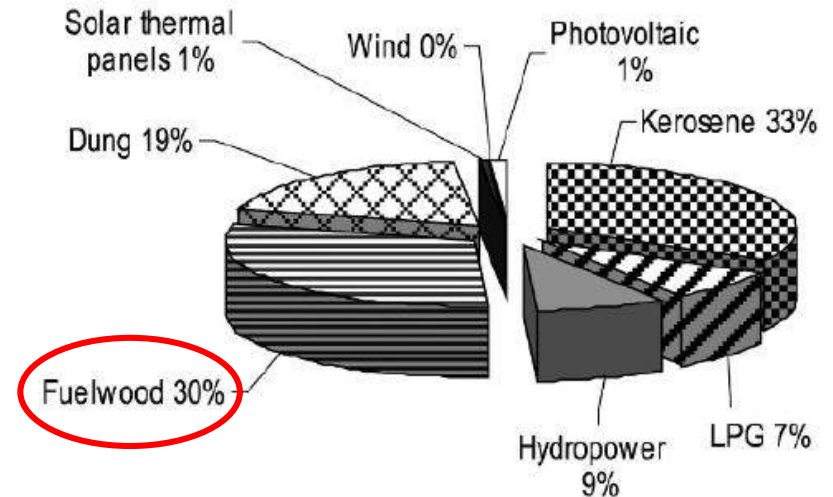


Main energy sources at SNP:
Kerosene 33% and Firewood 30%

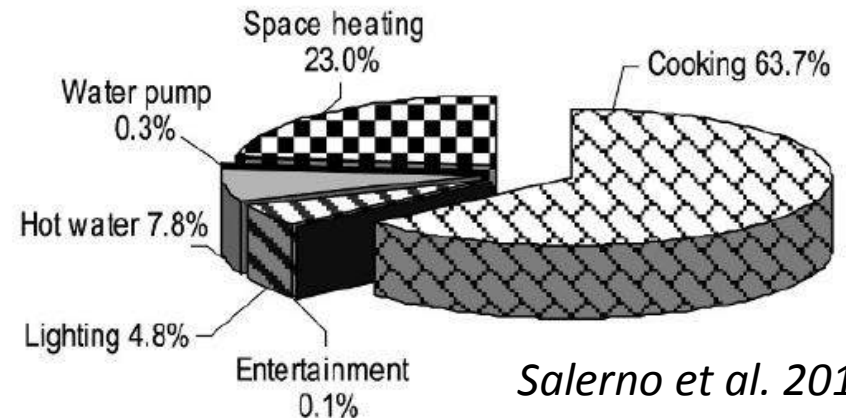
70% local people depending on forest resources.



A) Major energy sources



B) Energy for different household activities



Salerno et al. 2010

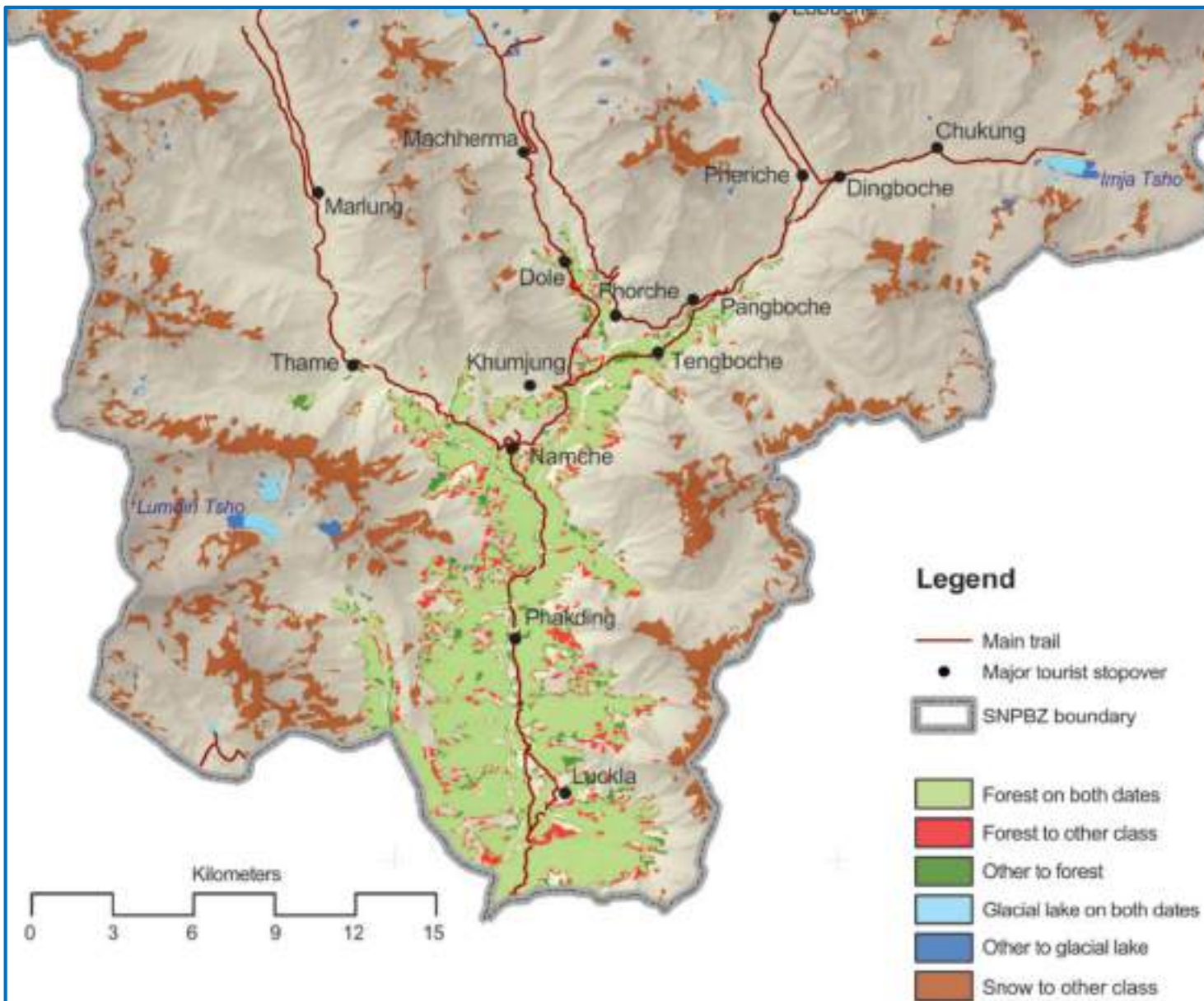
Main land cover transitions
(Period 1992-2006)

Deforestation
(3000-4000 m a.s.l.)

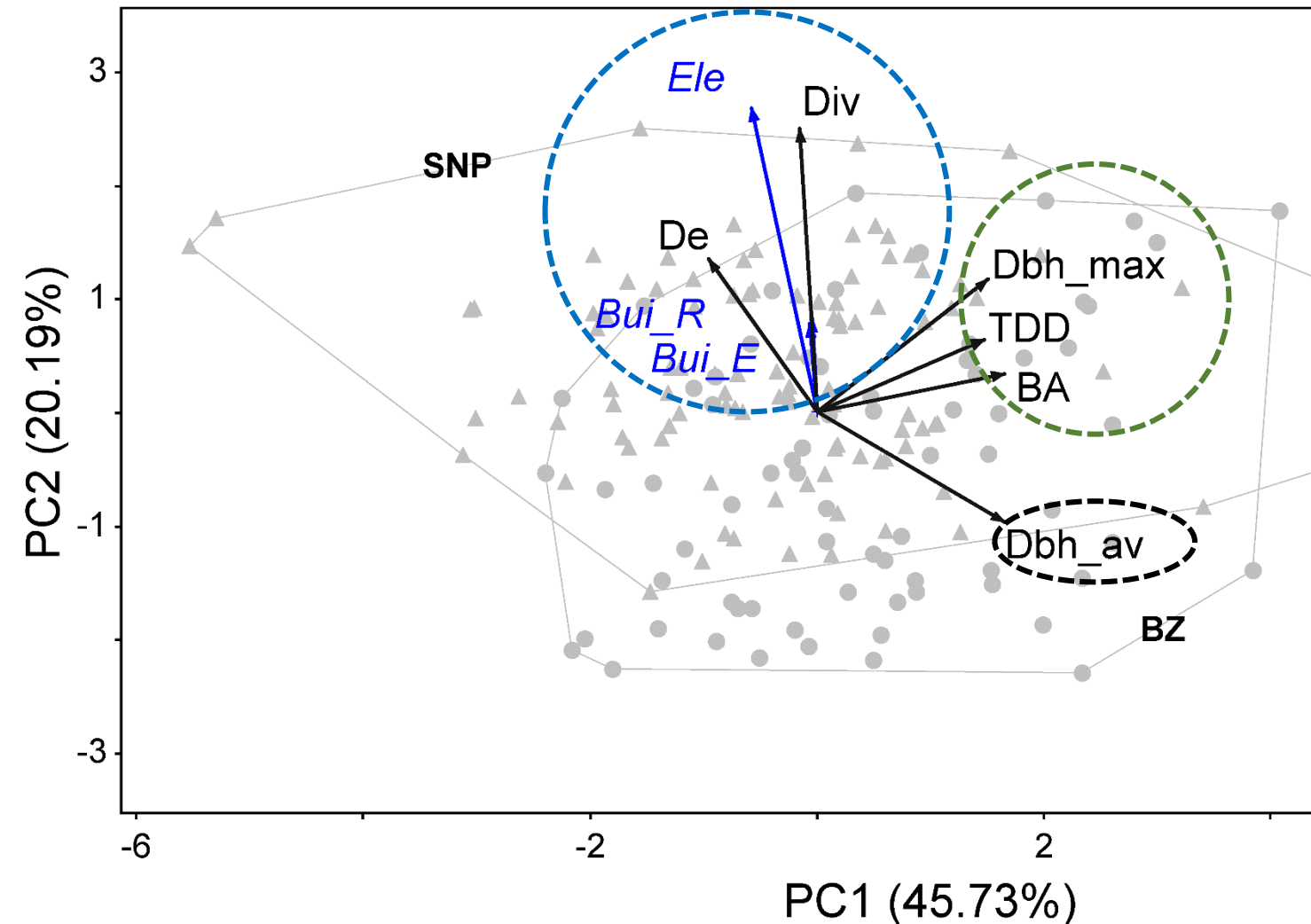
&

Shrubs removal
(4000-5000 m a.s.l.)

Bajracharya et al. 2010



Principal Component Analysis → forest structure VS environment



Denser and more diverse stands were far from Buildings and at higher elevations

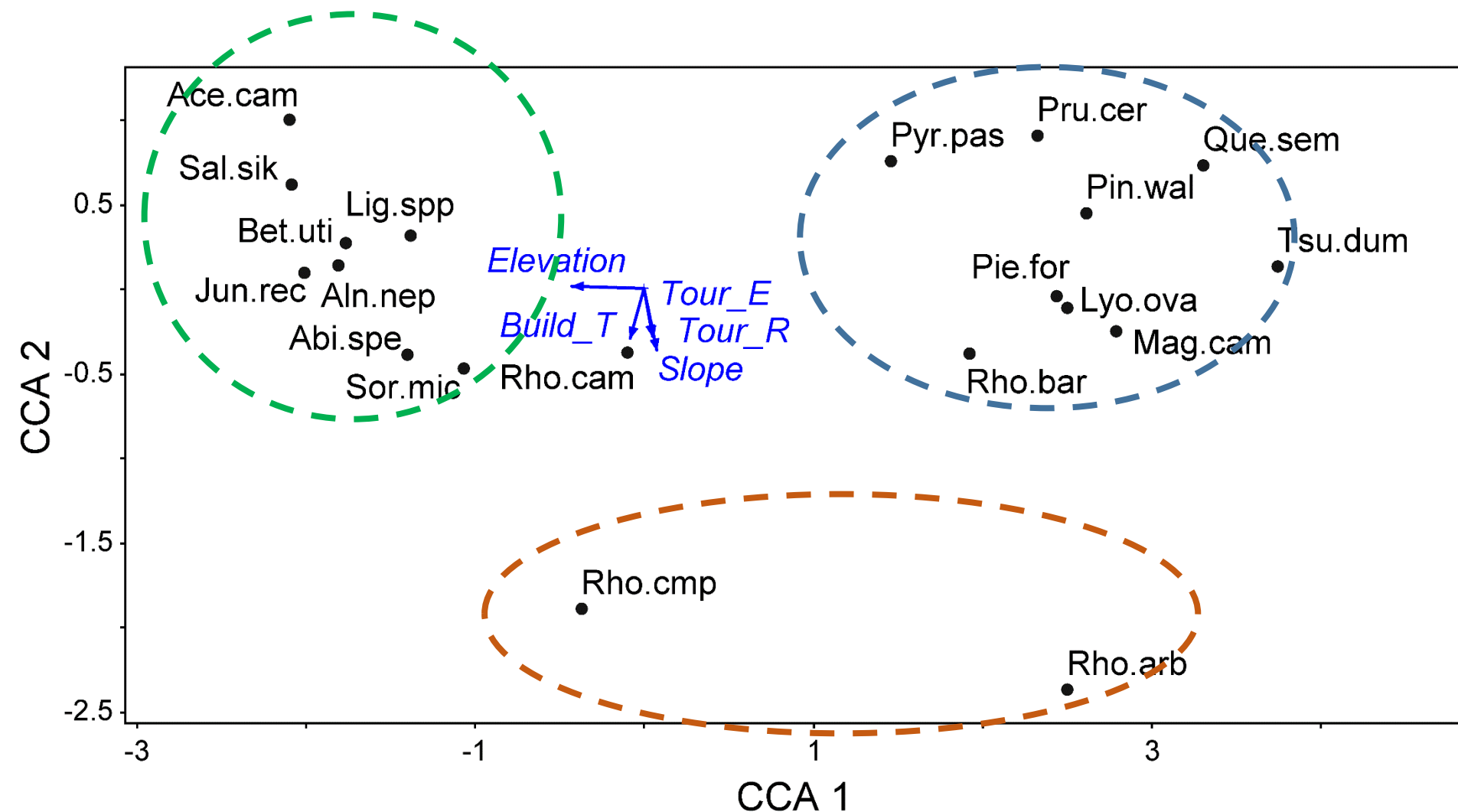
Living biomass and structural diversity were unrelated to environmental variables (natural or anthropic)

Elevation negatively influenced medium tree size

Rhododendron SP are confined to steeper slopes far from anthropic infrastructure

Higher elevation species

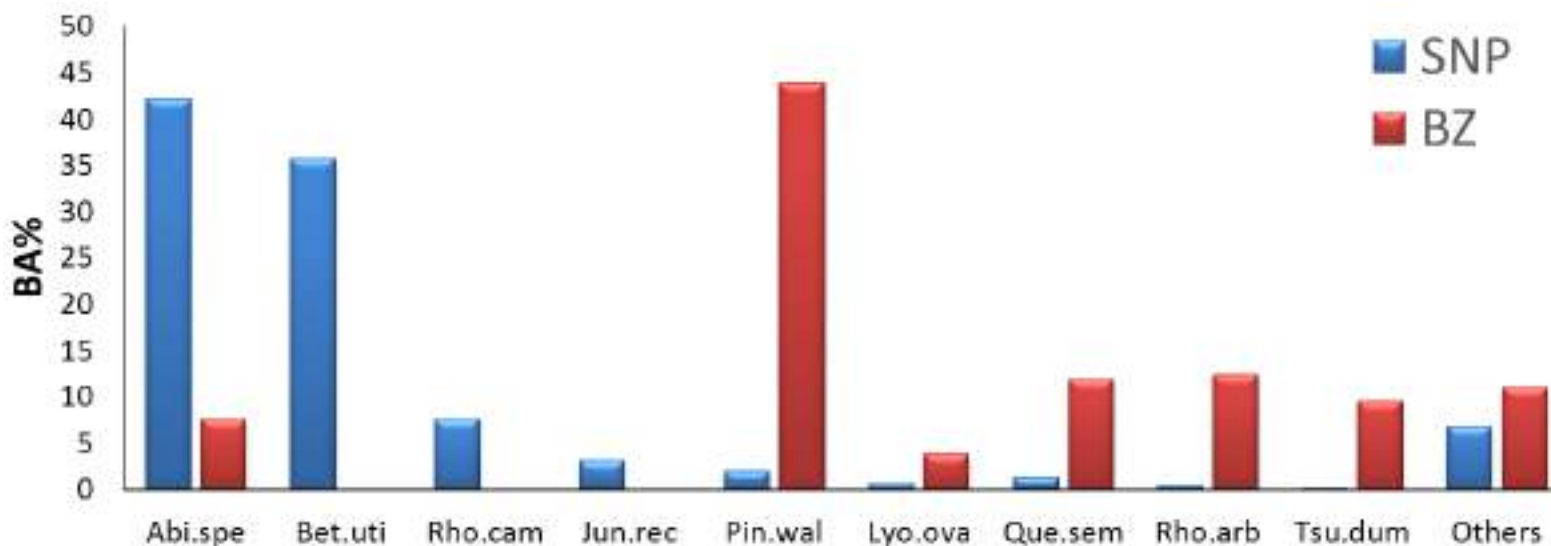
Lower elevation species



FOREST STRUCTURE

Descriptors	SNP		BZ	
BA (m ² /ha)	10.61	5.92	16.27	10.37
Dbh_av (cm)	16.67	7.38	23.61	6.38
Dbh_max (cm)	47.94	20.89	41.41	14.11
De (n/ha)	1172.33	1118.11	304.48	123.70
Div	0.67	0.34	0.58	0.52
TDD	1.55	0.32	1.42	0.32

SPECIES COMPOSITION



Low density stands with sparse trees and rare big trees were located in close **proximity to tourist lodges** and other buildings.

