Master in Interdisciplinary Studies in Environmental, Economic and Social Sustainability

Analysis and Management of Natural Landscapes. 2018/19

Dr. Carles Barriocanal

carlosalfredo.barriocanal@uab.cat

@barrioca

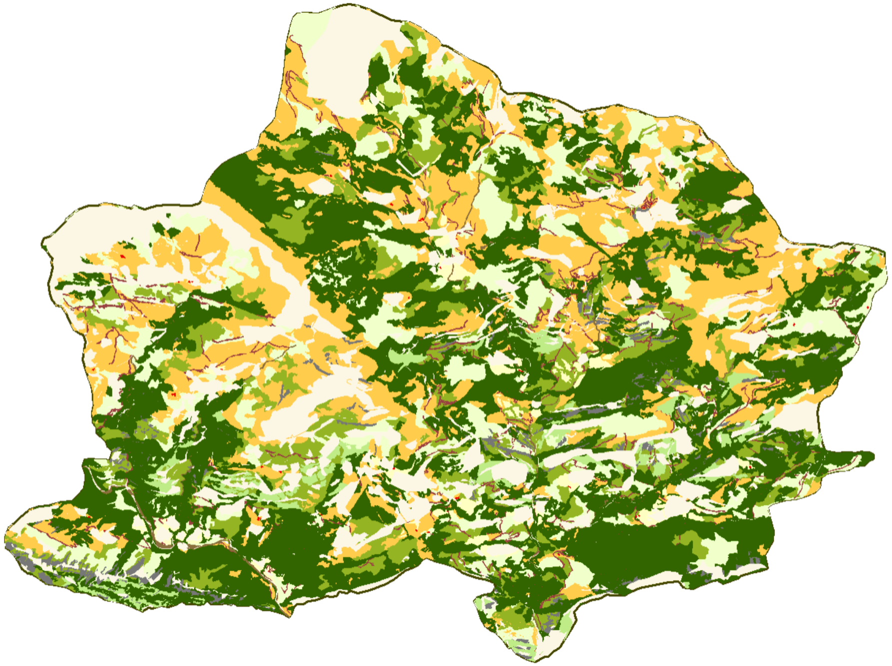
Institute of Environmental Science and Tecnology (ICTA)

Universitat Autònoma de Barcelona

Universitat Autònoma de Barcelona

Institut de Ciència i Tecnologia Ambientals • UAB

Class 1. Qualitative and quantitative approaches to landscape



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Carlosalfredo.barriocanal@uab.cat

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icta Institut de Ciència i Tecnologia Ambientals · UAB

UAB Universitat Autònoma de Barcelona

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Study case

The concept(s) of landscape

- In the 19th century, Alexander von Humboldt defined landscape as "the total character of a region" (Makhzoumi & Pungetti, 1999)
- Sauer (1925) defined landscape, at a regional level, *as a space defined by different associations of morphologies, both physical and cultural*.
- In 1950, Troll defined landscape as "*a part of Earth's surface with a space unity and with a specific character, due to its external image, the joint action of its phenomena, which can be delimited by geographic and natural borders"* (Farina, 2006; Sànchez-Mateo, 2010).
- Green *et al*. (1996) consider landscape as a particular configuration of the topography, vegetation cover, land uses and the structure of the population that delimits certain coherence in natural and cultural processes and activities.
- Landscape ecology considers landscape as a delimited study unit, result of a complex interaction between special structures and the ecological processes that occur in it.

- Landscape is understood as a differentiated and measurable unit with different relevant ecological characteristics: it is a recognizable and repeated grouping of ecosystems and disturbance regimes (Forman and Godron, 1981).

The concept(s) of landscape

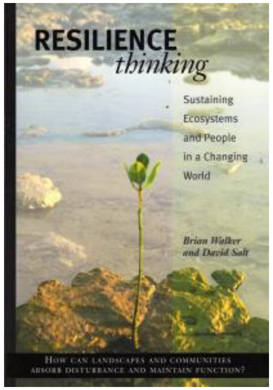
- All of the definitions discussed above agree on:
- Landscape is the result of the **interaction** between **biogeophysical** and **socioeconomic** factors.
- Landscapes can be approached as socioecological systems for their analysis and interpretation.

Socioecological systems

Socioecological systems

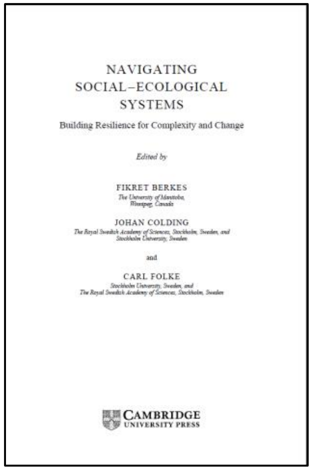
Division between **natural systems** and **cultural systems** is artificial and arbitrary (Berkes *et al.*, 2003)

To overcome this duality it was proposed to study socioecological systems from an integrated point of view



SOCIOECOLOGICAL SYSTEM

System defined as the result of the interaction between a social (human) component and an ecological (biophysic) component which determines a complex system in continous evolution according to changes.



Socioecological systems can be defined at different scales, from local to global, delimited by spatial or functional limits.

Socioecological systems

ANTHROPOGENIC VISION

Human as center

•Economy as the most important system.
•Nature as resources and ecosystem services provider.
•Nature as waste and pollution sink.
•Sustainability only important regarding to sustainability of human society

BIOCENTRIC VISION

Nature as center

•Human species is just another component of the system.
•Nature considered harmonic by definition.
•Modern and industrial society is responsible of all environmental problems

Reductionist visions!!! They don't match with postnormal science systemic vision and its approaches

Qualitative approach to landscape

Non-urban biogeography

This methodology has been experimented in the National Park and biosphere reserve of Montseny aiming to interpret the three biogeographic regions of the massif: Mediterranean, euro-siberian and boreoalpine.

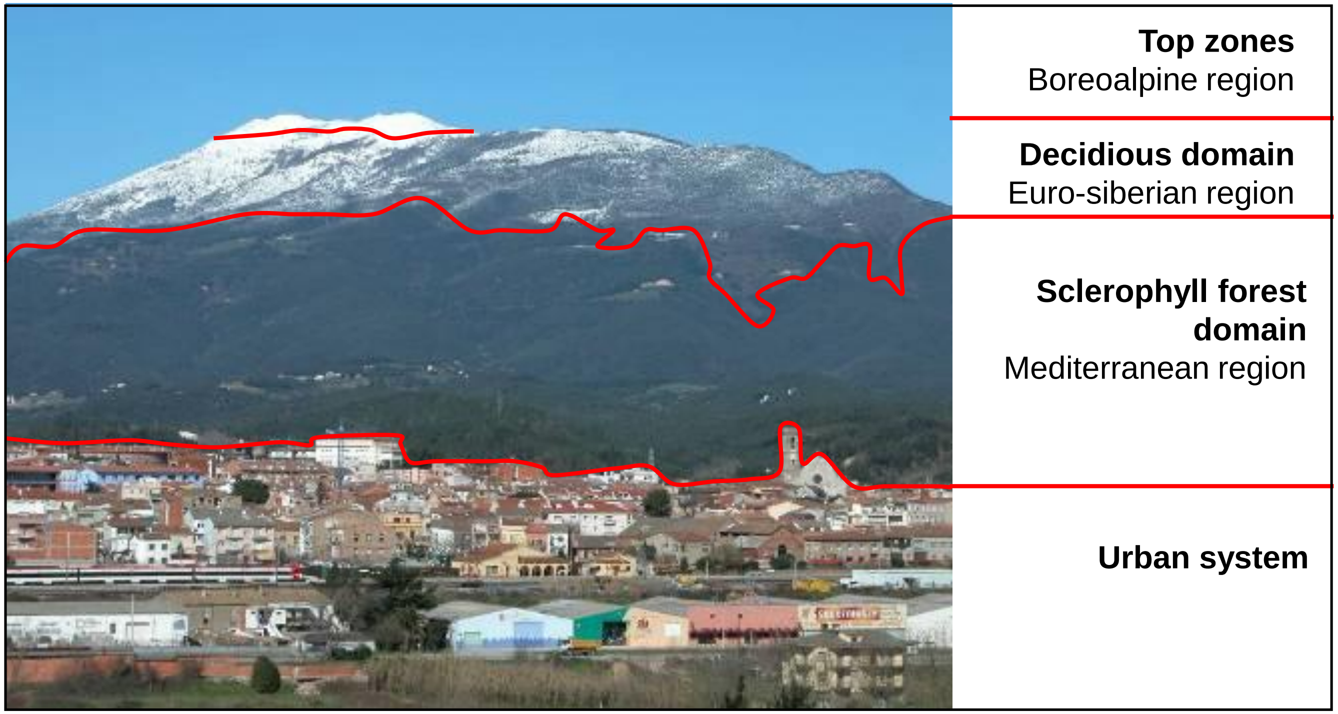
The analysis process of this system is based on the following stages:

1. **Chromatic assessment**
2. **Approach and description of the present elements**
3. **Confection of the transect of each socioecological system**

Non-urban socioecology

Chromatic assessment	Approach and description of the present elements	Confection of the transect of each socioecological system

Situated at a certain distance, the different biogeographic regions will be identified through the color changes of the vegetation stages. Throughout the year, this chromatic assessment will vary and the contrast will become more obvious in autumn and winter periods.



Non-urban socioecology

Chromatic assessment	**Approach and description of the present elements**	Confection of the transect of each socioecological system

In this stage, a visit to each of the biogeographic regions will be done in order to describe the environment and analyze each region profoundly. Each one will be approached from the biodiversity point of view (vegetation and fauna), through the identification of the species, as well as from the social perspective.

The social elements will be considered according to their relevance and classified according the following types:

Tangible elements: Those who express physically (material) . Examples: fountains, irrigation canals, livestock buildings…).

Intangible elements: Non-material values related to legends, beliefs and view of the world.

Practices: activities of appropriation and management of the environment (logging, agricultural practices, grazing, collection of plants, mushrooms, wild fruits…).

Non-urban socioecology

Chromatic assessment | Approach and description of the present elements | **Confection of the transect of each socioecological system**

The aim is to represent graphically and easily the previously analyzed elements depending on the following code:

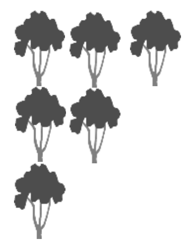
Wooded stratum
A Dominant specie
B Second dominant specie
C Third dominant specie

Shrub stratum
A_1 Dominant specie
B_1 Second dominant specie
C_1 Third dominant specie

Herbaceous stratum
a Dominant specie
b Second dominant specie
c Third dominant specie

Liana stratum
a_1 Dominant specie
b_1 Second dominant specie
c_1 Third dominant specie

Abundance (number of represented siluettes)



Dominant specie
Second dominant specie
Third dominant specie

Fauna symbols

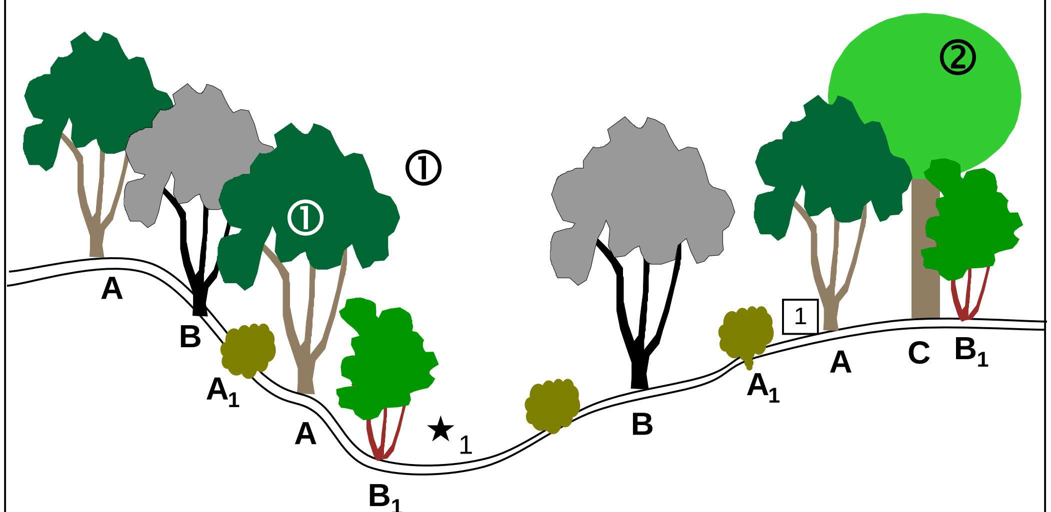
Reptiles
Amphibians
Fishes
Birds
Mammals

Social elements

T Tangible elements
I Intangible elements
P Practices

Non-urban socioecology

Chromatic assessment | Approach and description of the present elements | **Confection of the transect of each socioeconòmical system**



VEGETATION
Wooded stratum
A Holm Oak (*Quercus ilex*)
B Cork oak (*Quercus suber*)
C Stone pine (*Pinus pinea*)

Shrub stratum
A_1 Tree heath (*Erica arborea*)
B_1 Strawberry tree (*Arbutus unedo*)

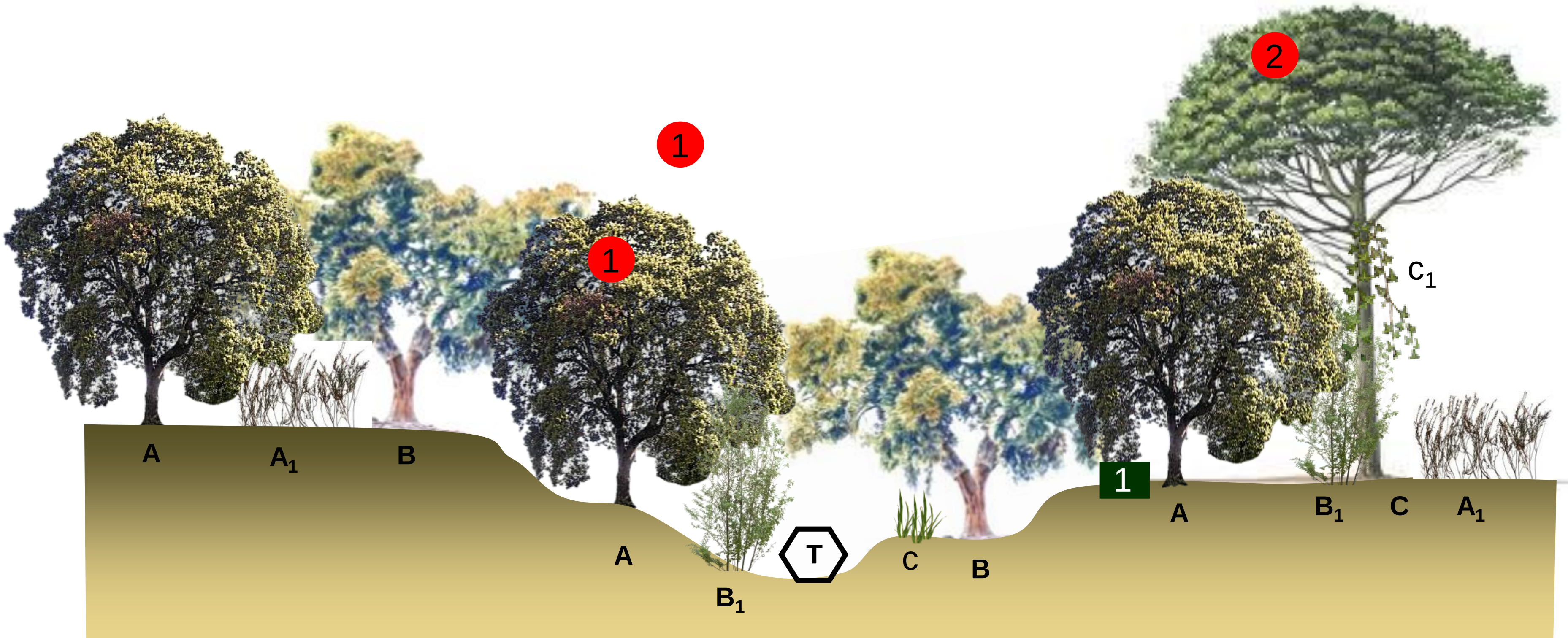
FAUNA
Birds
① Chaffinch (*Fringilla coelebs*)
② Common Wood Pigeon (*Columba palumbus*)

Mammals
1 Wild boar (*Sus scrofa*)

SOCIAL (Tangible)
★$_1$ Carbon emplacement

Non-urban socioecology

Chromatic assessment | Approach and description of the present elements | **Confection of the transect of each biotope**



VEGETATION

Wooded stratum
- **A** Holm Oak (*Quercus ilex*)
- **B** Cork oak (*Quercus suber*)
- **C** Stone pine (*Pinus pinea*)

Shrub stratum
- **A_1** Tree heath (*Erica arborea*)
- **B_1** Strawberry tree (*Arbutus unedo*)

Herbaceous stratum
c false brome (*Brachypodium* sp.)