Rhododendron species are **the more harvested** trees, probably due to their smaller size (easy harvest and move).



“**Trekking tourism**” is still increasing in the Khumbu Valley affecting Sherpas traditional use of forests.

The amount of **fuel wood** from forests is increasing too and it is not sustainable.

Forest degradation (**forest thinning** and **shrubs removal**) has a stronger impact than deforestation in SNPBZ.



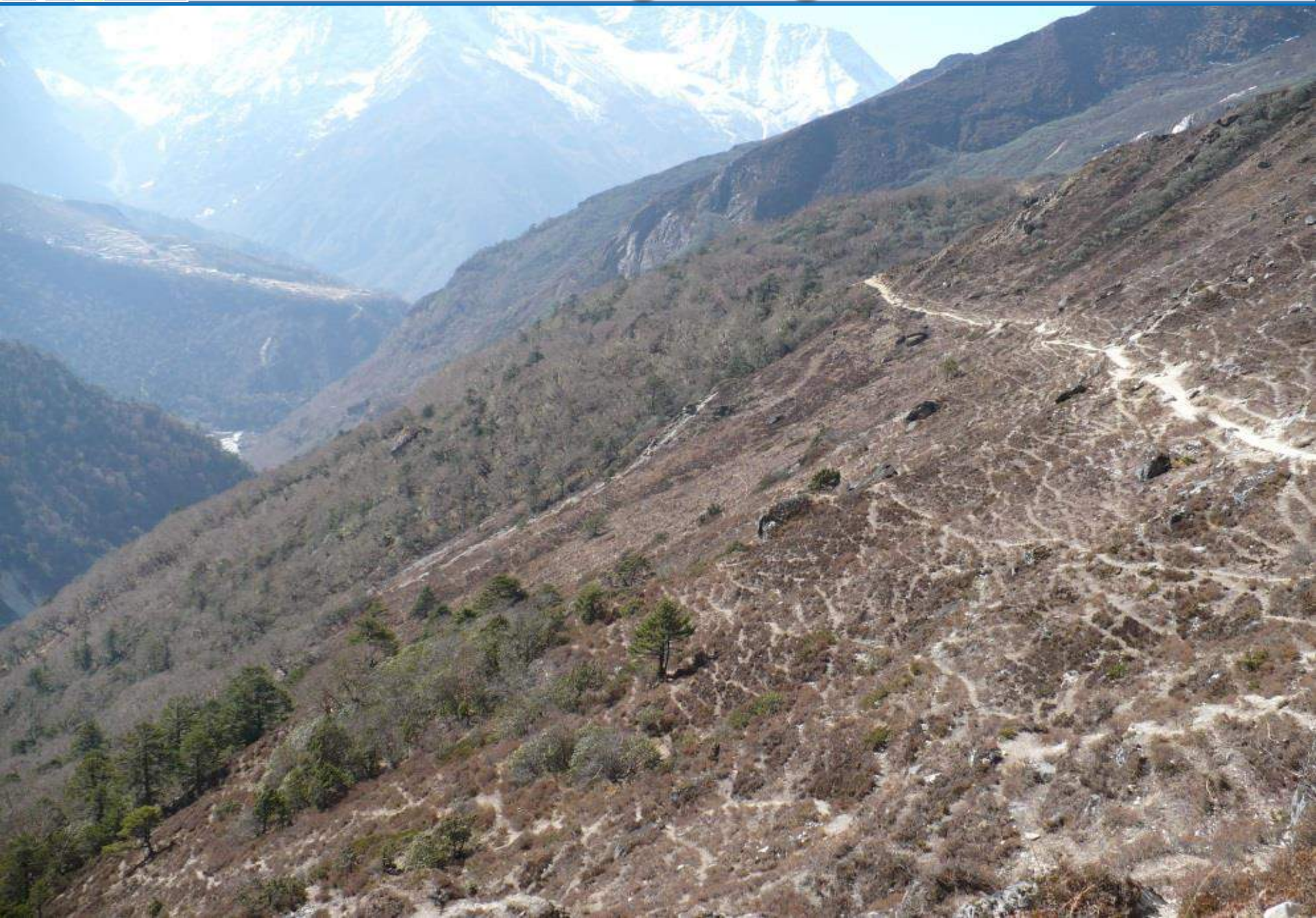
Natural resources have the potential to support the locals' needs, but **current practices do not allow sustainability.**

The **excessive logging** has **adverse effects** on the **growth** potentials of existing trees and the **regeneration** capacity of the forest stock.

A **new integrated management** approach would be necessary in order to enhance natural regeneration, maintain forest cover and **increase protective functions** against natural hazards.

Few examples







Damages to trees

5-11 October 2014
Salt Lake City, USA



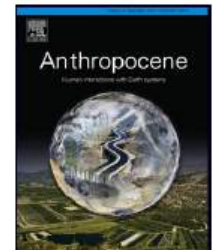
.. <http://www.sciencedirect.com/science/article/pii/S2213305414000277>



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

Anthropocene

journal homepage: www.elsevier.com/locate/ancene



Human interactions with forest landscape in the Khumbu valley, Nepal

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Dinesh Bhujju^d, Marco Carrer^b

^a Department of D3A, Università Politecnica delle Marche, Ancona, Italy

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*Thank you for your
attention*



Nature and society facing the Anthropocene
challenges and perspectives
for landscape ecology

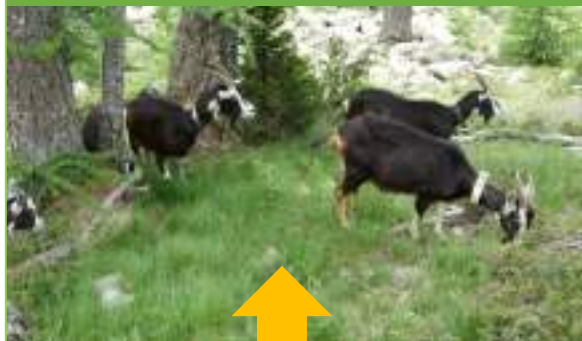
Land use history legacies on forest landscape dynamics in the Alps and the Apennines

M. Garbarino, F. Malandra, D.
Morresi, E. Sibona, R. Motta, C.
Urbinati, A. Vitali, P. J. Weisberg



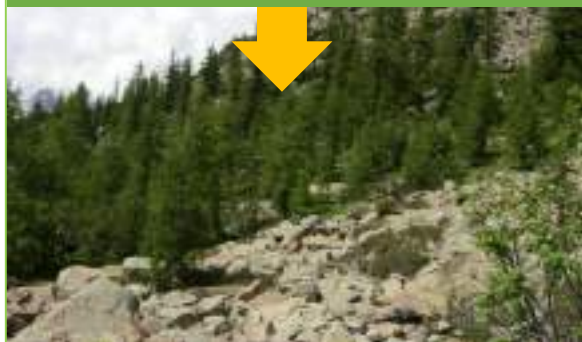
A history of land use and abandonment

Traditional Land Use



INTERACTIONS

Physical Template



ABANDONMENT

- Marginalization 1850
- Abandonment peak 1950 (2° WW)

Semi-natural hab.



LU CHANGE

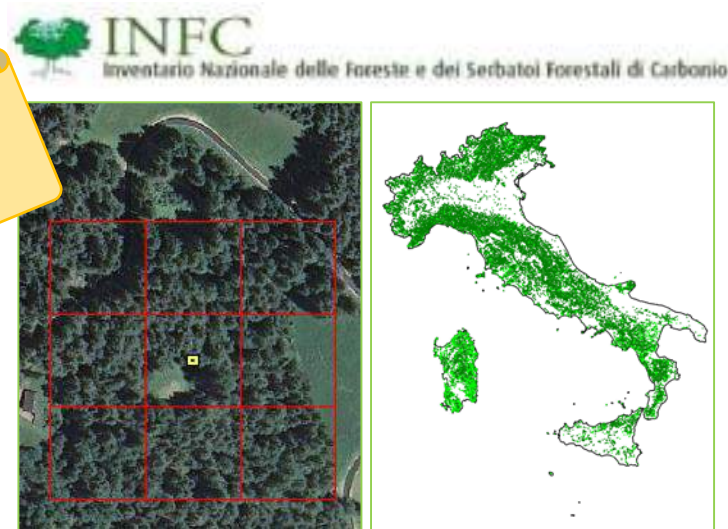
Forest Expansion



Forest expansion in Italy



HETEROGENEOUS DATA



Year	Data Source	Total Ha	% Var. – '36
1936	Forest Map of the Italian Kingdom	6.028.301	-
1985	1° Forest Inventory IFNI85	8.675.100	43,91
2005	2° Forest Inventory INFC05	10.467.533	73,64
2012	Corine Land Cover Map CLC12	9.973.516	65,44



Hypotheses & Research Questions

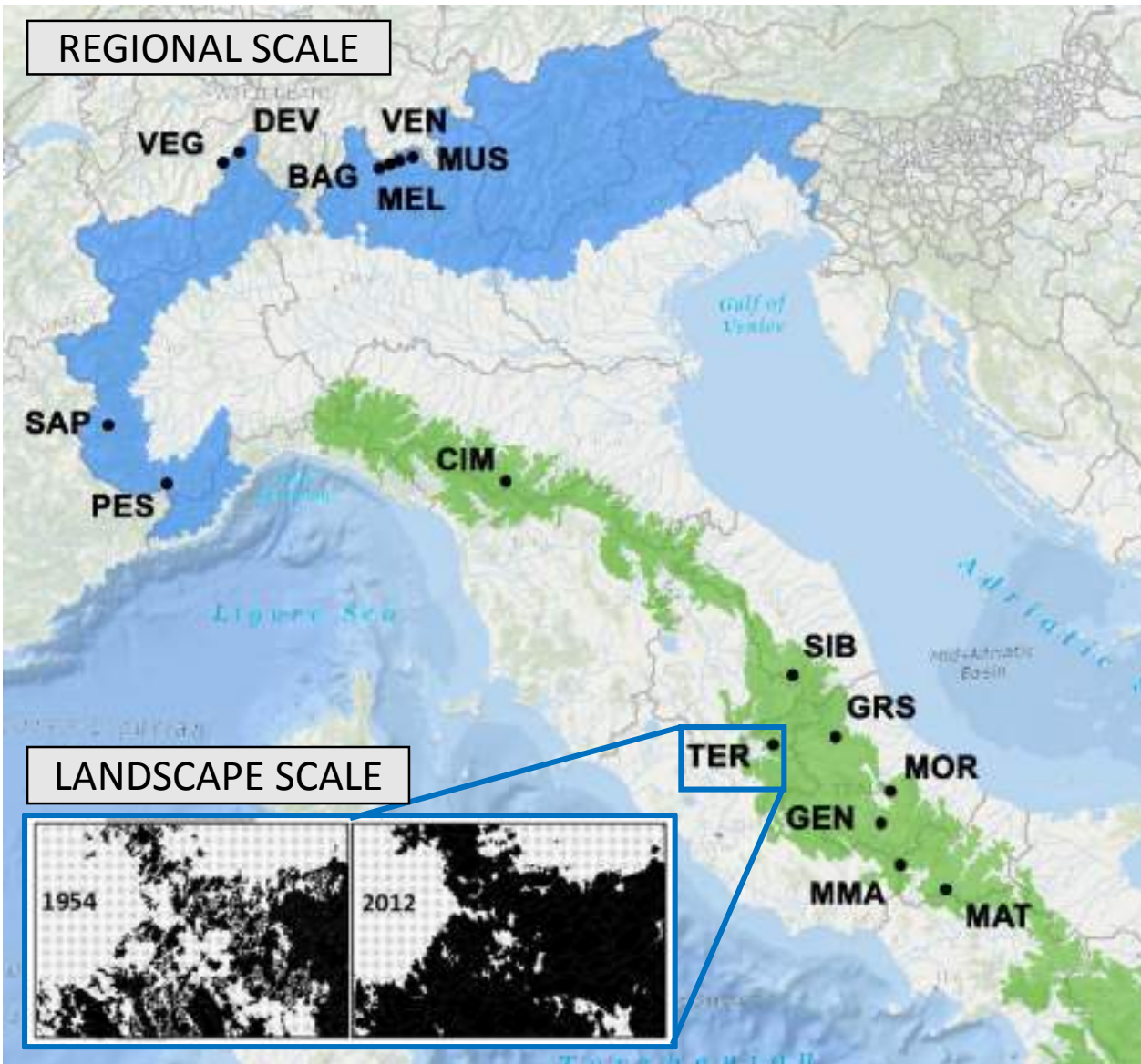
GENERAL HYPOTHESIS

The forest cover is increasing with different patterns on the Alps & the Apennines! Which pattern/patterns?

SPECIFIC QUESTIONS

- Which are the most important landscape transitions at high elevation?
- Has forest landscape structure changed remarkably?
- Which are the main environmental drivers (topography, climate, anthropogenic) of the transition “to-Forest” ?

Study area & Sampling design



Multiscale approach *Alps VS Apennines*

REGION

> 500 m a.s.l.

Alp (52.002 Km²)

Ape (44.615 Km²)

LANDSCAPE

500-2600 m a.s.l.

16 landscapes (8+8)

22.910 ha

FOREST

Virtual Plots

Fishnet

Data Analysis

1) Region

Corine Land Cover
Harmonization

(5 cat.)

Change (1990-2018)

Transitions



2) Landscape

Image analysis

Ortho RMSE 23 m

MMU = 100 m²

Accuracy K > 0.62

36 LU MAPS (1 m)

CATEGORIES

- 1) FOREST
- 2) GRASSLAND
- 3) CROPLAND
- 4) ANTHROPIC
- 5) UNVEGETATED

Changes (1954-2012)

Transition diagram

Transitions to-Forest

I M A G E A N A L Y S I S

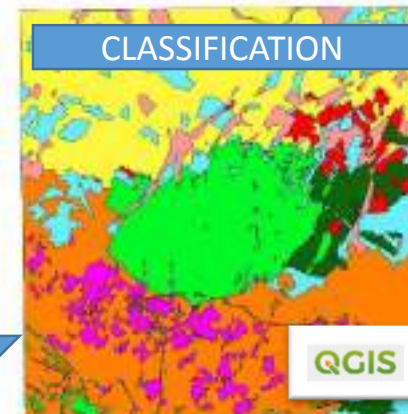
ORTHORECTIFICATION



SEGMENTATION



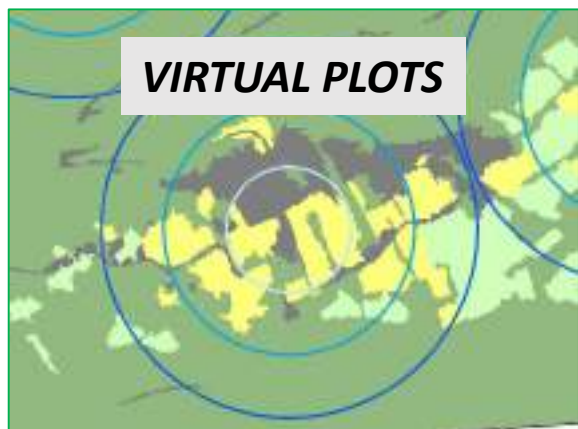
CLASSIFICATION



Data Analysis

3) Forest

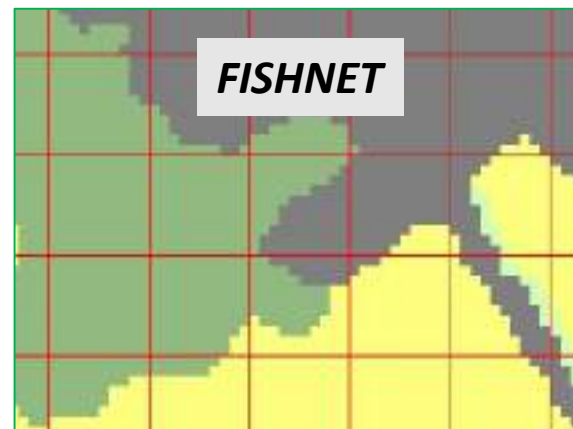
Forest Landscape Structure



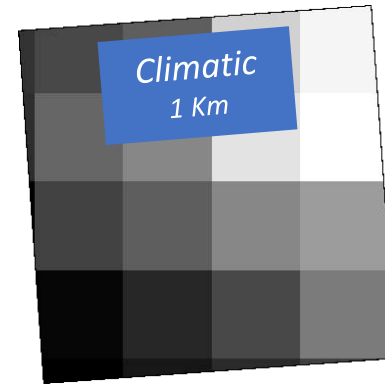
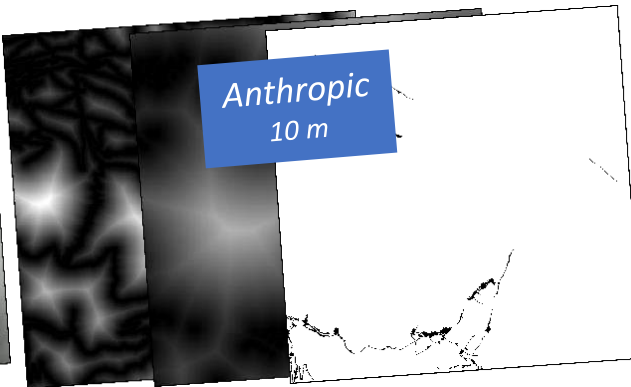
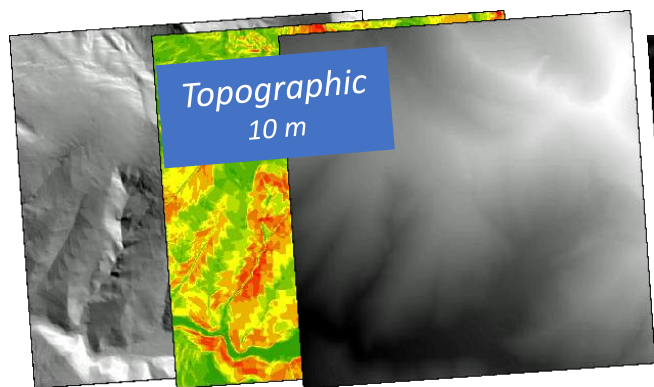
Fragata