Liana stratum
c_1 Heura (*Hedera helix*)

FAUNA

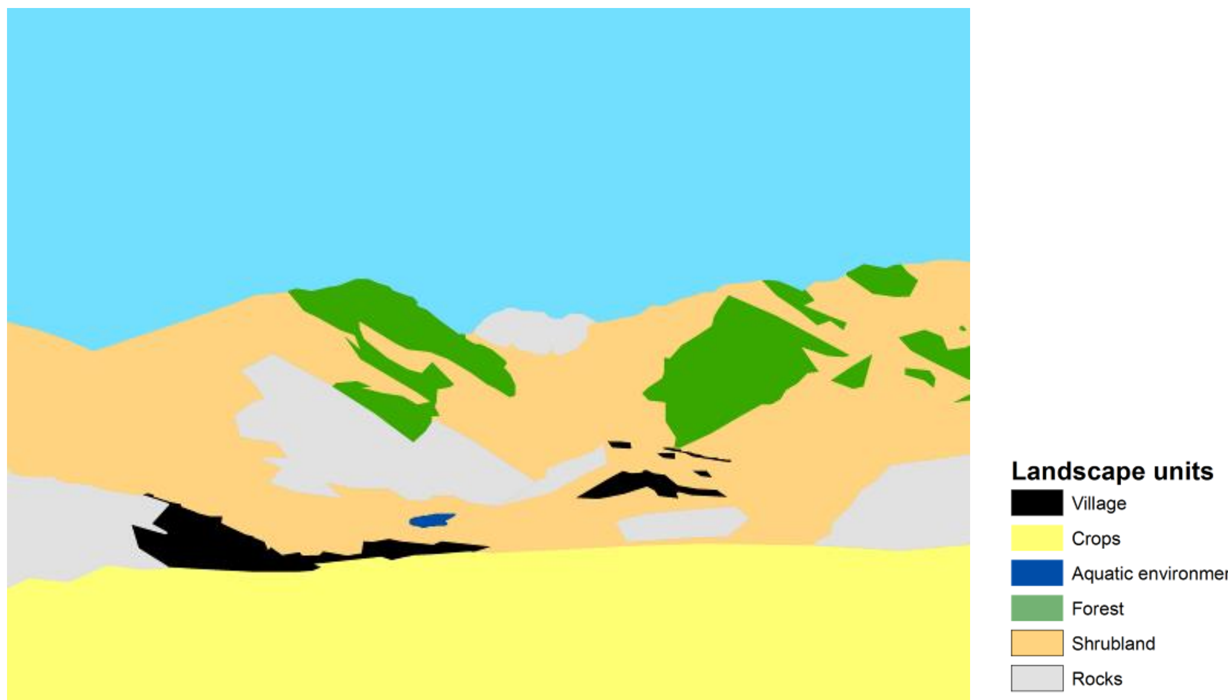
Birds
- 1 Chaffinch (*Fringilla coelebs*)
- 2 Common Wood Pigeon (*Columba palumbus*)

Mammals
- 1 Wild boar (*Sus scrofa*)

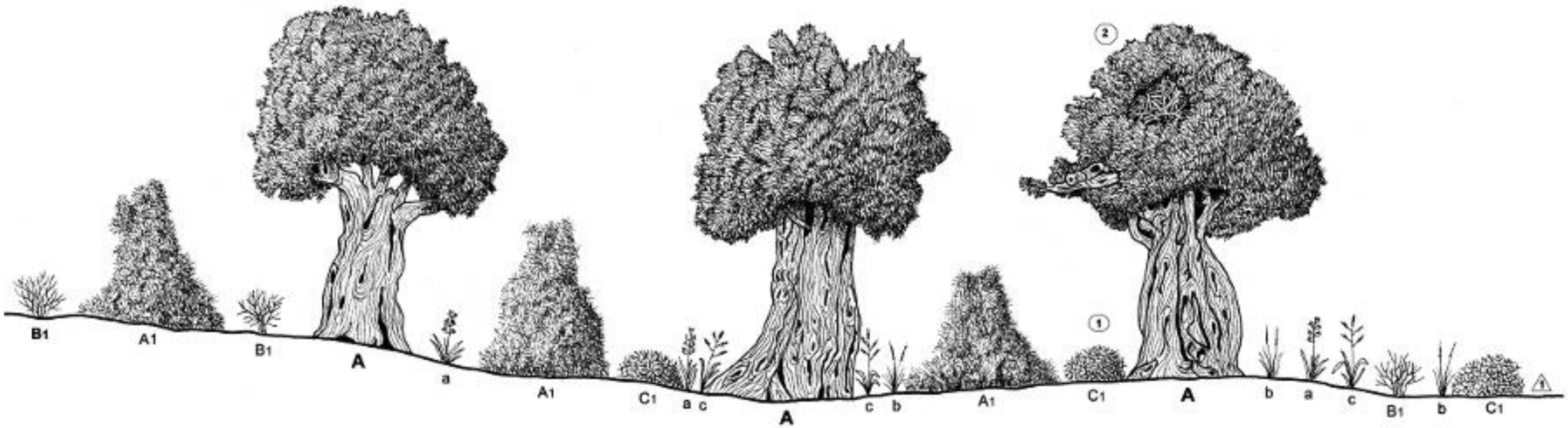
SOCIAL

T Carbon emplacement

Chromatic assessment: a study case in Zat valley (High Atlas, Morocco)




Chromatic assessment: a study case in Zat valley (High Atlas, Morocco)



Wooded stratum	
A	*Juniperus thurifera*
Shrub stratum	
A_1	*Juniperus thurifera*
B_1	*Juniperus oxycedrus*
C_1	*Ephedra fragilis*
D_1	*Bupleurum spinosum*
Herbaceous stratum	
a	*Asphodelus ramosus*
b	*Stipa tenacissima*
c	*Dactylis glomerata*

Reptiles	
1	*Quedenfeldtia trachyblepharus*
2	*Podarcis vaucheri*
3	*Scelarcis perspicillata*
Birds	
1	*Oenanthe seebohmi*
2	*Lanius senator*
3	*Phoenicurus moussieri*
Social elements	
T1	Singular *Juniperus thurifera* trees
P1	Cattle pasture

Land Use and Land Cover Change

Global change

Human activities

DRIVING FORCES

GLOBAL CHANGE

Set of environmental alterations in Earth System

Global scale

Unprecedented speed and magnitude of change

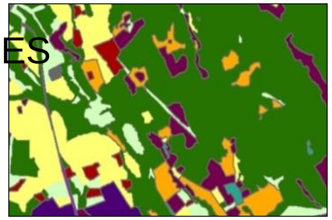
Land Use and Cover Change

Alteration of biogeochemical cycles

Biothic changes

Regional and local manifestations

CAUSED BY HUMAN SPECIES



MULTISCALE ANALY

Land use and land cover change

Human Domination of Earth's Ecosystems
Peter M. Vitousek *et al.*
Science **277**, 494 (1997);
DOI: 10.1126/science.277.5325.494

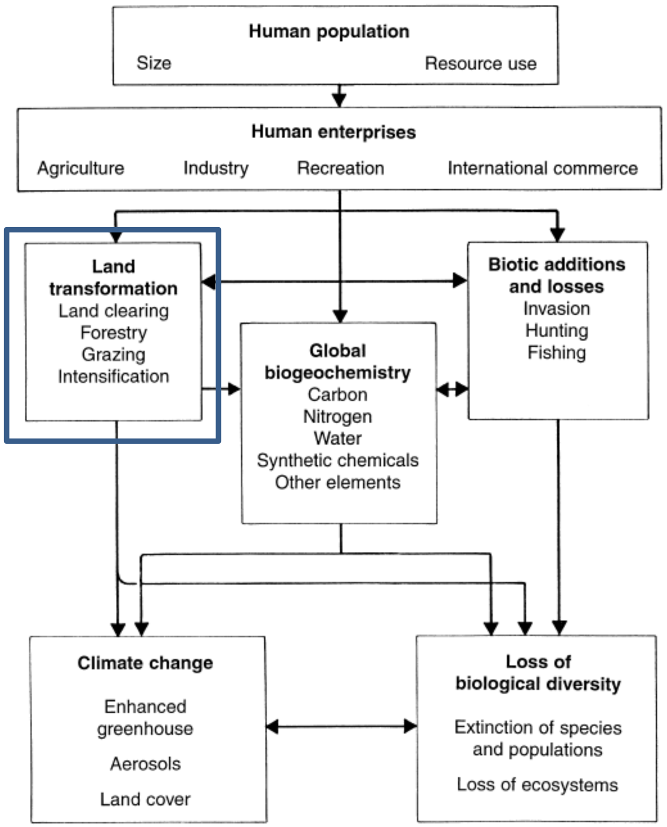


Fig. 1. A conceptual model illustrating humanity's direct and indirect effects on the Earth system [modified from (*56*)].

Land use and land cover change is a central process in global change. Due to this reason is one of the main research fields in Environmental Science.

Land use and land cover change

Human Domination of Earth's Ecosystems
Peter M. Vitousek *et al.*
Science **277**, 494 (1997);
DOI: 10.1126/science.277.5325.494

Land use and land cover change alter the structure and functionality of ecosystems and landscapes. Potential impacts:

•Loss of biodiversity (including agricultural biodiversity).

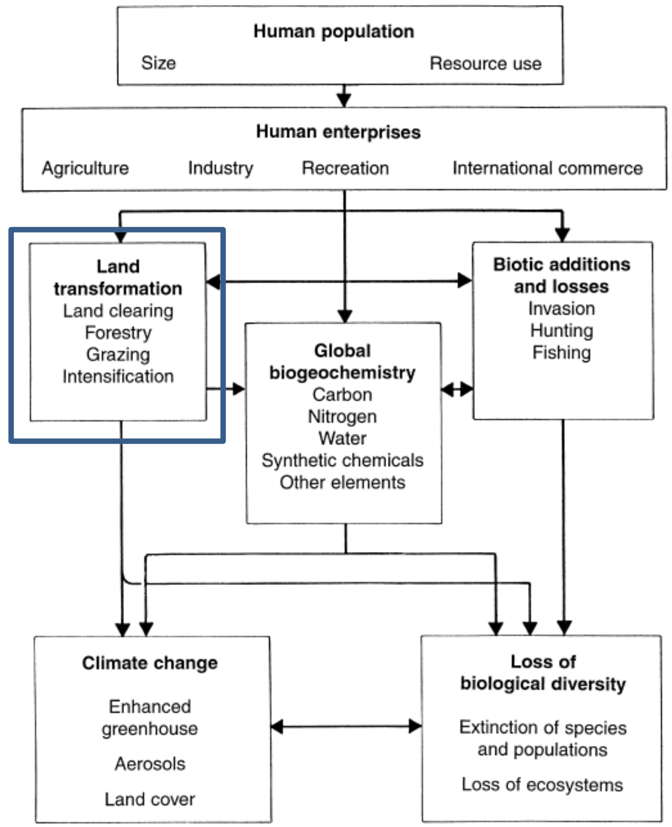
•Alteration of biogeochemical cycles.

•Increase in the emissions of greenhouse effect gases.

•Reduction in soil quality and functionality.

•Change in vegetation.

Fig. 1. A conceptual model illustrating humanity's direct and indirect effects on the Earth system [modified from (*56*)].



Land use and land cover change

Some highlights to understand the magnitude of land use land cover change:

• Estimations that 39-50 % of global land cover (excluding land covered by glaciers) has been modified by human activities (Vitousek *et al.*, 1997).
•Primary sector of the economy have been historically the main driver of land use/land cover change.
•Nowadays a third of global land is used for crops and pasture lands (FAO, 2004).
•It is estimated that during the last 300 years, under the influence of population growth:
    •Area occupied by crops **x5.**
    •Area occupied by pasture lands **x3-6.**
    •Replacing mainly forest land (Lambin *et al.*, 2006).
•During last decades this growth concentrates mainly in depeloping countries.
•Western Europe: inverse process, abandonment of agriculture.

Land use and land cover change

Study of land use and land cover change:
LUCC program (Land Use and Cover Change). Created in 1993. Included in the International Geosphere-Biosphere program (IGBP).
The program has been a conceptual and methological reference for the development of a "land use science" (Lambin *et al.*, 2006), becoming an important contribution for the study of global change.

International Geosphere-Biosphere program (IGBP):
http://www.igbp.net/globalchange.4.d8b4c3c12bf3be638a80001026.html

Land use and land cover change

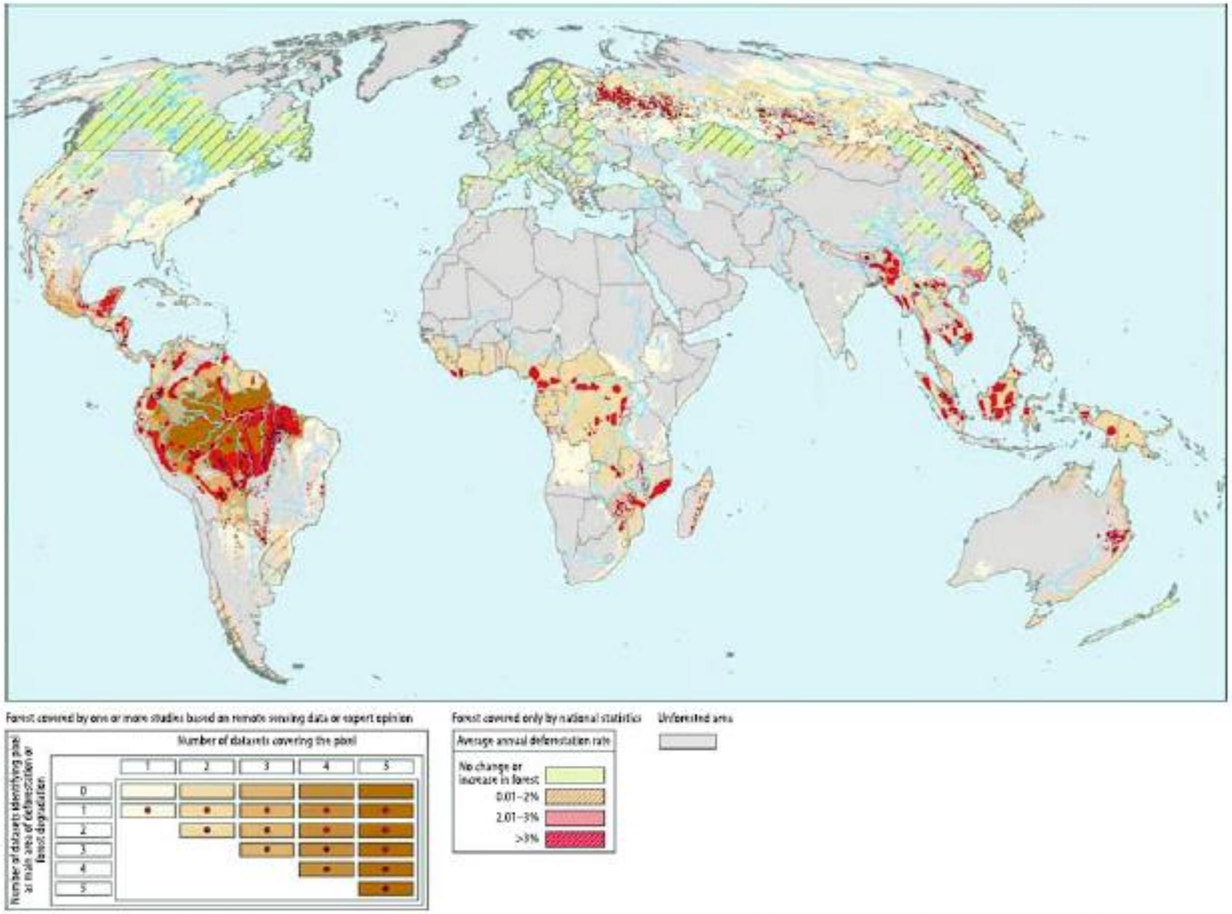
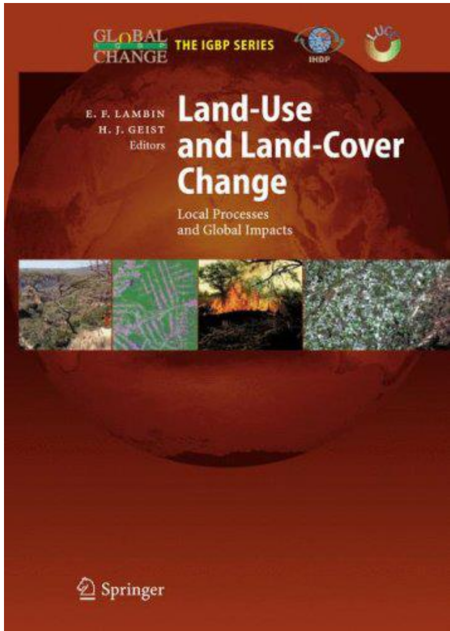


Fig. 2.4a. Results from the LUCC-MA Rapid Land-Cover Change Assessment showing major areas of forest-cover change in the world between 1980 and 2000

Lambin *et al.*, 2006



Land use and land cover change. Driving forces of deforestation

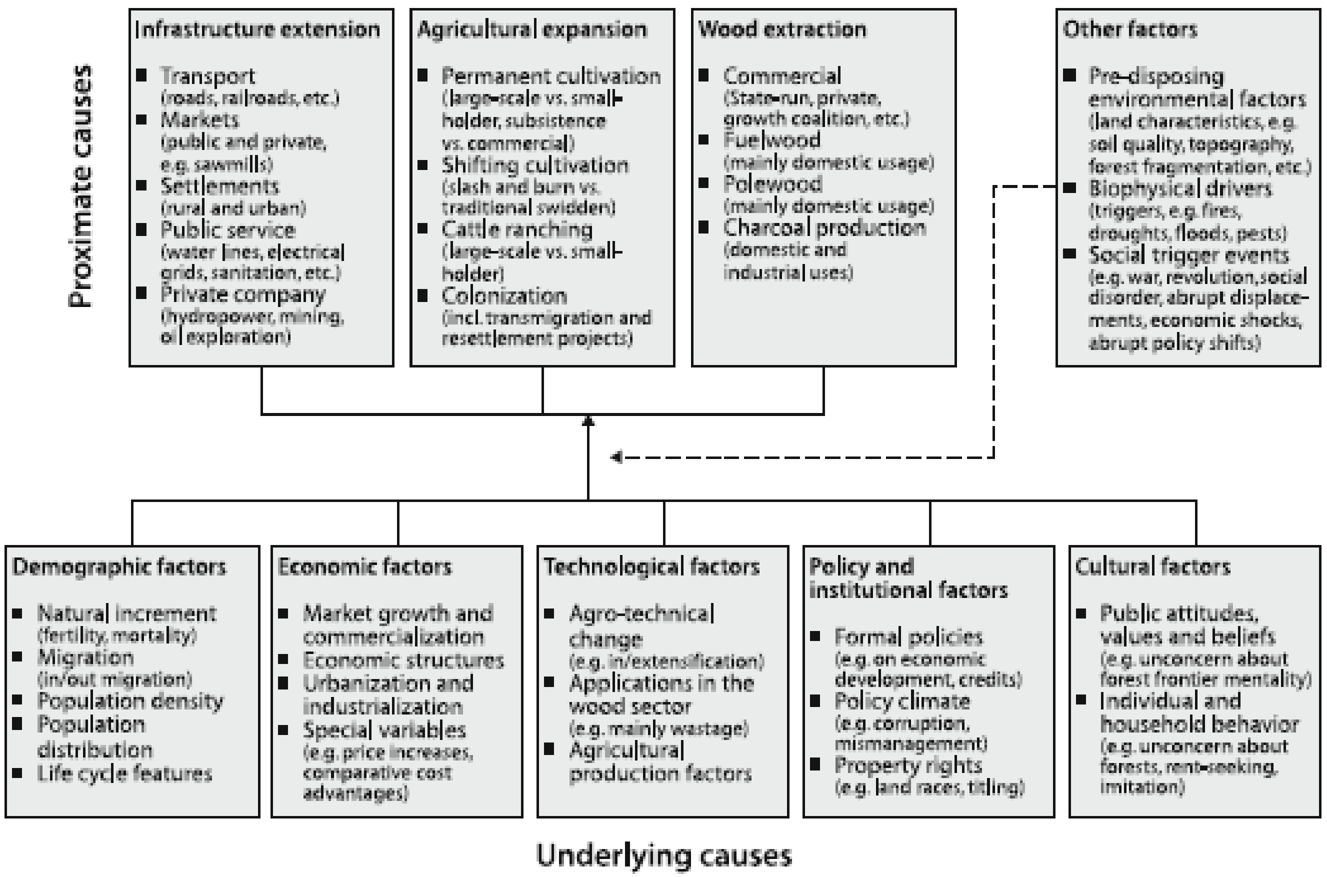


Fig. 3.2. Proximate causes and underlying driving forces of forest decline. *Source:* Geist and Lambin (2002), p. 144