Multivariate Analysis (PCA)
(Class metrics VS environment)

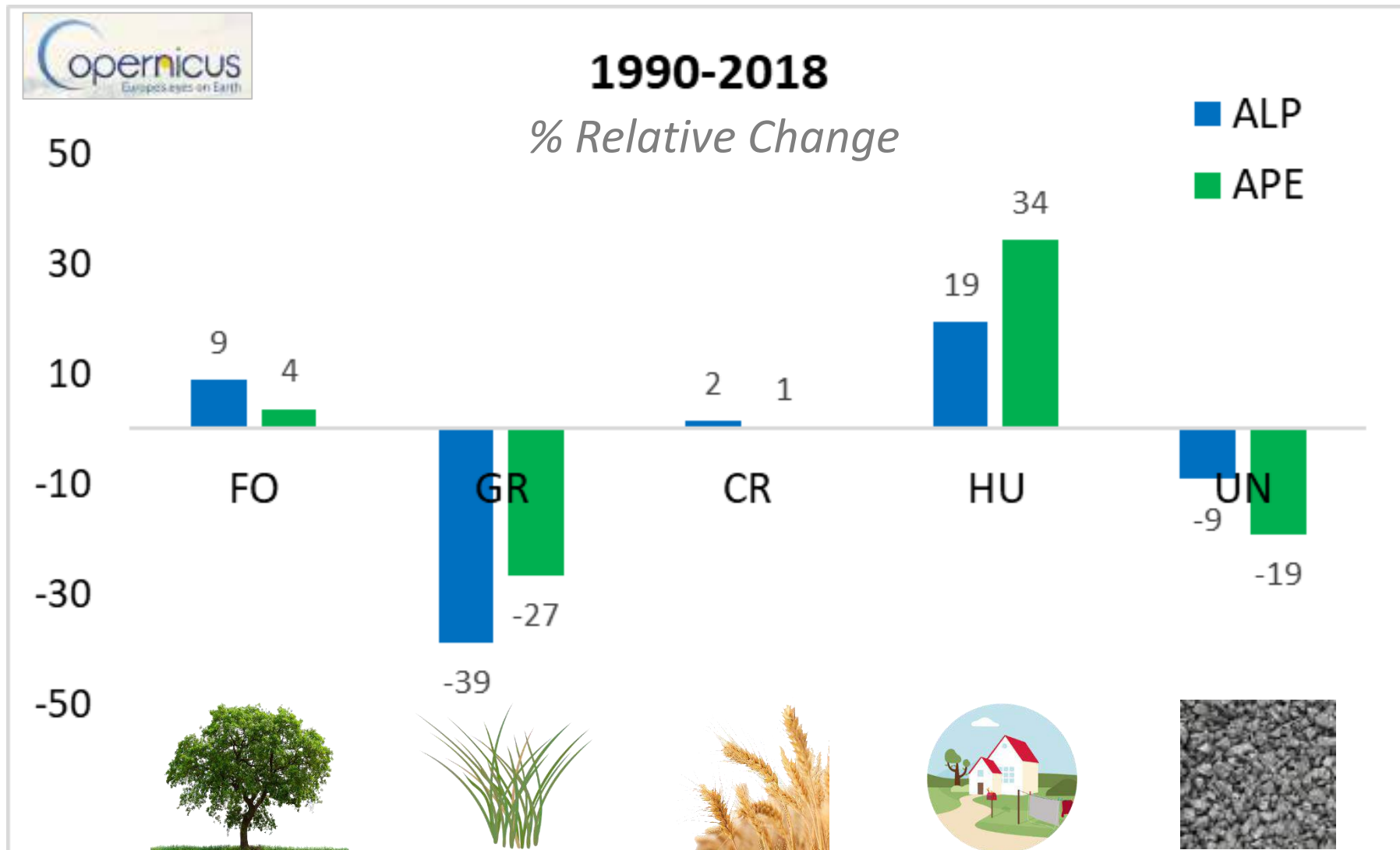
Drivers of “to-Forest” transitions



GLMM:
All to-Forest \sim **Environs** + (1 | landscape)



Regional: LC Change (Corine)

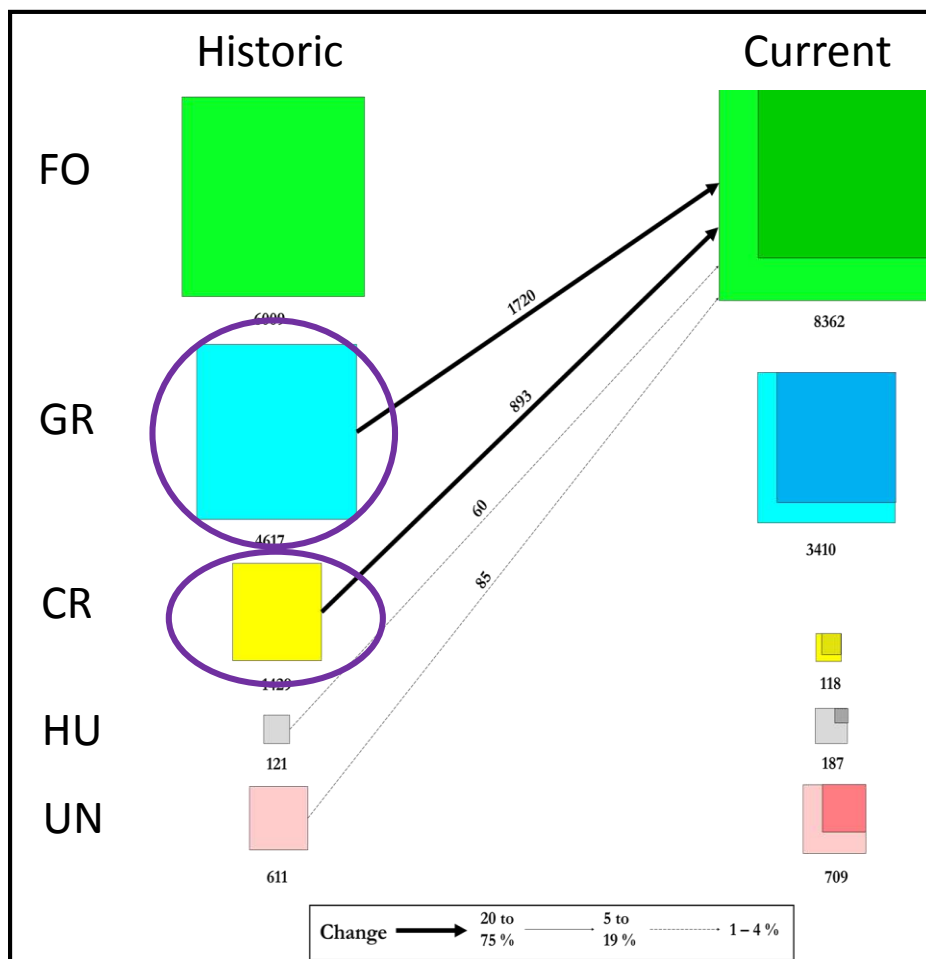
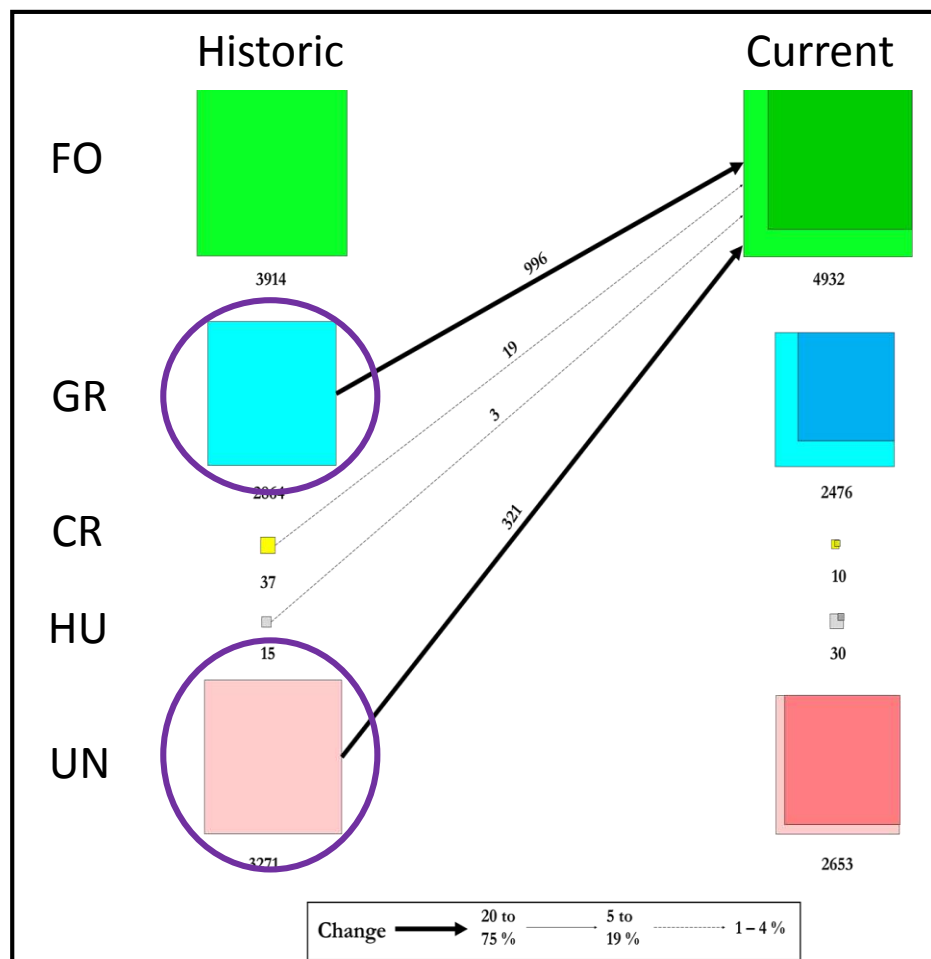