Lambin *et al.*, 2006

Land use and land cover change

Urbanization

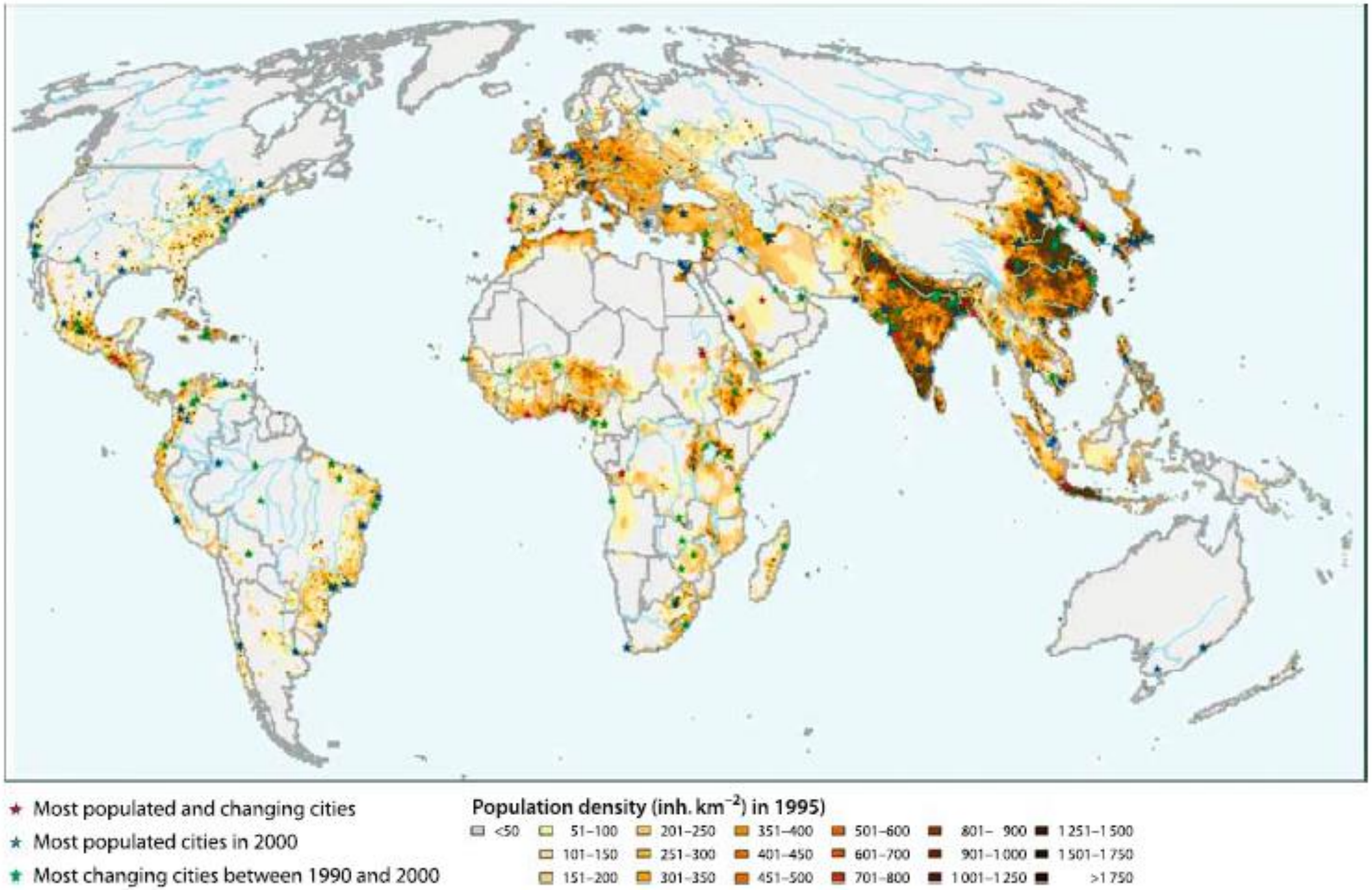


Fig. 2.4c. Results from the LUCC-MA Rapid Land-Cover Change Assessment showing population density in 1995 and most populated and changing cities over 750 000 inhabitants between 1980 and 2000

Lambin *et al.*, 2006

Land use and land cover change

Distinction between land use and land cover:

Land cover: refers to the biophysical conditions of land surface.

Land use: refers to the human transformation of land surface and the purposes or intentions behind it.

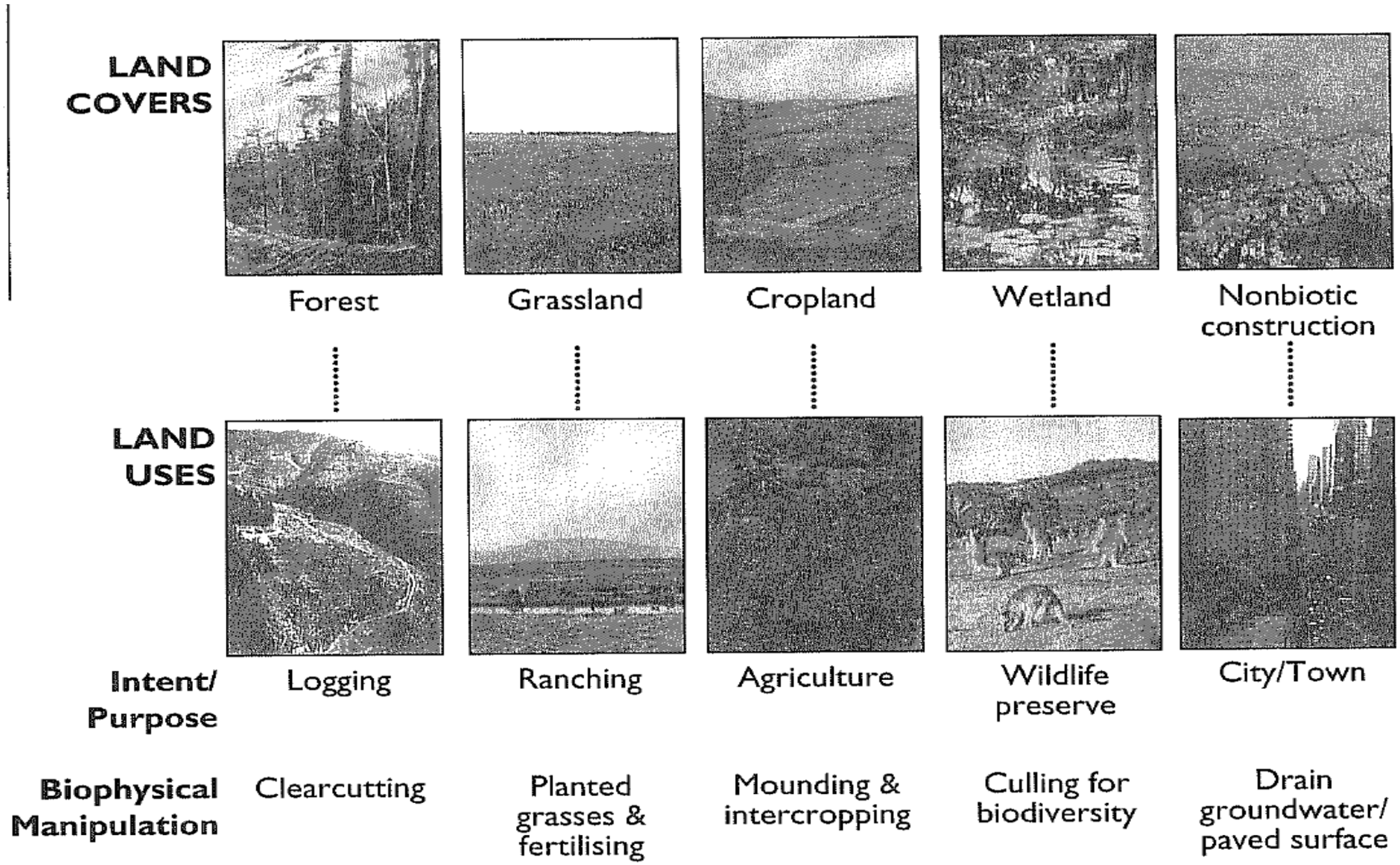
Land uses affect land cover in two different ways:
•Land uses can transform land cover substituting a land cover with another. Deforestation of a forest to transform it in crops.
•Land uses can modifiy the characteristics of land cover without substituting it.