Landscape: Transition diagram

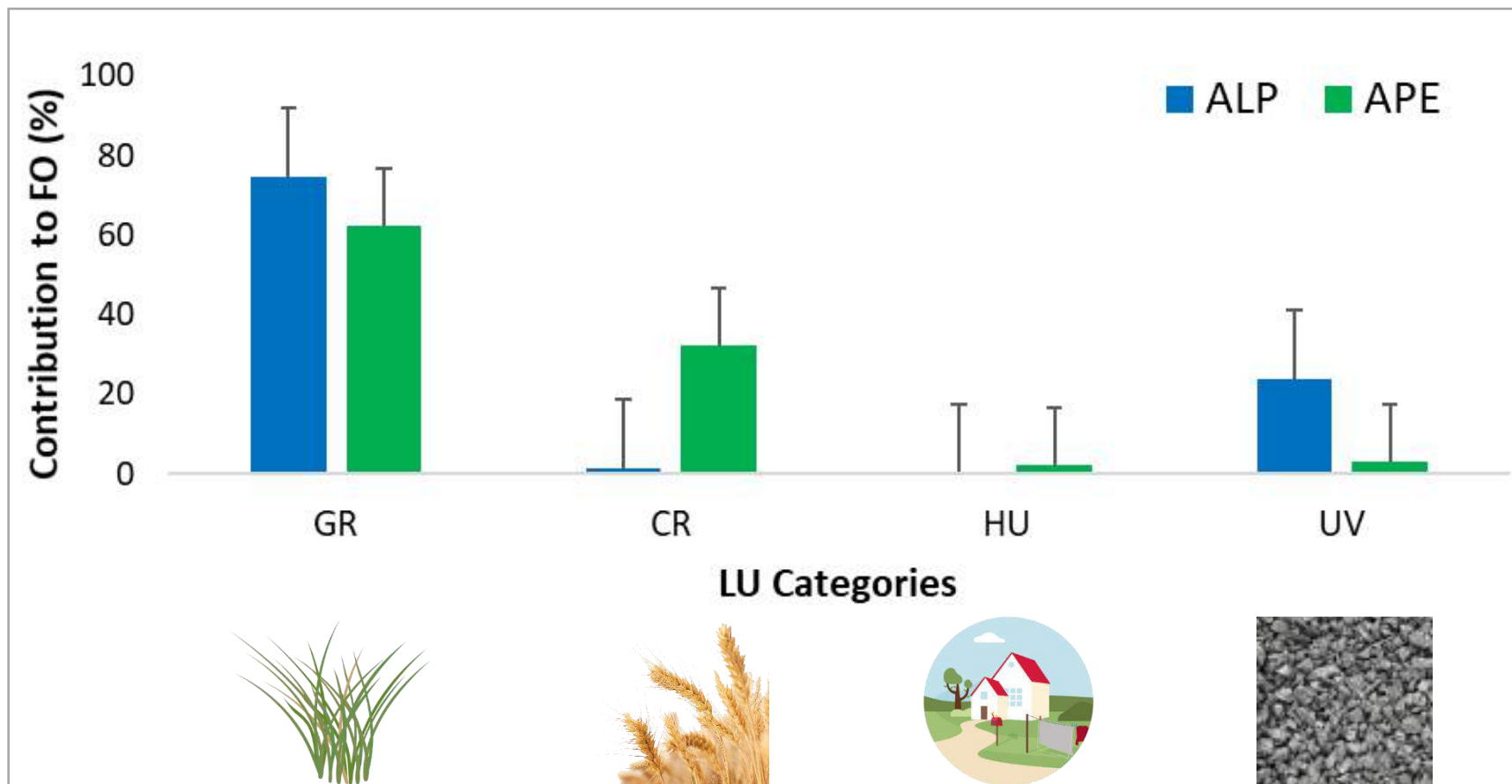
ALP

APE



Landscape: «to-Forest» transitions

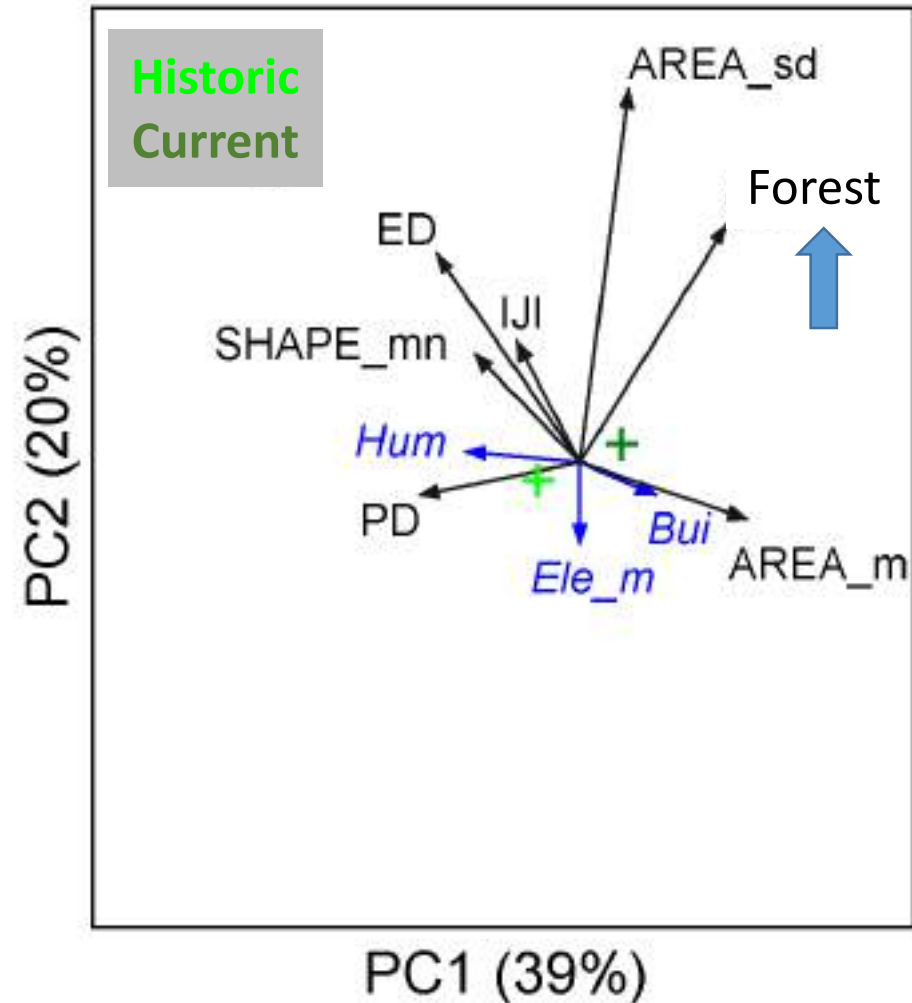
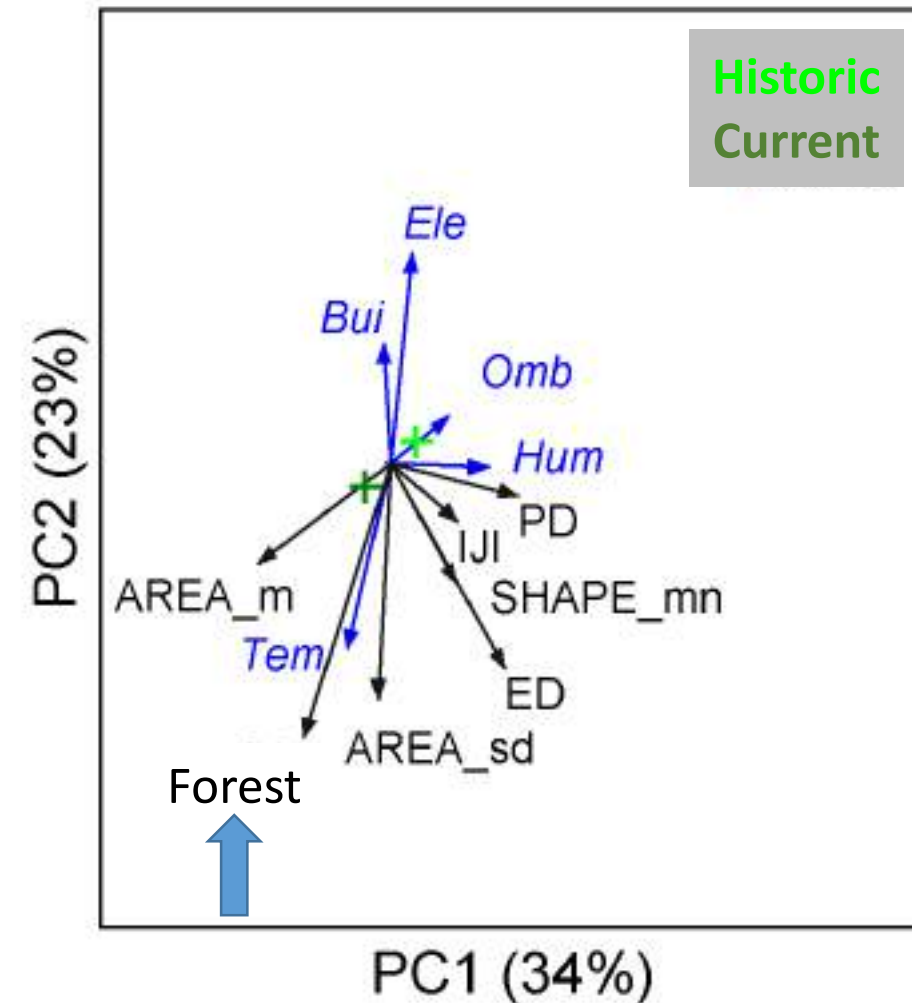
Contribution of each land cover category



Forest: Class Metrics - PCA

ALP

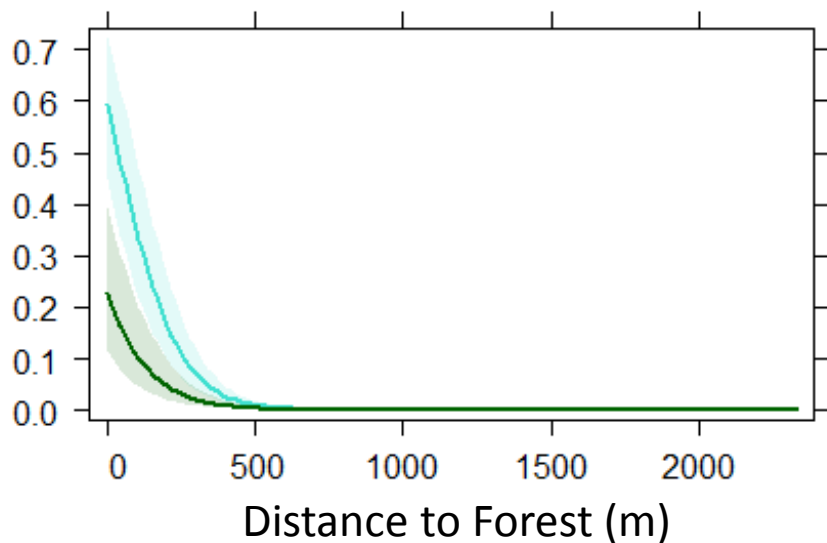
APE



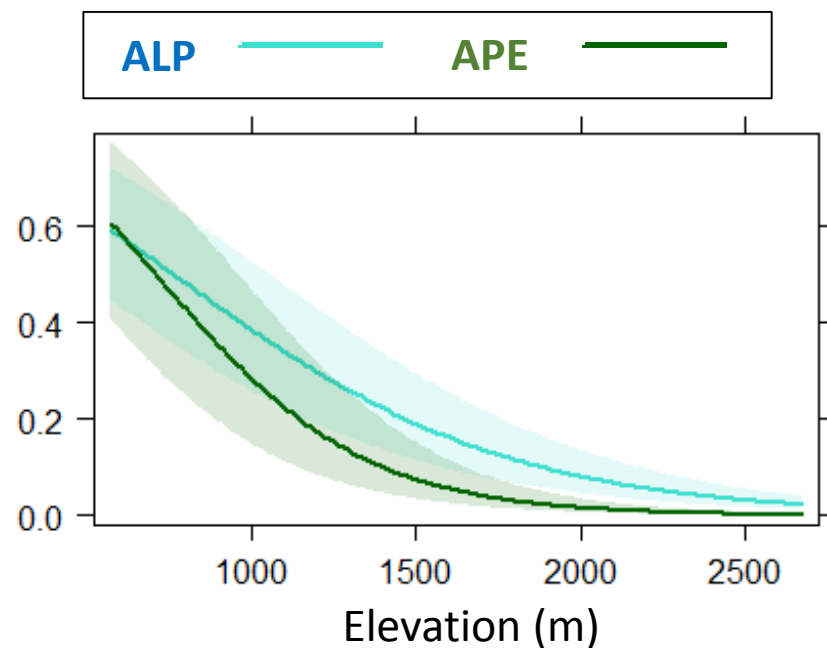
Forest: All to-Forest - *GLMM*



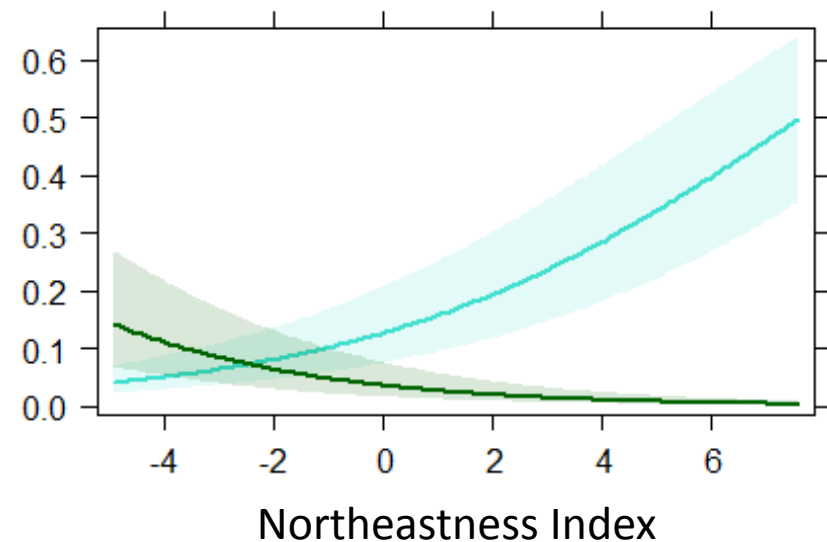
Transition to Forest



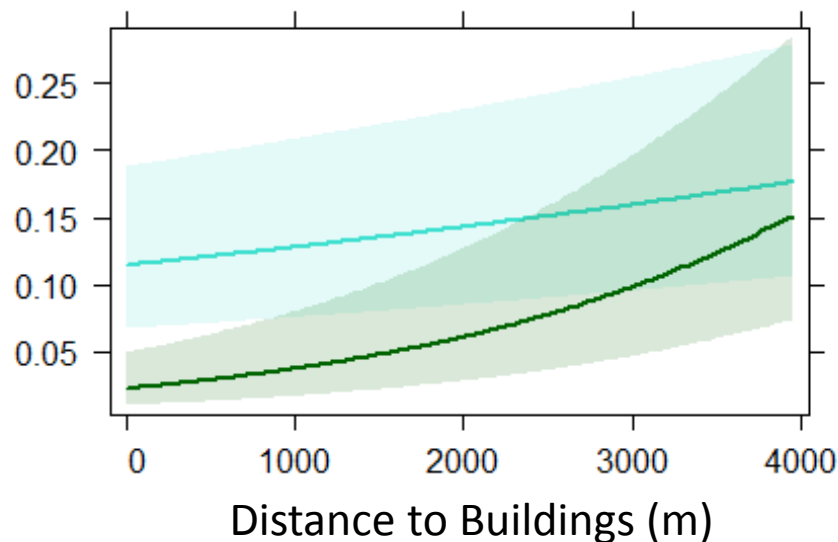
Transition to Forest



Transition to Forest



Transition to Forest





ALP vs APE

What	ALP	APE	Comments
Overall forest expansion	strong (26%)	very strong (39%)	Possible role of latitude and conifer plantations (legacy)
Dominant transitions	Grassland- & Unvegetated- to- forest	Grassland- & Cropland- to- forest	Treeline dynamics (ALP) and infilling processes (APE)
Forest landscape structure	Increase of forest patch size and variability	Landscape homogenization (+ size and – density)	Role of tree species: <ul style="list-style-type: none">- Conifers ALP- Broadleaves APE
Drivers of forest expansion	Forest proximity + Elevation – Remoteness + Cool (NE) +	Forest proximity ++ Elevation -- Remoteness ++ Warm (SW) +	APE: Abandonment everywhere ALP: «Well exposed» sites still grazed

Final remarks, hypotheses

The Alps and the Apennines are different (climate, soil, land use legacy, species composition), so they express different LUC patterns.

- Tree encroachment on old-pastures (secondary succession) and on former unvegetated areas (primary succession) dominates on the Alps, where climate change has a stronger influence.
- In the Apennines the land use legacy seems stronger than climate change, but the scarcity of primary succession processes could be due to the limited ability of beech treeline to “move” up-ward.

Possible improvements: extend the dataset to eastern and Northern Alps; predict future changes with a modeling approach.

Acknowledgments

**Nicolò Anselmetto, Michela Basso, Alessandra Bottero,
Ariele Cinti, Floriano Lenatti, Emanuele Lingua, Sara
Martelletti, Fedele Maiorano, Fabio Meloni,
Sara Saraceni, Laurent Perron, Mario Pividori, Marta
Martinez Subira, Tiziana Stangoni**

This research was partially financed by the project

REGIONAL SCALE ANALYSIS OF NATURAL AND HUMAN IMPACTS ON APENNINE FORESTLINES



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ALEXANDRA URZA², PETER J WEISBERG²,
CARLO URBINATI¹

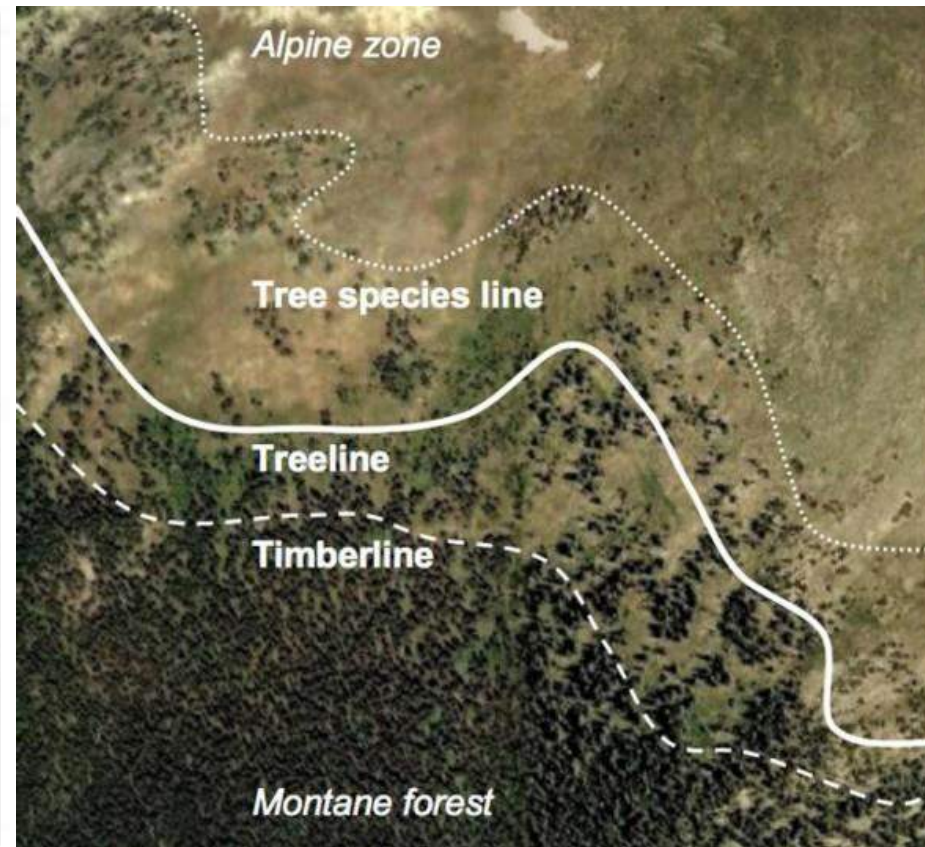
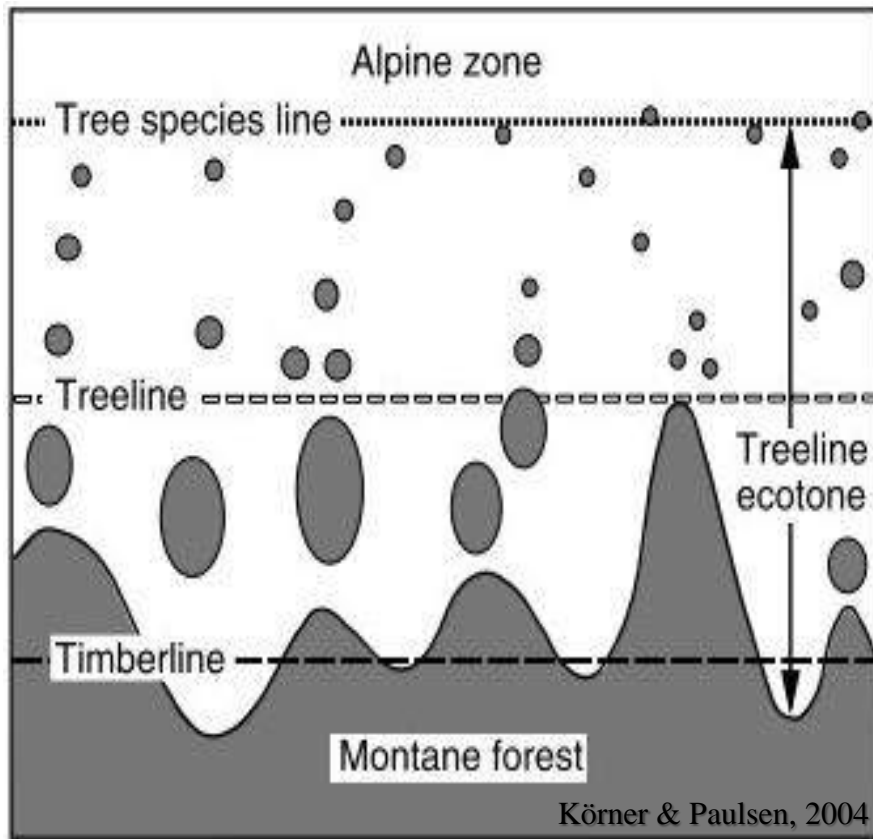


University of Nevada, Reno

Treeline/Forestline

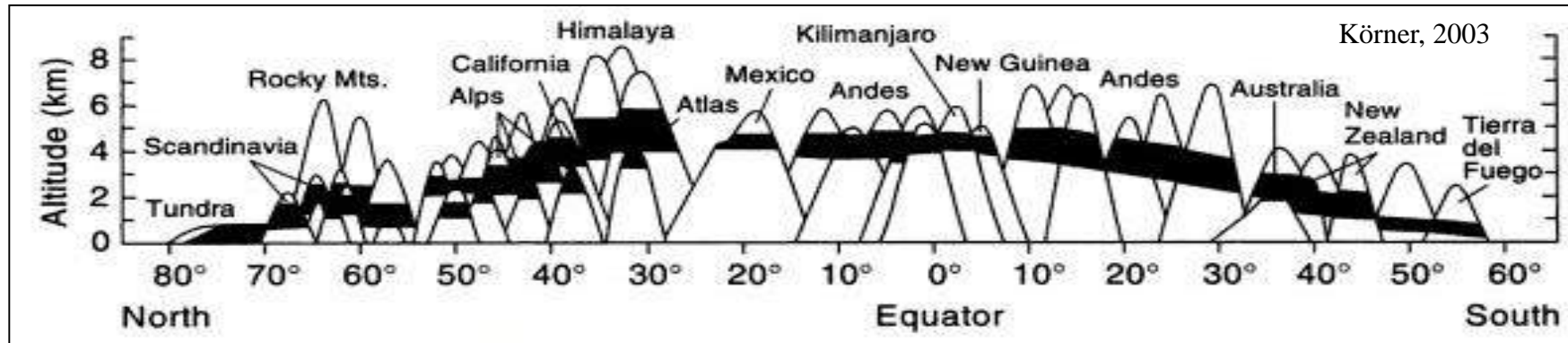
Treeline ecotone = transition zone from uppermost closed montane forests to the treeless alpine vegetation.

Forestline or Timberline = line representing the uppermost closed montane forest.



Natural treelines

Climatic Treelines = mostly controlled by climate (temperature).

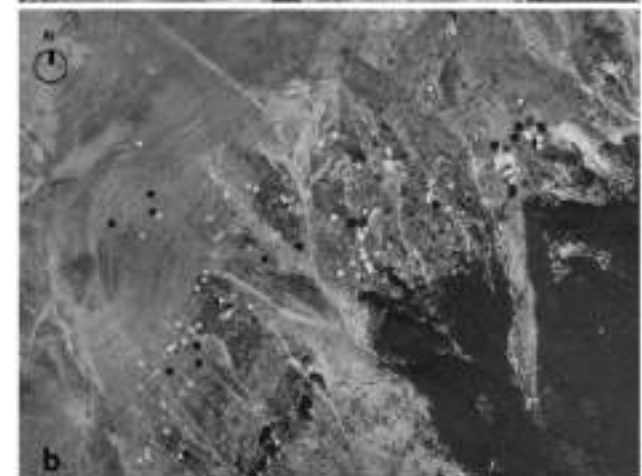
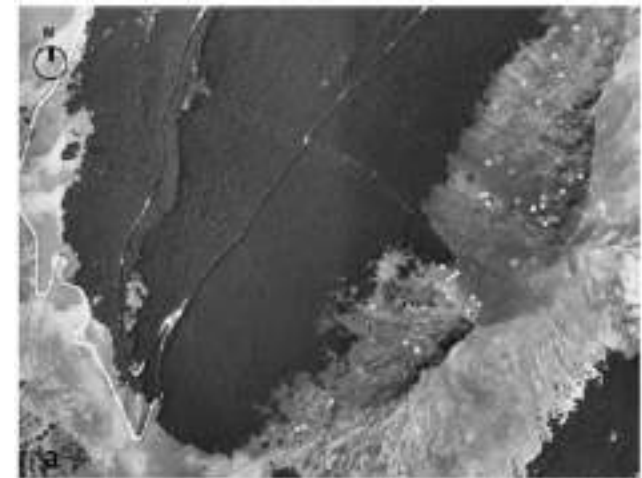


Topographic/Edaphic treelines = mostly limited by topographic and edaphic constraints.



Anthropogenic treelines

- Natural constraints are often overcome by human activities
- Abrupt transition between forest and high elevation pastures

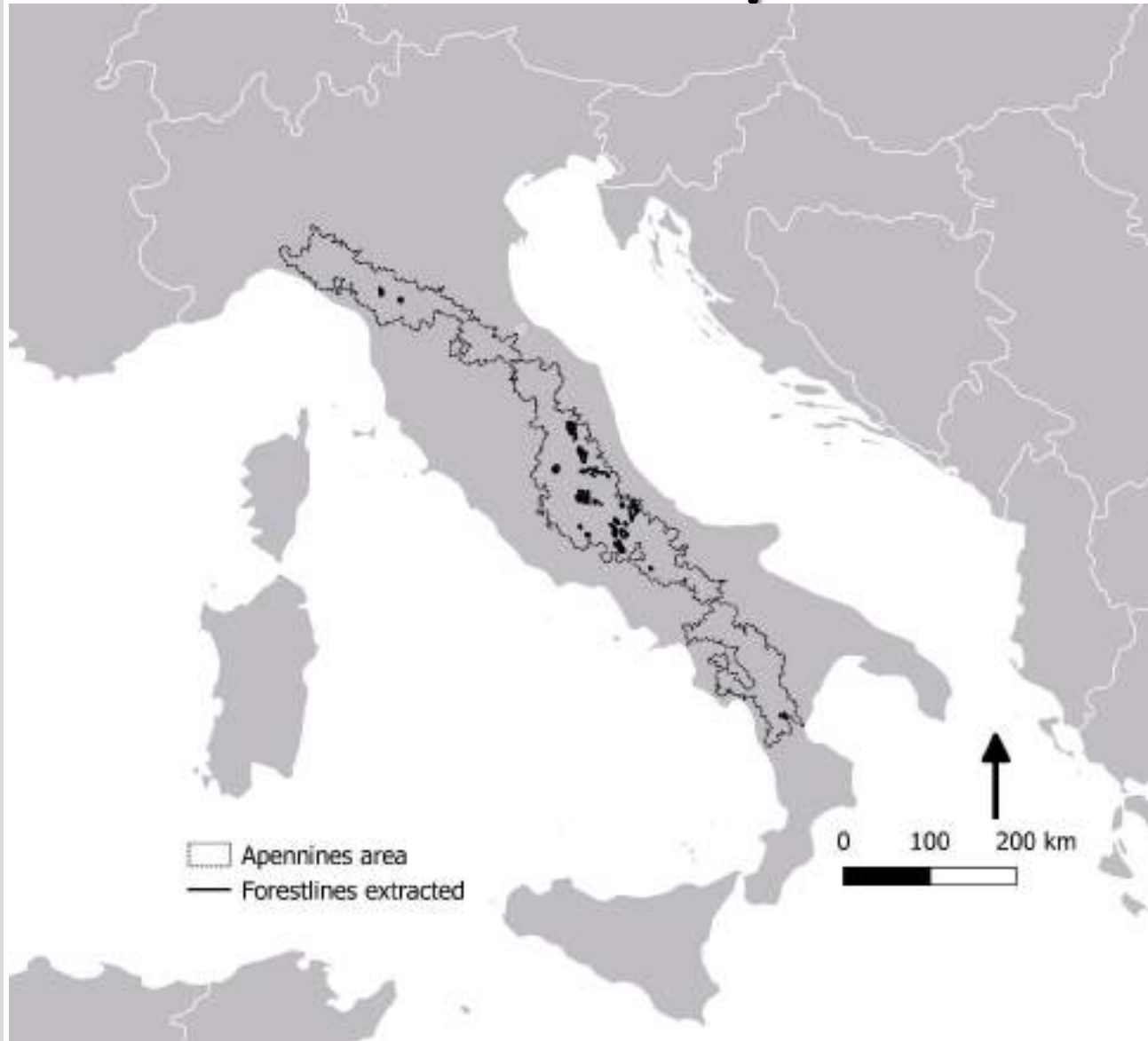


Objectives

- Our analysis on the Apennine anthropogenic forestlines consist of three steps that aimed to:
 - 1) Locate the upper forestline at regional scale (whole Apennine range) using remote sensing technique;
 - 2) Explore the correlation structure of natural and anthropogenic environmental variables;
 - 3) Quantify the relative influence of variables on treeline elevation using a statistical modeling approach.



The Apennines



~ 43000 km²

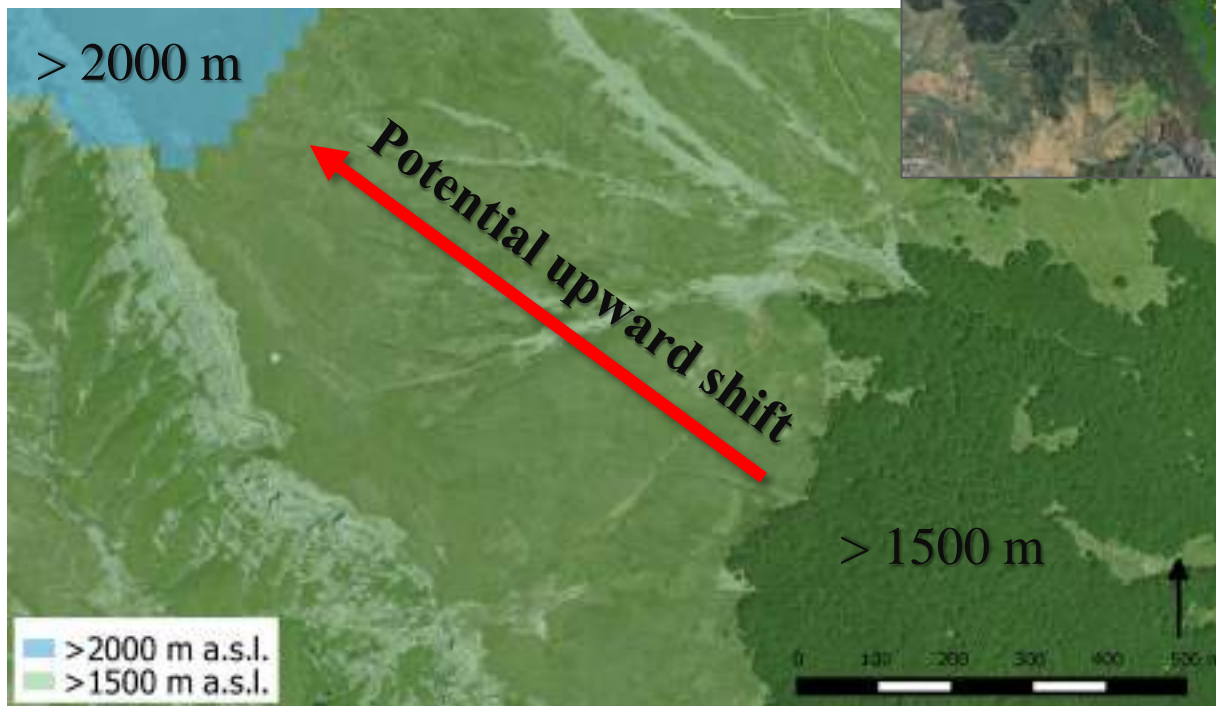
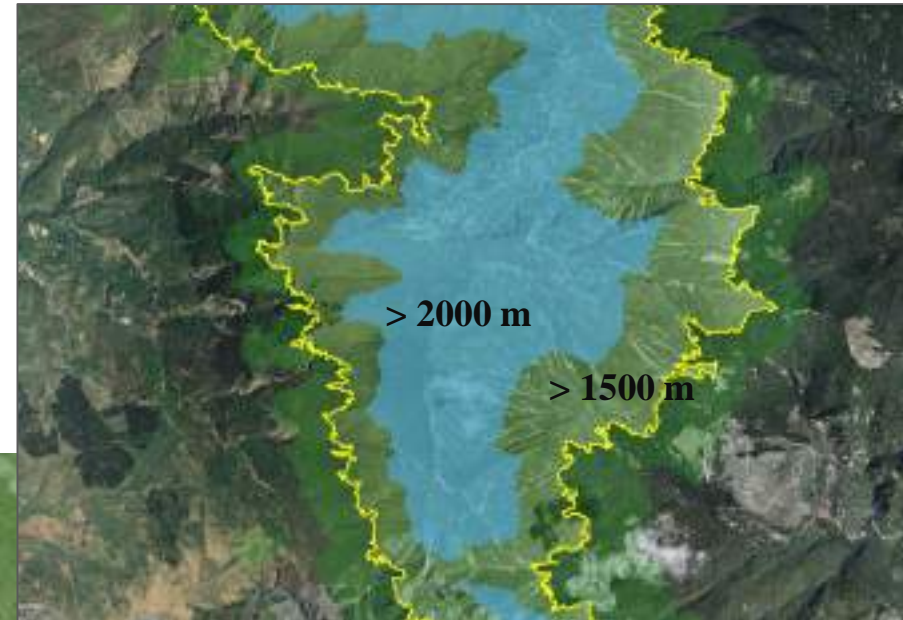
776
mountain
municipalities
(sensu ISTAT)

22
“mountain groups”
(selected by topographic features)

Mountain Tops detection

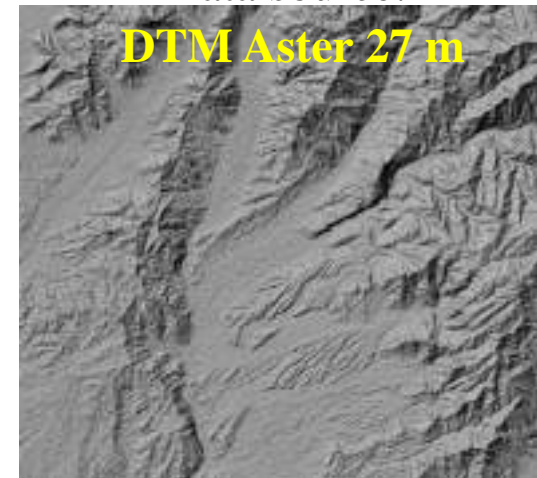
Polygons with 2 conditions:

- **Forests** > 1500 m a.s.l.
- **Mountain tops** > 2000 m a.s.l.