•Land use and land cover are expressions of transformations experienced by socioecological systems.

Land use and land cover change

Land cover: refers to the biophysical conditions of land surface.

Land use: refers to the human transformation of land surface and the purposes or intentions behind it.



Land use and land cover change

The **complexity** of land use and land cover change processes, as well as its **cumulative** nature, demands its study at **regional and local scales**, to contribute to identify properly its causes and effects (Turner et al, 1994).

Since its proposal at the beginning of the 1990s, the LUCC methodology has been successfully applied in multiple study areas all over the world (Lambin *et al.*, 2006).

Equally, it has been successfully applied to Mediterranean mountain areas

Land use and land cover change

Successfully applied to Mediterranean mountain areas:

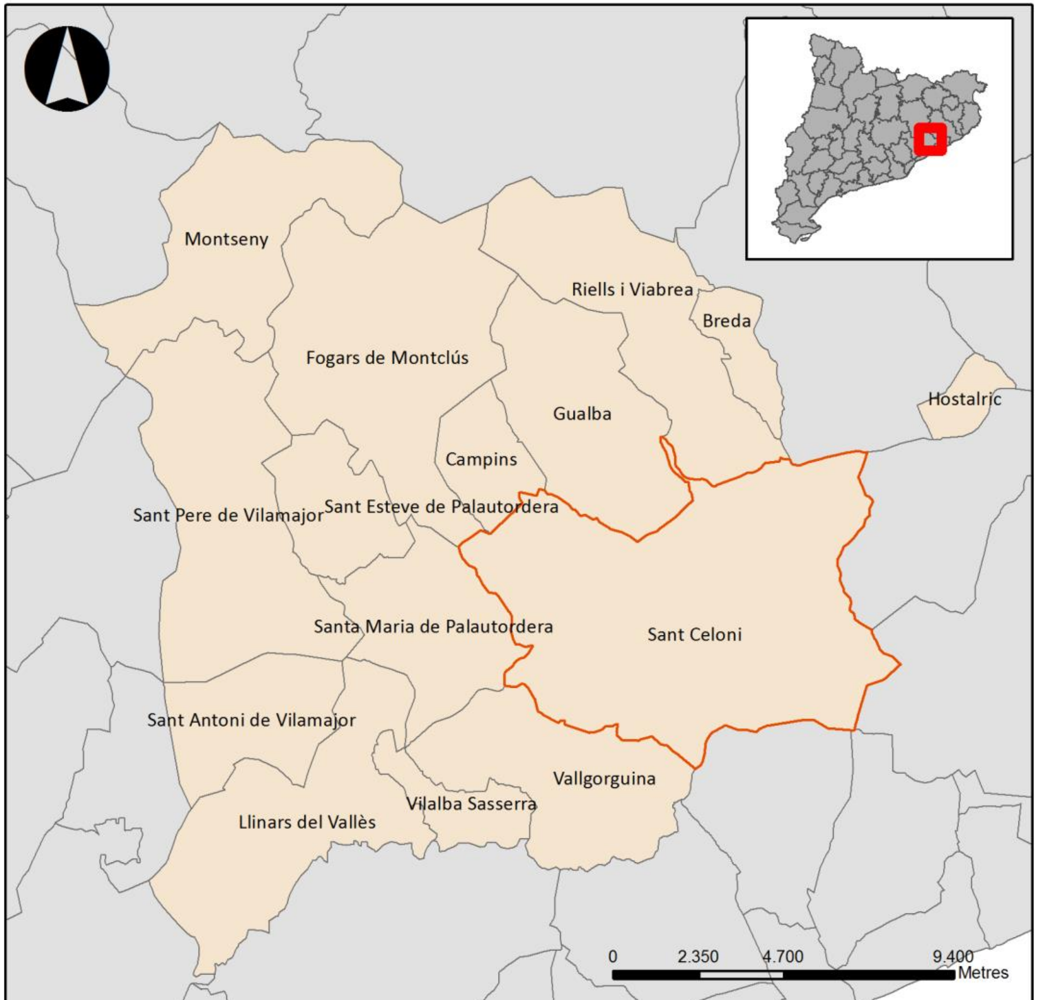
- Bielsa, I.; Pons, X. i Bunce, B. (2005): *Agricultural Abandonment in the North Eastern Iberian Peninsula. The Use of Basic Landscape Metrics to Support Planning*. Journal of Environmental Planning and Management 48 (1): 85–102.
- Cohen, M.; Varga, D.; Vila Subirós, J.; Barrasaud, E. (2011): *A multi-scale and multi-disciplinary approach to monitor landscape dynamics: a case study in Catalan pre-Pyrenees, Spain*. Geographical Journal 177: 79-91.
- Lasanta-Martínez; T.; Vicente-Serrano, S. M.; Cuadrat-Prats, S. M. (2005): *Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: a study of the Spanish Central Pyrenees.* Applied Geography 25: 47–65.
- Métailié, J.P.; i Paegelow, M. (2004*): Land abandonment and the spreading of the forest in the Eastern french Pyrenées in the nineteenth to twentieth centúries*. In: S. Mazzoleni; G. Di Pasquale; M. Mulligan; P. Di Martino; F. Rego (eds.): *Recent dynamics of the mediterranean vegetation and landscape*. Wiley.
- Mottet, A.; Ladet, S.; Coqué, N. i Gibon A. (2005): *Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees*. Agriculture, Ecosystems and Environment 114: 296–310.
- Nogués-Bravo, D. (2006): *Assessing the effect of environmental and anthropogenic factors on land-cover diversity in a Mediterranean mountain environament*. Area 38(4): 432–444.
- Serra P., Saurí D., Pons X. (2008): *Land-cover and land-use in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors*. Applied Geography, 28: 189-209.
- Sluiter, R. i de Jong, S. M. (2007): Spatial patterns of Mediterranean land abandonament and related land cover transitions. Landscape Ecology 22:559–576.
- Taillefumier, F.; Piegay, H. (2002): *Contemporary land use changes in prealpine Mediterranean mountains: a multivariate GIS-based approach applied to two municipalities in the Southern French Prealps*. Catena 51: 267–296.

Study Case

Global Change Manifestations in Mediterranean mountain areas:
a study case in Baix Montseny

Study area

El Baix Montseny



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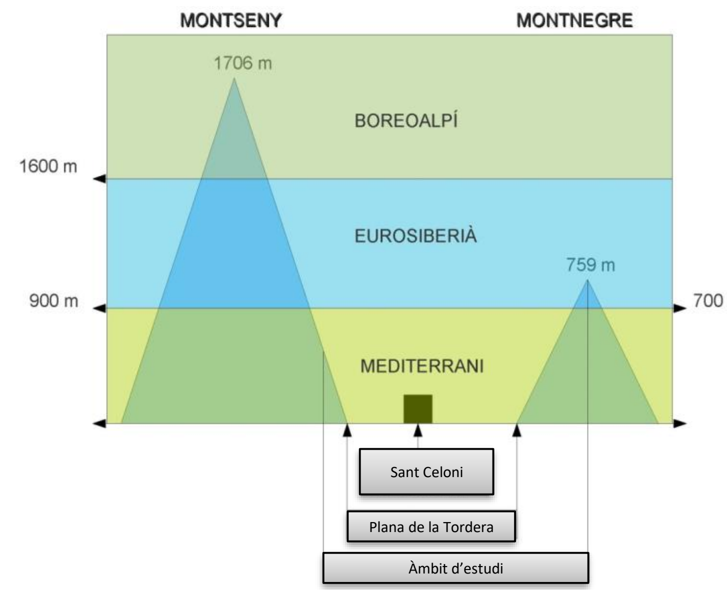
15 municipalities.
Area: 329,3 km^2.
Population: 60.802 habitants (2010).
Population density: 184,6 hab./km^2.