Data source:

DTM Aster 27 m



Forestline detection

Object-oriented segmentation of aerial images with



Automatic segmentation

(scale 25 & color 0.9)

+

Manual classification

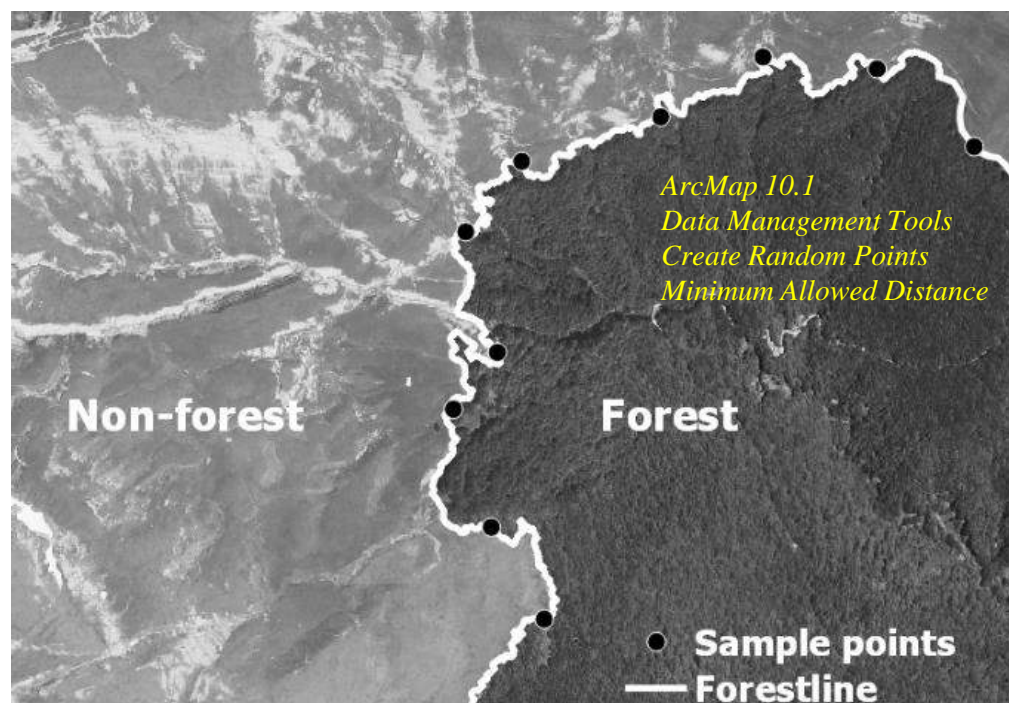
(forest/non forest MMU = 1ha)

=

Polygons → **Polylines**

Data collection

Around 6000 points extracted (every 500 m) along the forestlines (*Case & Duncan, 2014*)



Data types

Topography

(Aster DTM)

Climate

(WorldClim)

Dominant species

(thematic maps)

Socio-economic

(ISTAT and road database)

Data analysis

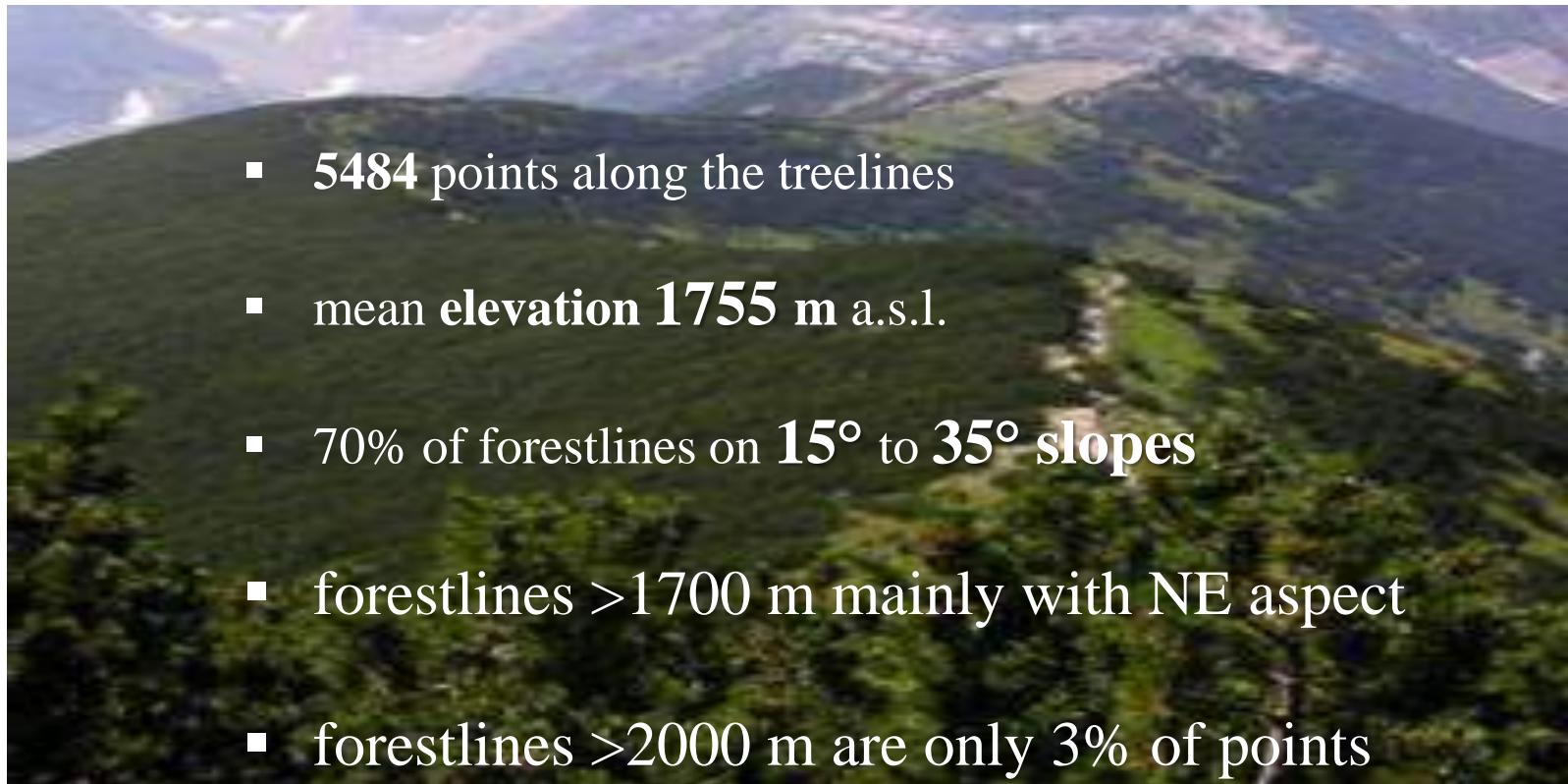
Correlation structure of all variables → PCA

GLMM of selected explanatory variables on FORESTLINE ELEVATION

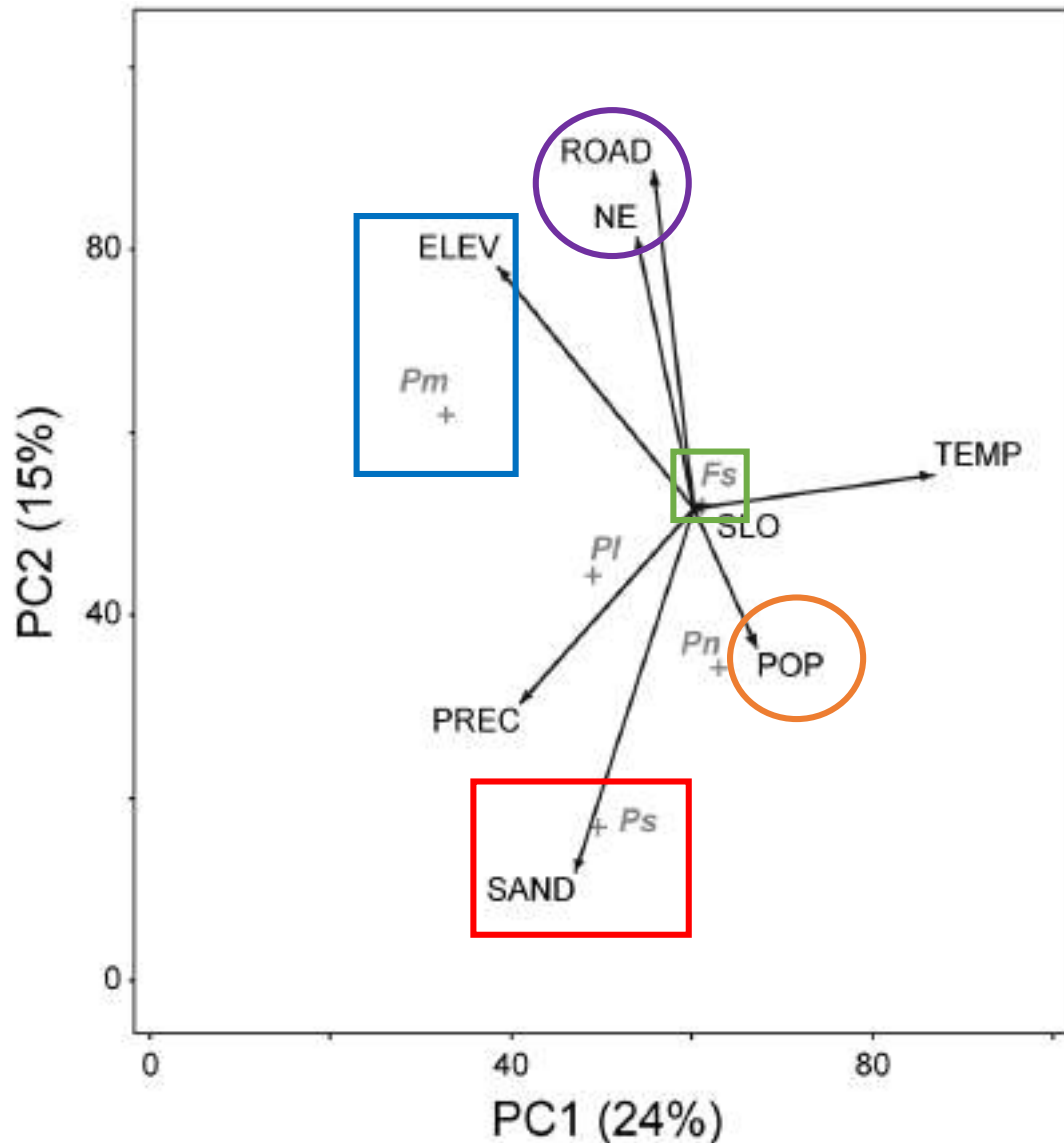
Forestline summary statistics

Elevation (m)	Slope (°)	Temperature (°C)	Precipitation (mm)	NE index	Road dist (m)
1755	25	5.7	832	0.1	563
± 133	± 10	± 1.0	± 27	± 0.7	± 486

- **5484** points along the treelines
- mean **elevation 1755 m** a.s.l.
- 70% of forestlines on **15° to 35° slopes**
- forestlines >1700 m mainly with NE aspect
- forestlines >2000 m are only 3% of points



Species VS Environment



- Human population (**POP**) is negatively correlated with NE and elevation
- **Highest** forestlines are far from ROADS mainly on NE exposures
- *Fagus sylvatica* (Fs) is the prevailing species (98%) and is everywhere
- *P. mugo* (Pm) dominates at higher elevations
- *P. sylvestris* (Ps) is limited to very few sites on sandy soils in the Northern Apennine

Constraints for forestline elevation

The linear-mixed models (GLMMs) of forestline elevation

		Estimate	Std.Error	p-value
TEMP	-	46.64	1.755	<0.001
NE	+	18.55	1.667	<0.001
SAND	-	3.06	0.412	<0.001
PREC	+	2.25	0.142	<0.001
ROAD	+	0.01	0.003	<0.001
SLO	-	0.15	0.108	0.163
POP	-	0.03	0.117	0.822

- Negative effect of temperature (TEMP) and positive effect of precipitation (*P*).
- Positive influence of NE aspect (coldest slopes) and distance from the closest road (ROAD).

The human presence (POP) seems to limit forestline elevations (not-significant).

Forestline Elevation

- Apennine forestlines are **dominated by European beech**; **pine** species are locally abundant or **favored by anthropogenic activities** (central Apennines)
- **Aspect** influenced **human activities** and indirectly affects **forestline elevation**
 - Highest forestlines on NE slopes
 - SW slopes more grazed and disturbed by *P. nigra* plantations
- Growing season Temperature is the strongest (negative) factor for forestline elevation → natural or anthropogenic factor??
- **Road distance** is a **good proxy** for human impact at regional scale

Ongoing multi-scale research

Regional

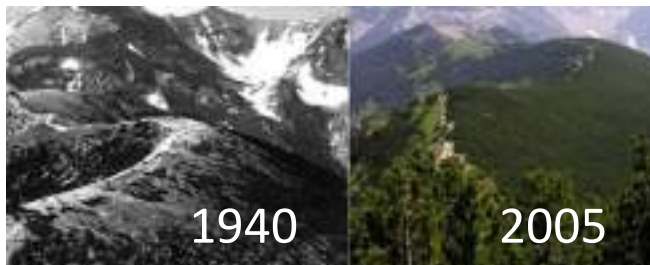


Land use change → Corine Land Cover maps

Forestlines detection → automatic segmentation

Environmental constraints → PCA, GLMMs

Landscape

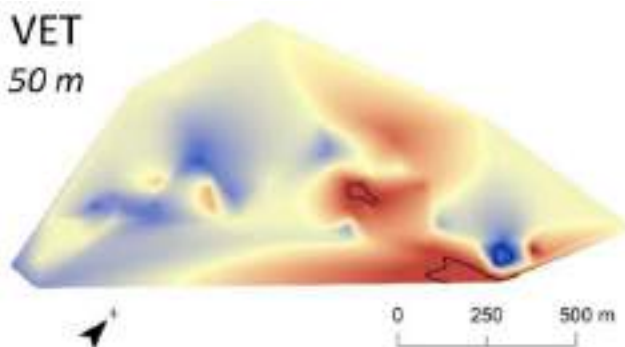


→ change detection

Land use history

→ landscape metrics

Site-tree



Encroachment dynamics → spatial-pattern analysis

Climate impact → dendroecological analysis

Micro-topography → VHR remote sensing

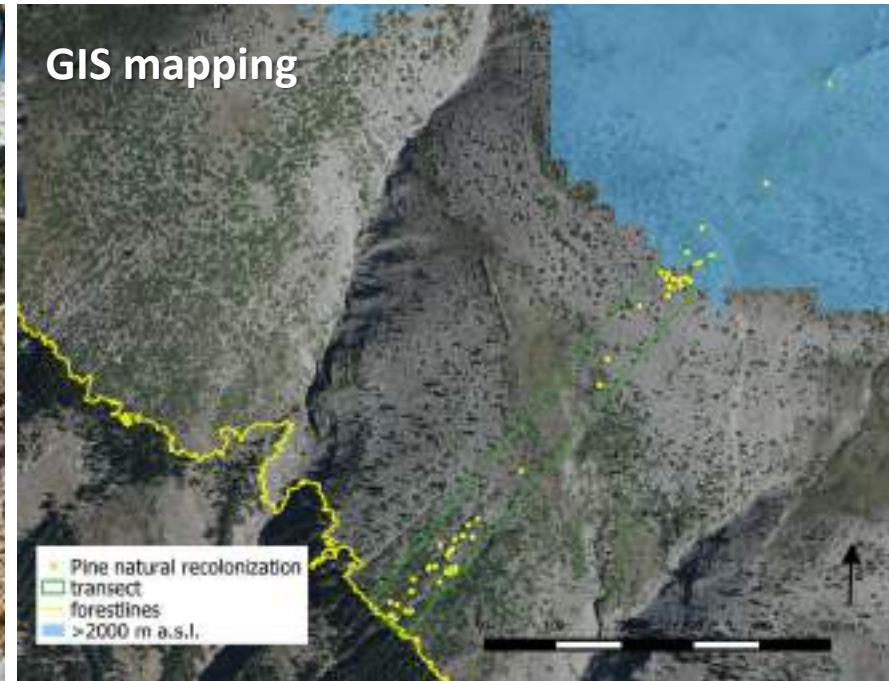
Ongoing research (fine-scale)



GPS



Age estimation



GIS mapping



M. Genzana (2015)



M. Genzana (2015)

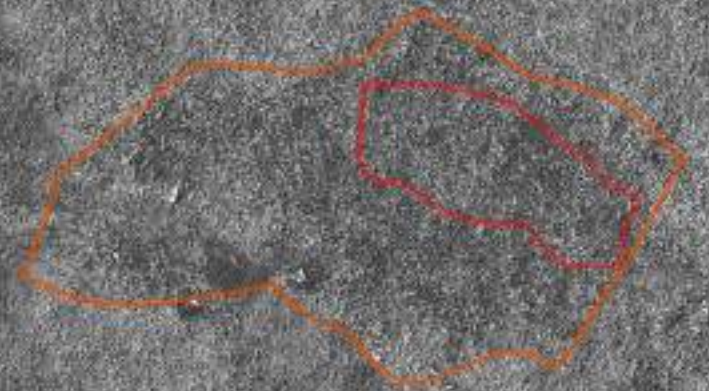


M. Portella (2015)

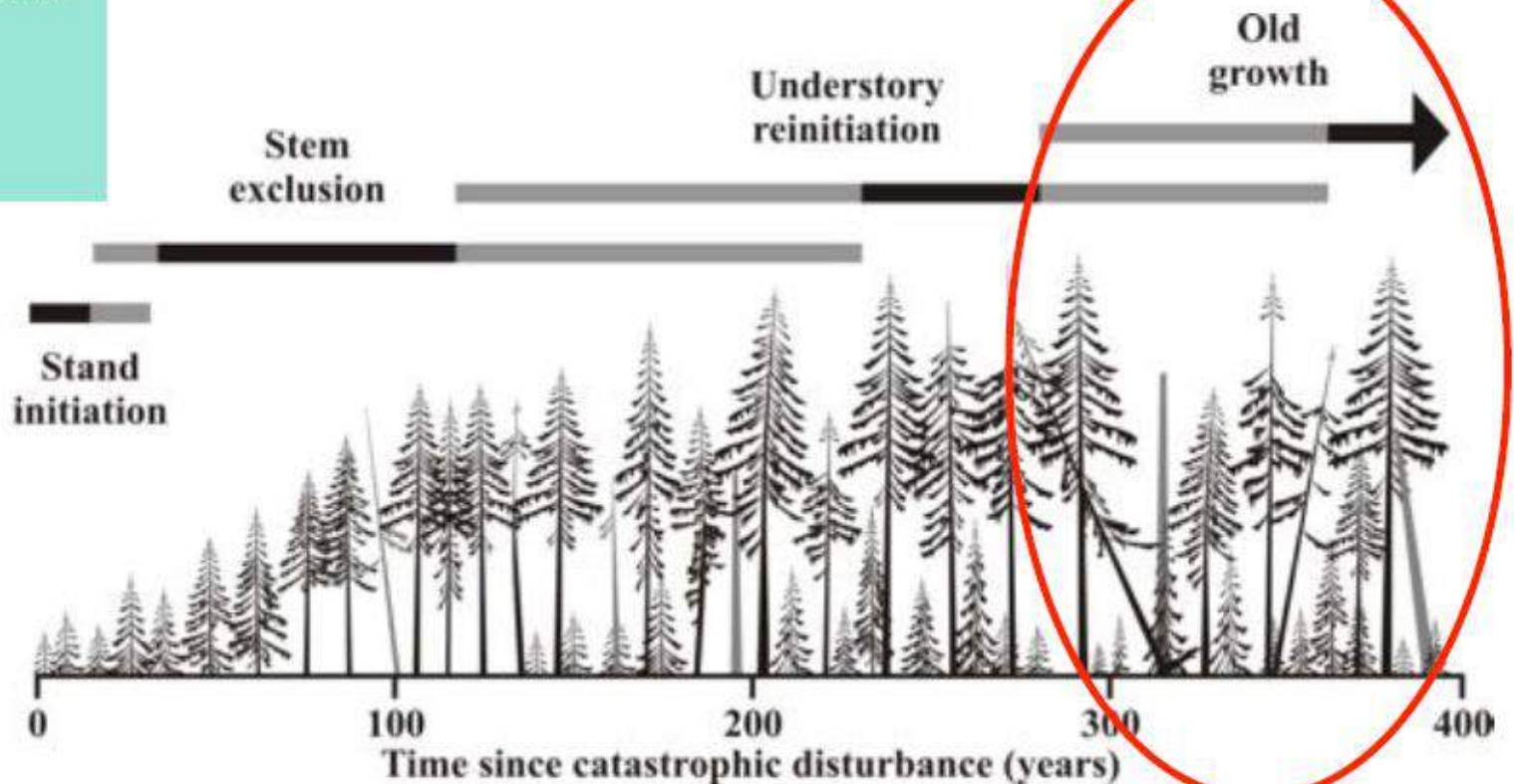
The background of the slide is a photograph of a mountain landscape. The top half shows a wide view of a mountain ridge with a mix of green grass and small evergreen trees under a cloudy sky. The bottom half is a closer view of a similar hillside, showing more detail of the vegetation and rocky patches.

Thank you
Grazie

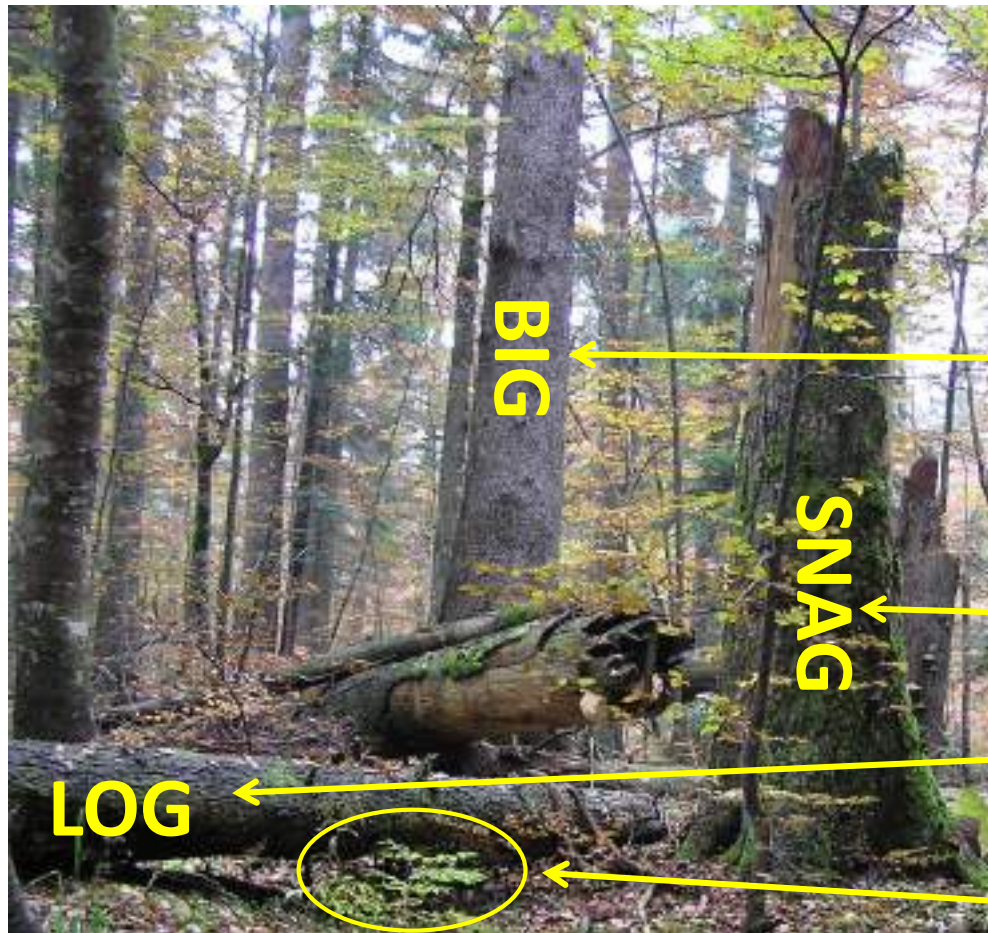
Old-Growth forests of the Balkans



Old-growth forest?



Some characteristics



Many vegetation layers

High diameter variability

Old and big trees

A lot of DEADWOOD
standing (SNAG) or lying
on the ground (LOG)

Patch of regenerating trees

Patchy and heterogeneous spatial distribution (random or clustered) of trees within the landscape.

Forest Canopy Gaps

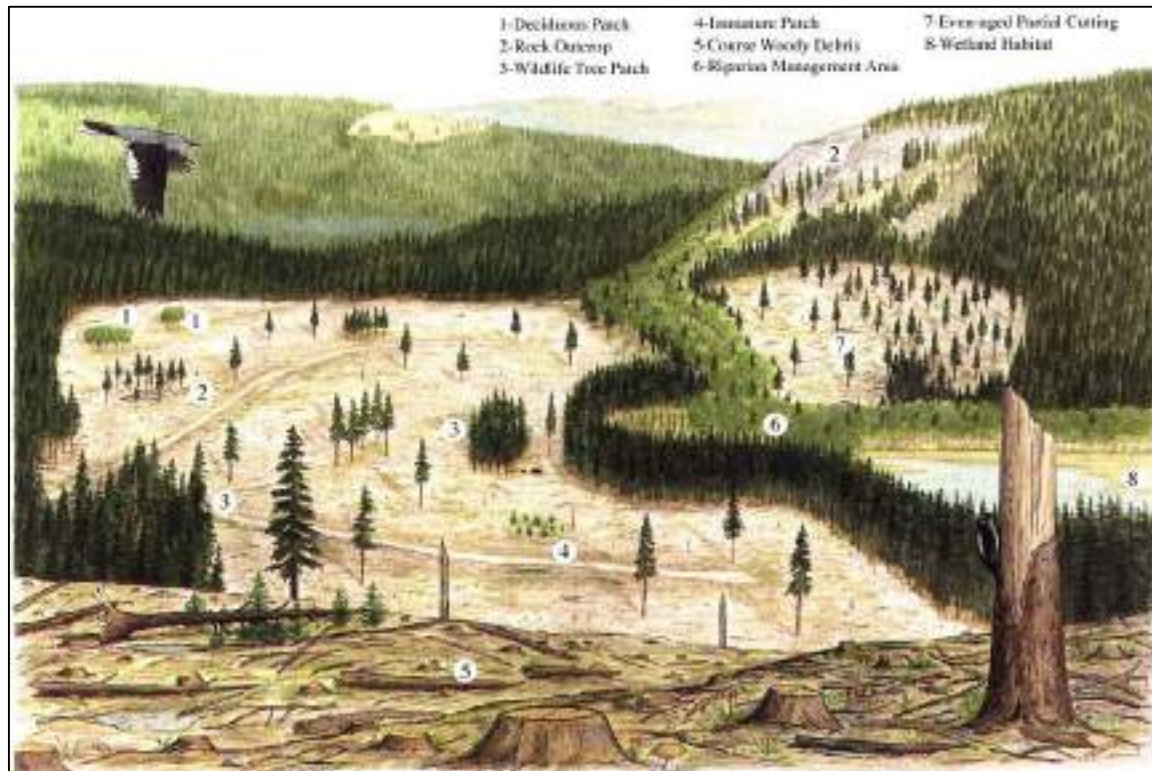


Dead Wood ... a lot!



Why are important?

- Scientific: a model of the natural development of a forest!
- Management: a model to follow to apply a «close-to-nature» silviculture!



Habitats for different species



Photo by A. Gukasova

Where?

- ✓ Boreal OG → Alaska, Canada, Scandinavia, Russia
- ✓ Tropical and rain OG → Amazonia, Congo, Nuova Guinea



In Europe

Primary forests **are rare** as a result of centuries of land use and forest management.

Many are **not strictly protected** and most are **small and fragmented**, making them **prone to extinction** debt and human disturbance.

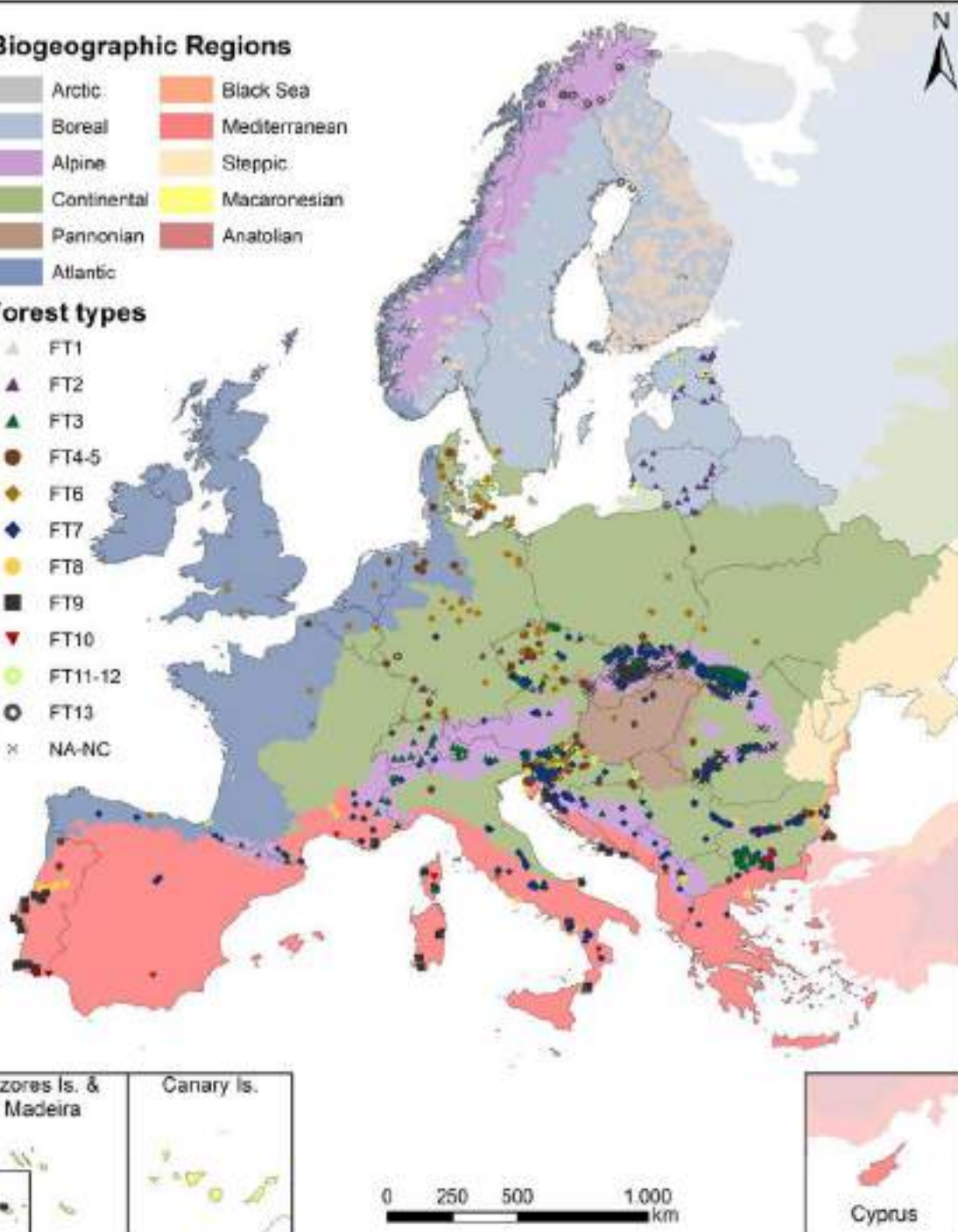
Predicting where unmapped primary forests likely occur **could guide conservation efforts**, especially in Eastern Europe where they are disappearing.

Biogeographic Regions

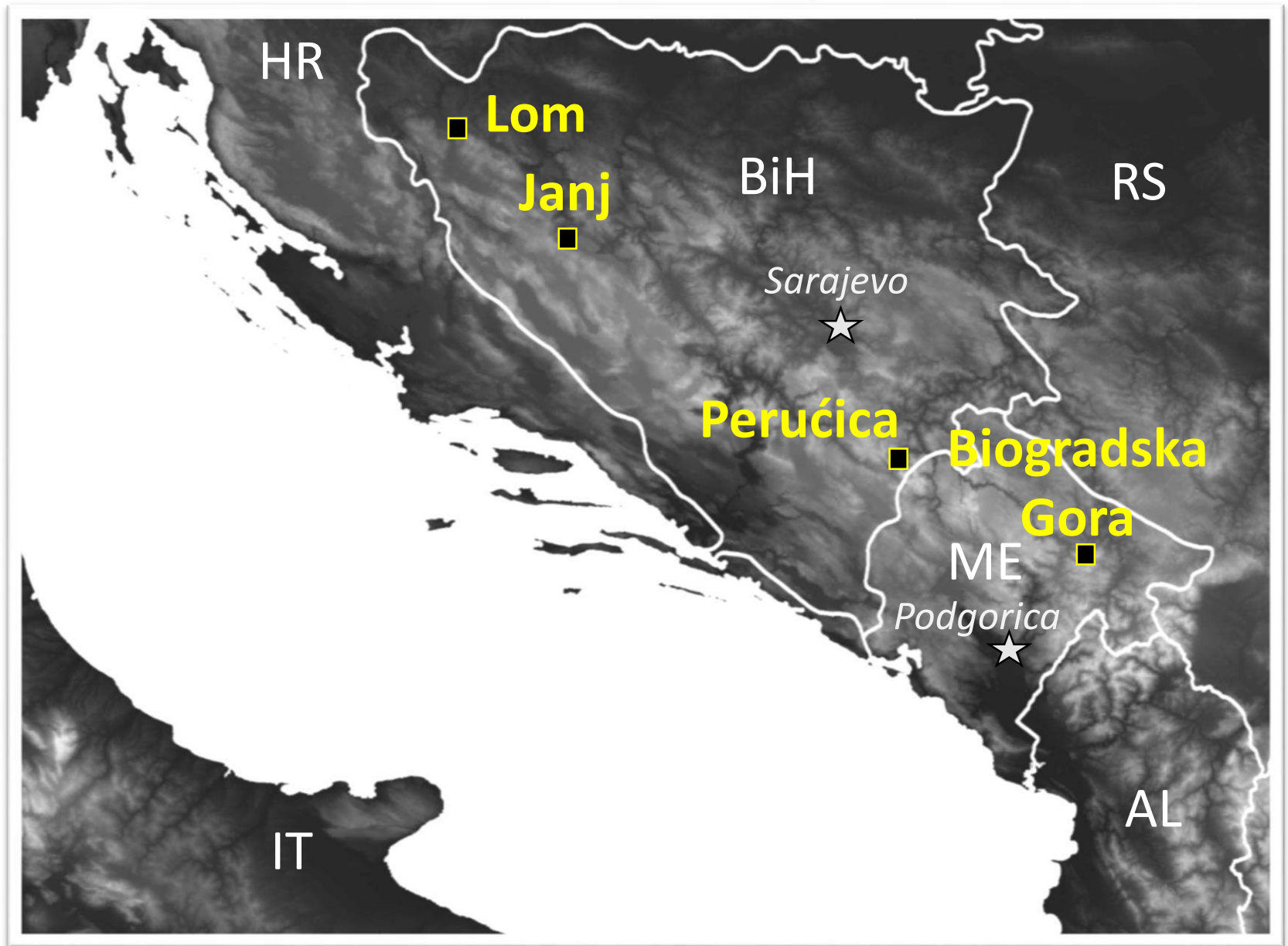
Arctic	Black Sea
Boreal	Mediterranean
Alpine	Steppic
Continental	Macaronesian
Pannonian	Anatolian
Atlantic	

Forest types

▲ FT1
▲ FT2
▲ FT3
● FT4-5
◆ FT6
◆ FT7
● FT8
■ FT9
▼ FT10
● FT11-12
○ FT13
× NA-NC



Balkans: 4 study areas



Study areas

LOM

Estensione: 300 ha (56 ha)

Sp. Dominanti: Picea-Abies-Fagus

Quota: 1200-1500 m s.l.m.