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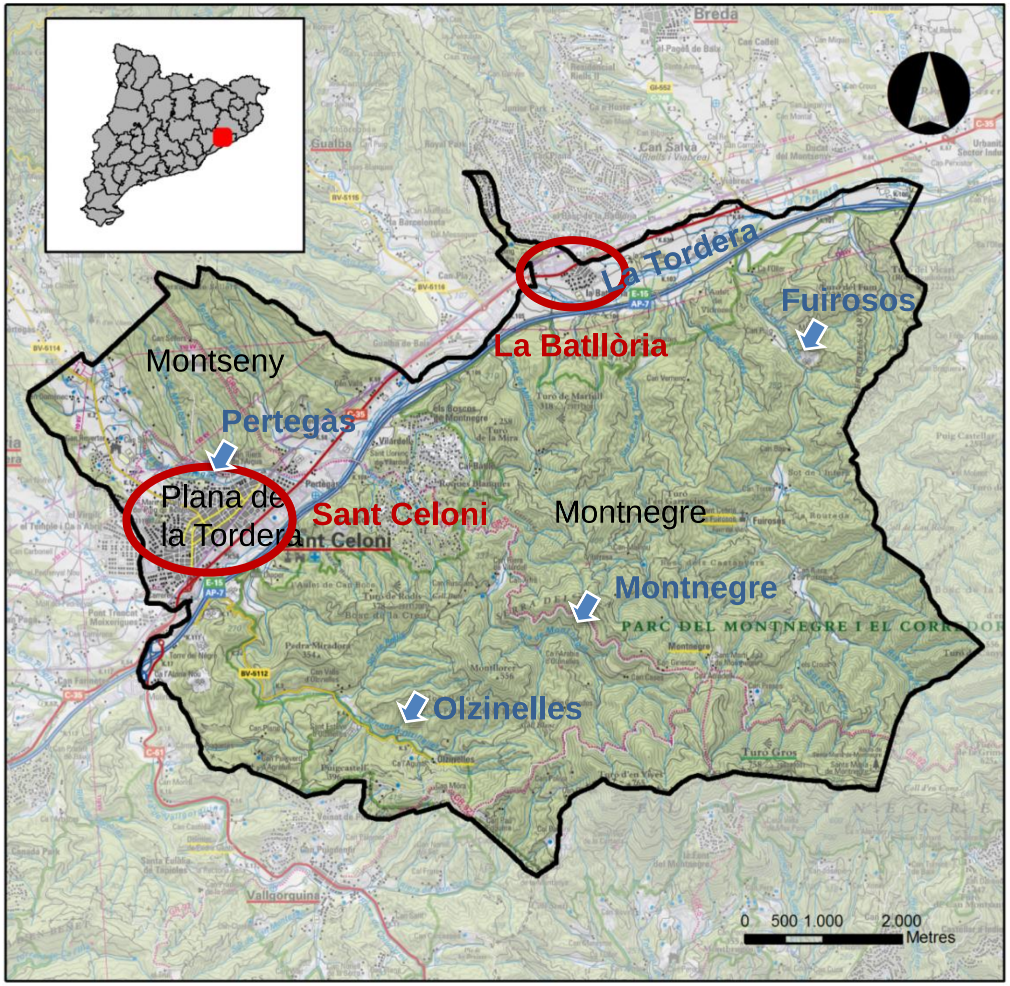
Three biogeographic regions.
Elevated forest area.
Historical predominance of forestry activities

Study area

Municipality of Sant Celoni

Area: 65,44 km^2.
Population: 16.860 habitants (2010).
Population density: 259,2 hab./km^2.



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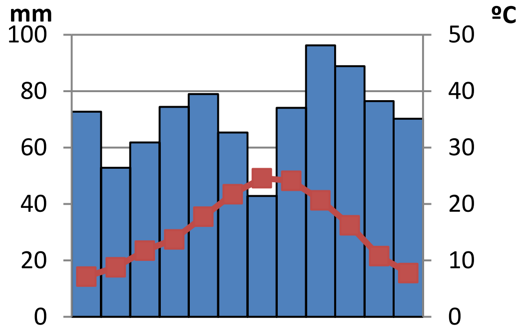
Mountainous area:

- Montnegre.
- Montseny.
- Tordera plain.

Annual mean precipitation: 750-850 mm
Annual mean temperature: 16ºC.

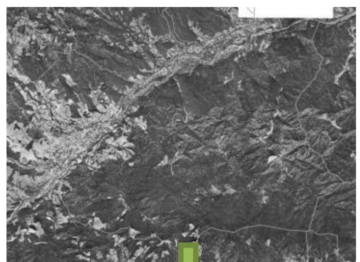


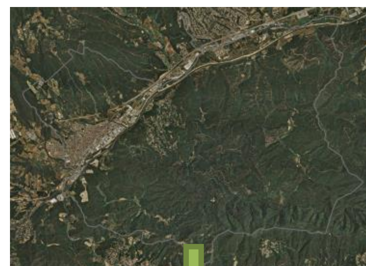
Methodology

GIS Software: ArcGIS, Miramon...

BASE CARTOGRÀFICA

Ortophotomap year 1956
(Diputació de Barcelona)





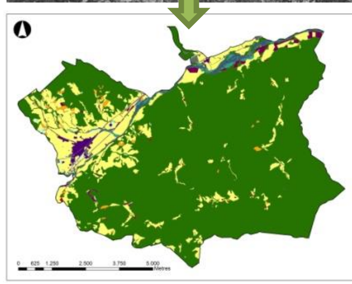
Catalonia Land Cover Map
(3rd edition, CREAF 2006)

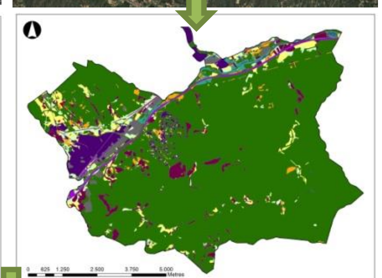
Field work

Ortophotomap year 2010
(Institut Cartogràfic de Catalunya)

MAPES

Land use and land cover map 1956





Land use and land cover map 2010

Analysis of land use and land cover change 1956-2010

Land use and land cover change. Comparative between 1852-63 (amillaraments), 1956 and 2010

Landscape indices calculation

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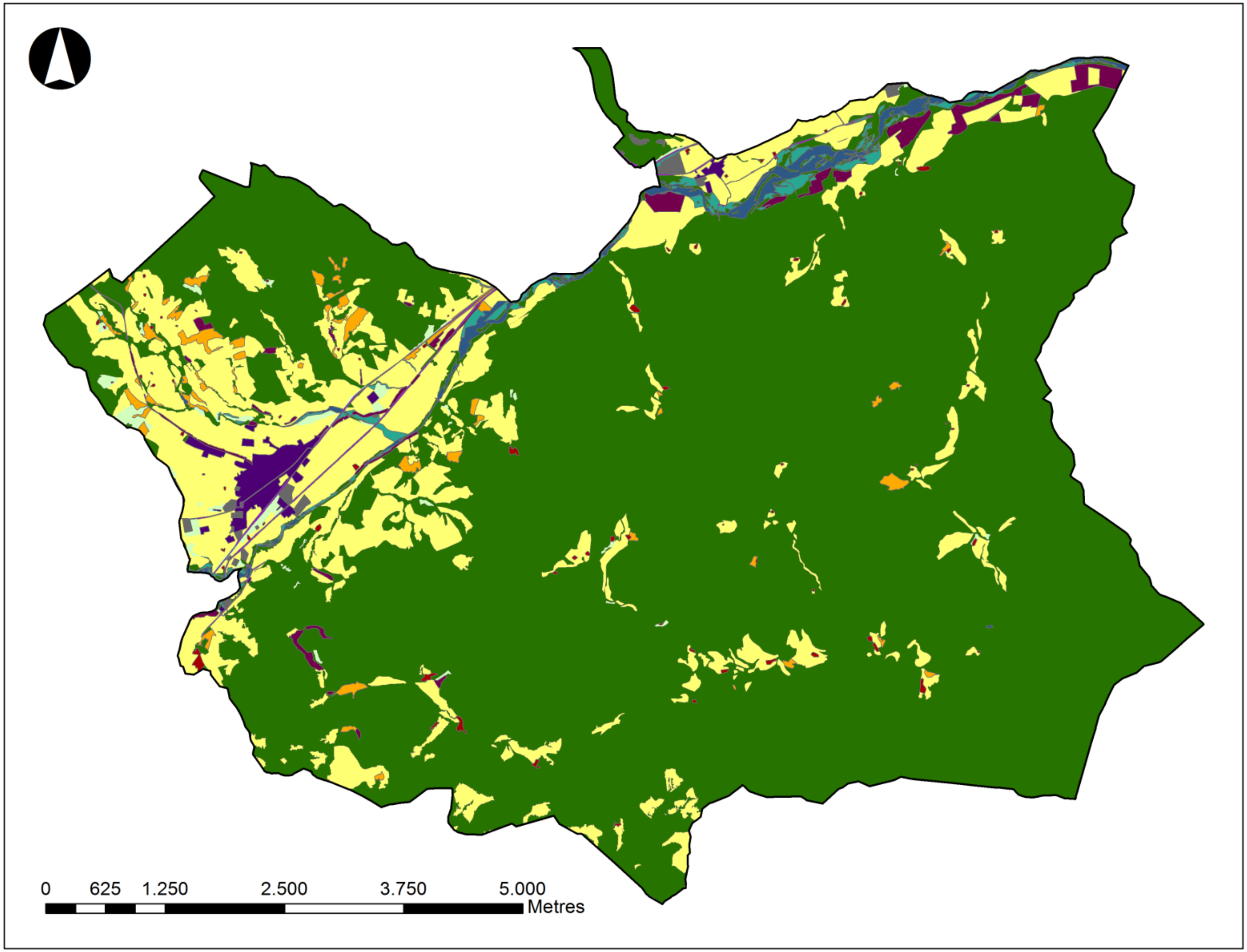
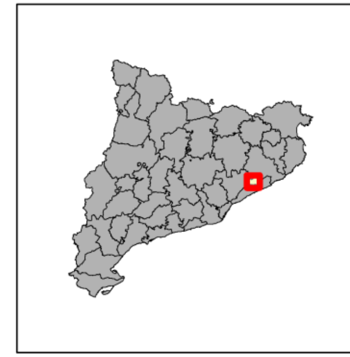
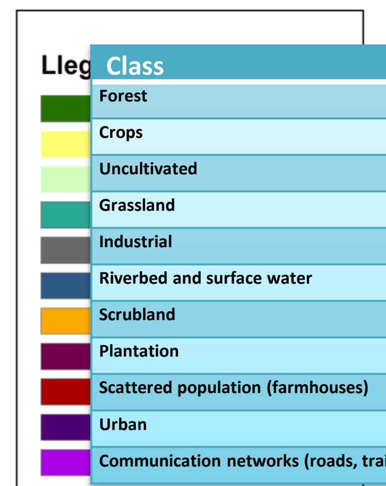
Land use and cover map.1956