Topografia: altipiano carsico

Precipitazioni: 1600 mm/anno

Studi: RS, gaps, strutt., dendro.



Study areas

JANJ

Estensione: 295 (57) ha

Sp. Dominanti: Picea-Abies-Fagus

Quota: 1180-1510 m s.l.m.

Topografia: altipiano carsico

Precipitazioni: 1200 mm/anno

Studi: RS, Struttura forestale



Study areas

PERUĆICA

Estensione: 1500 ha

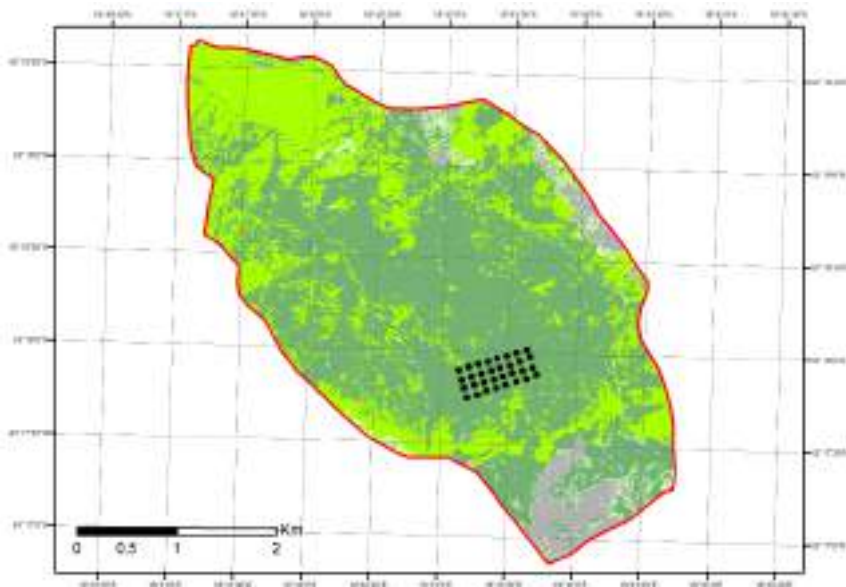
Sp. Dominanti: *Abies-Fagus*

Quota: 600-2400 m s.l.m.

Topografia: vallata fluviale

Precipitazioni: > 1400 mm/anno

Studi: RS, gaps, struttura for.



Study areas

BIOGRADSKA GORA

Estensione: 6033 ha (2833 ha)

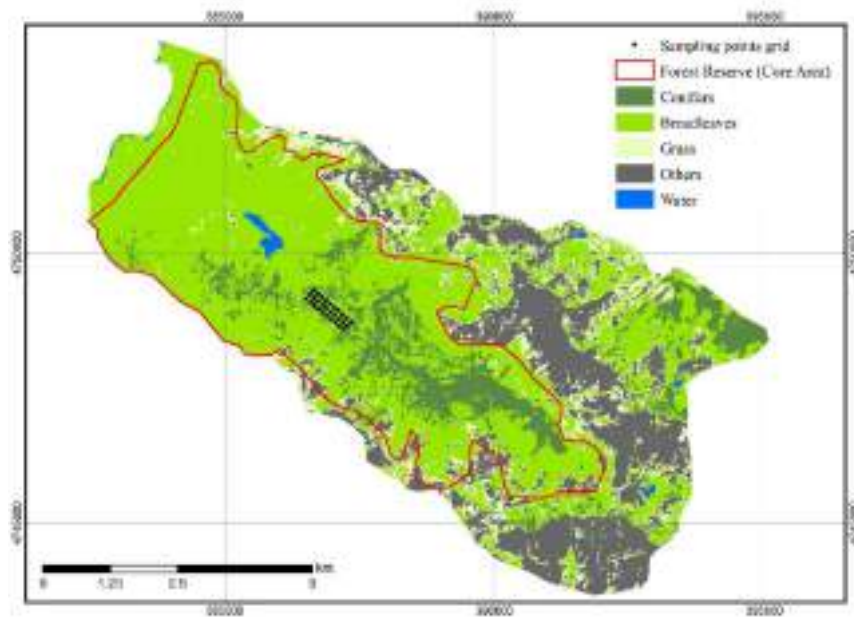
Sp. Dominanti: *Abies-Fagus*

Quota: 830-2139 m s.l.m.

Topografia: vallata fluviale

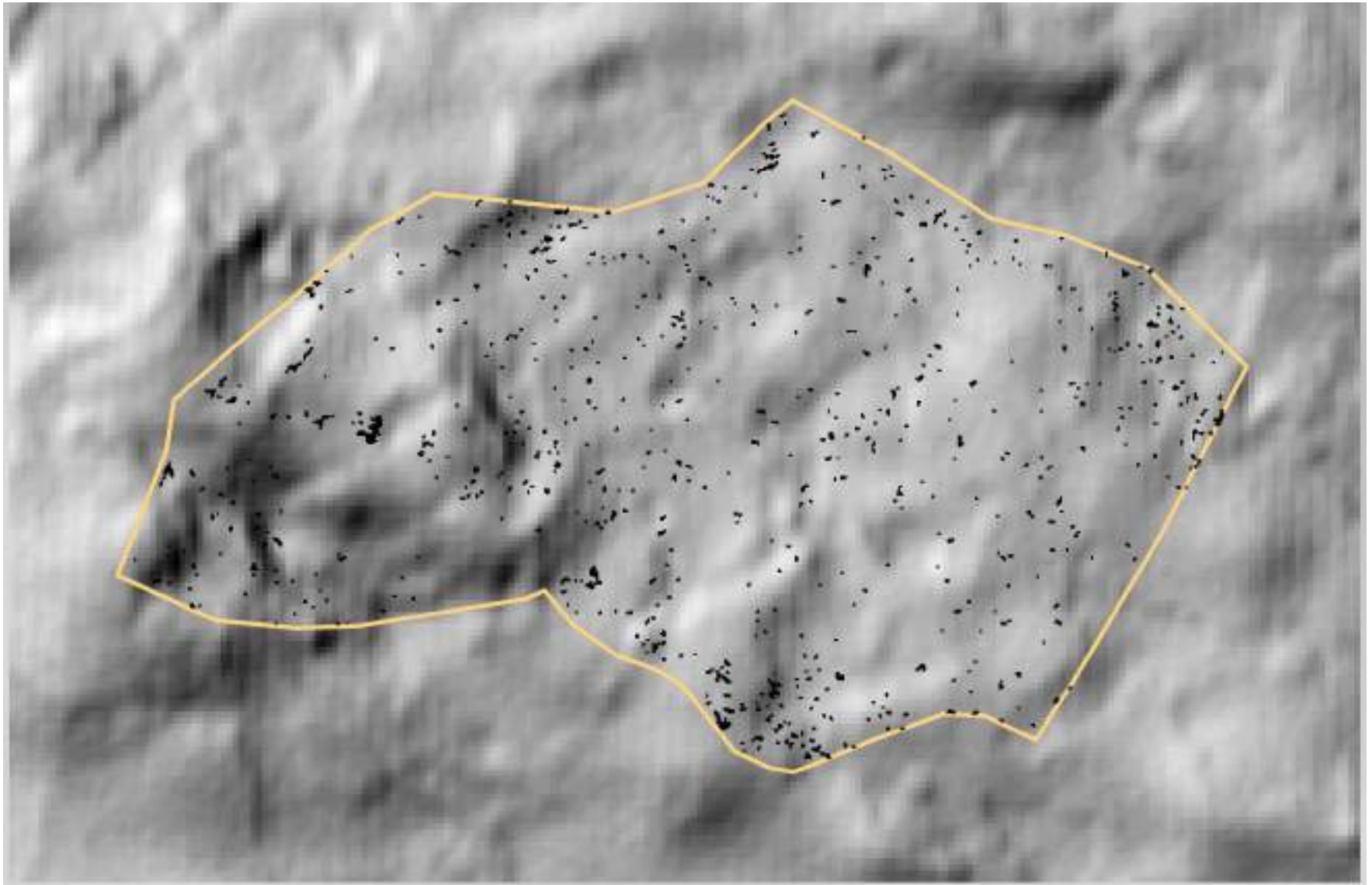
Precipitazioni: 1962 mm/anno

Studi: RS, gaps, struttura for.



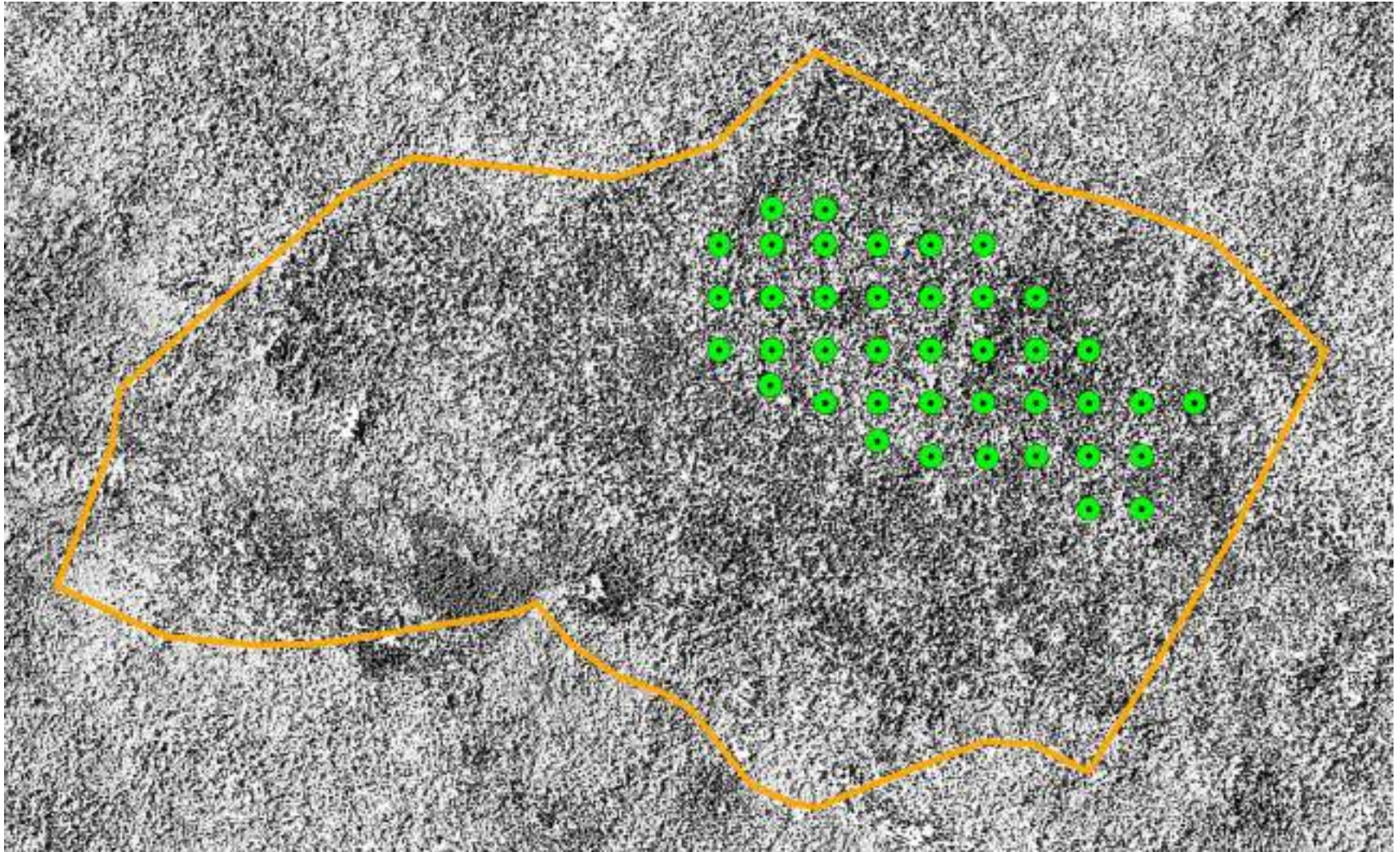
Landscape scale

Map of forest canopy gaps at LOM



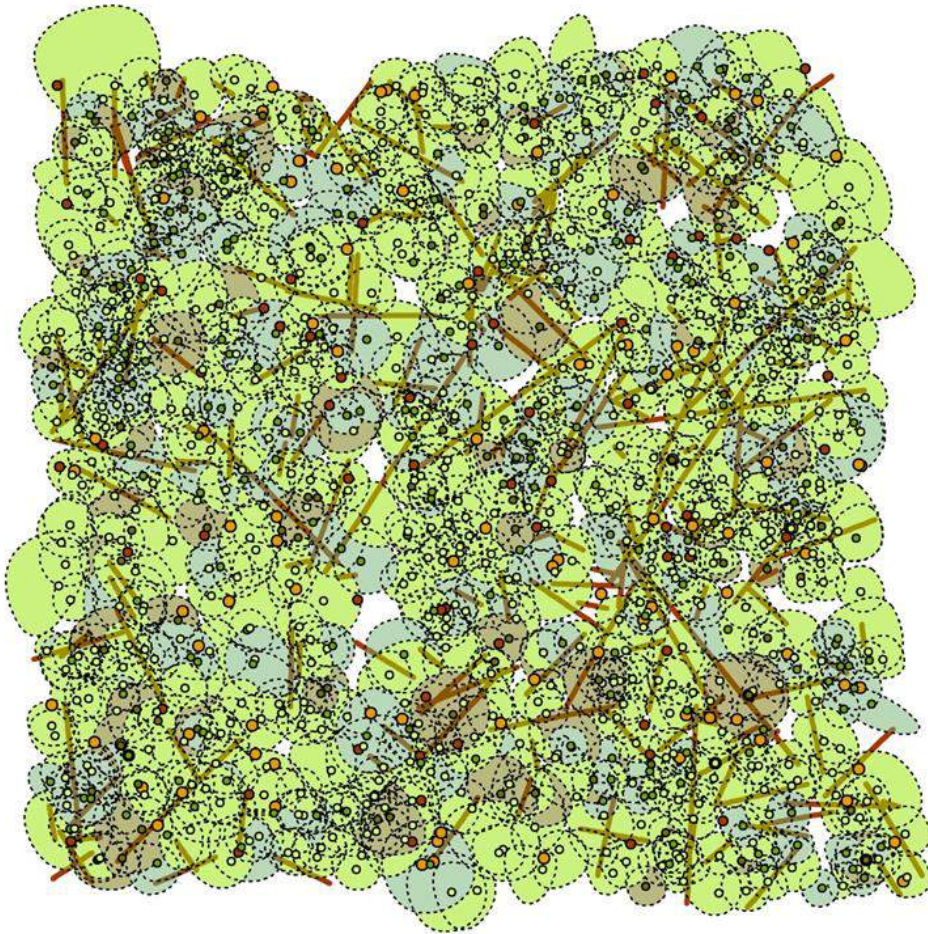
Stand scale

Network of temporary plots on forest structure

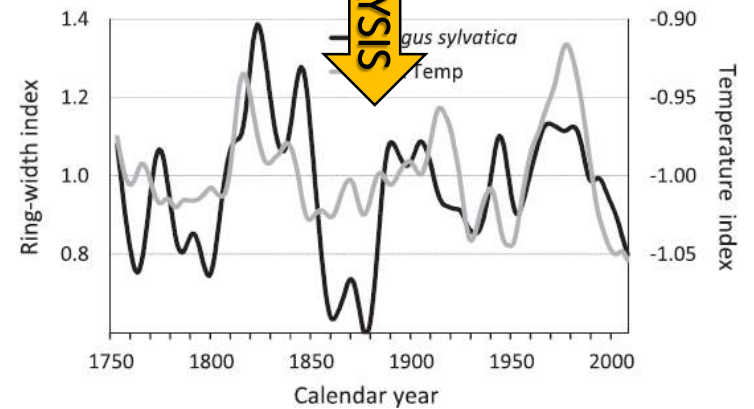


Stand scale

Permanent plots: stem-mapped trees and CWD



Tree scale



Castagneri et al. 2014

The Balkans ... not only OG!!



Acknowledgements

- Il gruppo di ricerca: R. Motta, E. Lingua, F. Meloni, D. Castagneri, R. Berretti, E. Borgogno, A. Bottero, T.A. Nagel, V. Dukic, S. Keren.
- Tutti coloro i quali ci hanno aiutato nei rilievi in campo: Svoboda, Tihomir Rugani, Dejan Firm, Beppe Dolce e molti altri.
- Il progetto Planet Action che ci ha fornito le immagini satellitari → <http://www.planet-action.org/>



THANK YOU

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