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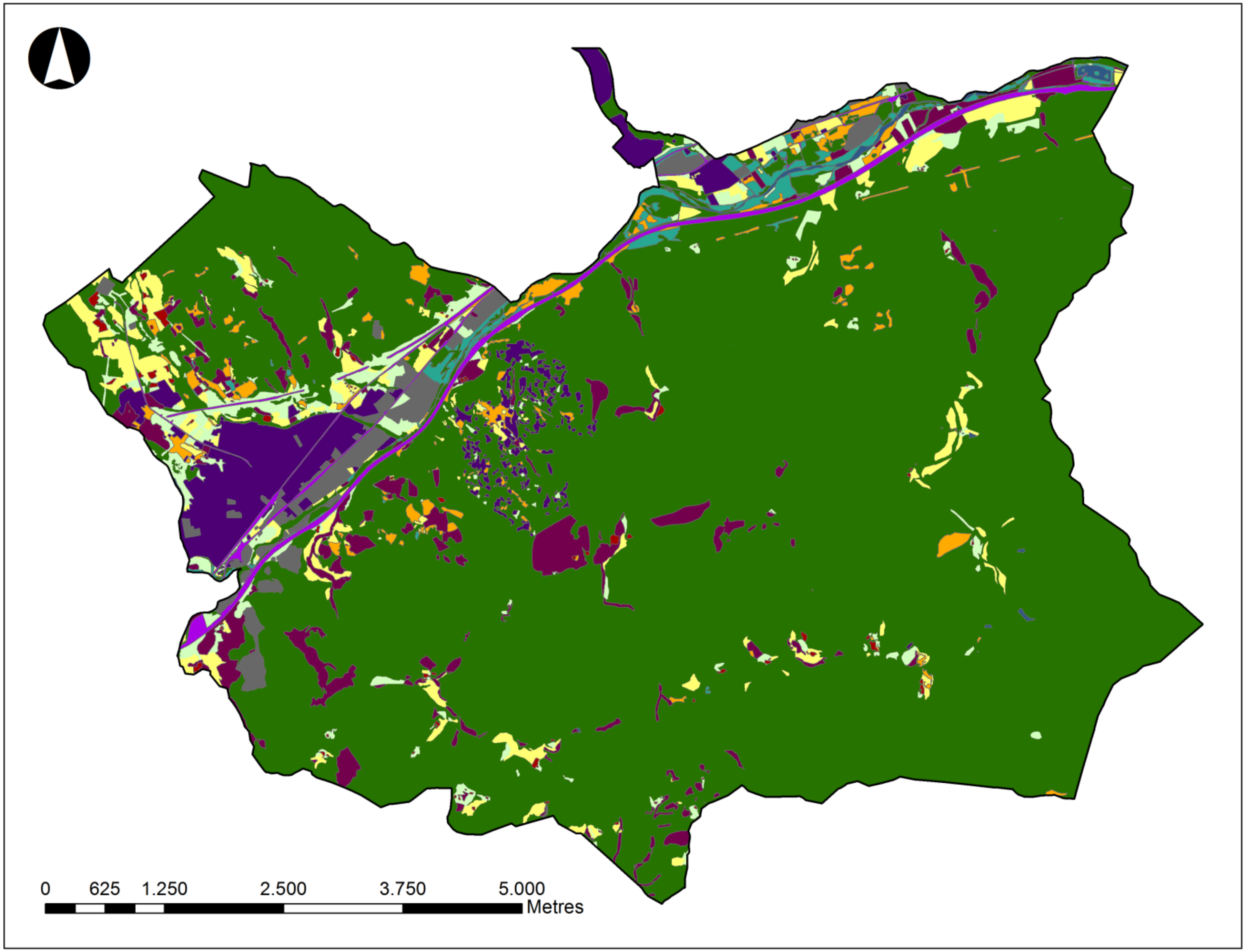
Land use and cover map. 2010



Lleg

Class
Forest
Crops
Uncultivated
Grassland
Industrial
Riverbed and surface water
Scrubland
Plantation
Scattered population (farmhouses)
Urban
Communication networks (roads, trai

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Results

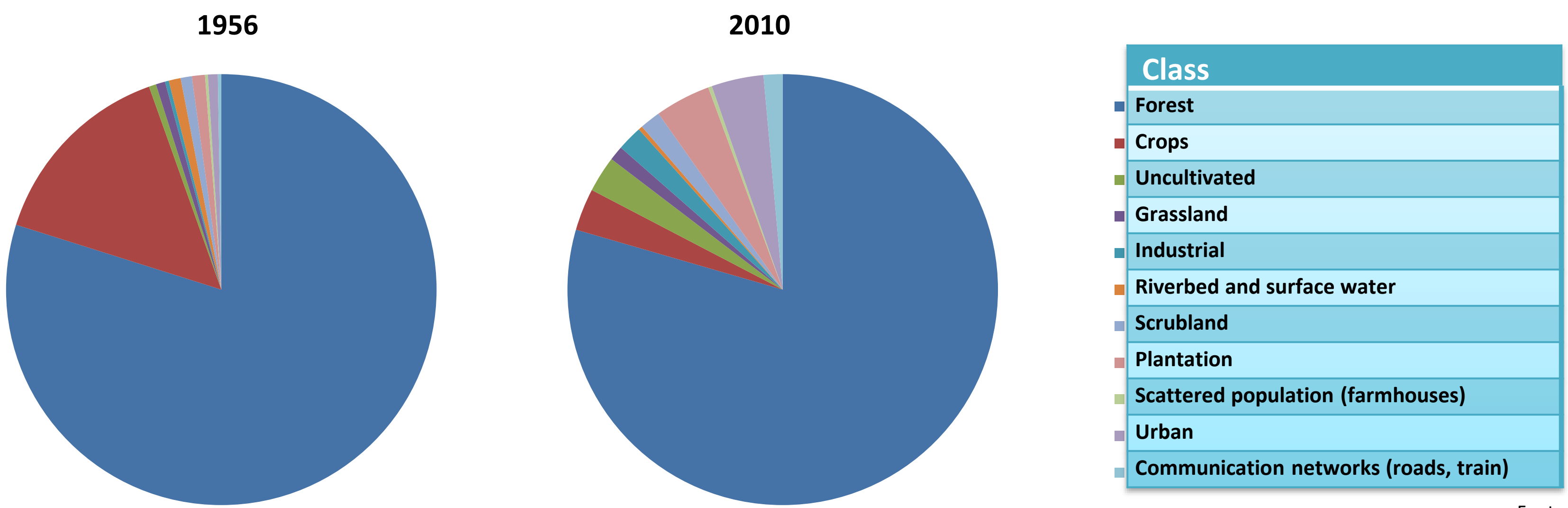
Land use and cover change 1956-2010

Dominant and stable cover

Important regression

Abandonment of 78,50 % of crops
Since 1956

Category	Difference1956-2010 Area (ha)	Percentage (%)	Percentage 1956 (%)
Forest	-24,56	-0,38	-0,47
Crops	-756,13	-11,52	-78,50
Uncultivated	142,65	2,17	403,87
Grassland	26,15	0,40	57,21
Industry	105,17	1,60	553,94
Riverbed and surface water	-38,73	-0,59	-65,90
Scrubland	47,30	0,72	86,02
Plantations	208,83	3,18	323,88
Scattered population (farmhouses)	4,69	0,07	33,37
Urban	208,28	3,17	430,27
Communication networks (roads, train)	76,75	1,17	450,77
Total	0,39	0,00	0,01



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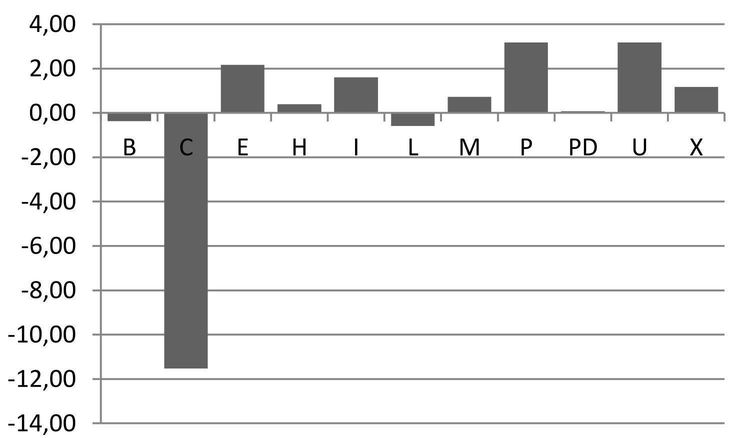
Results

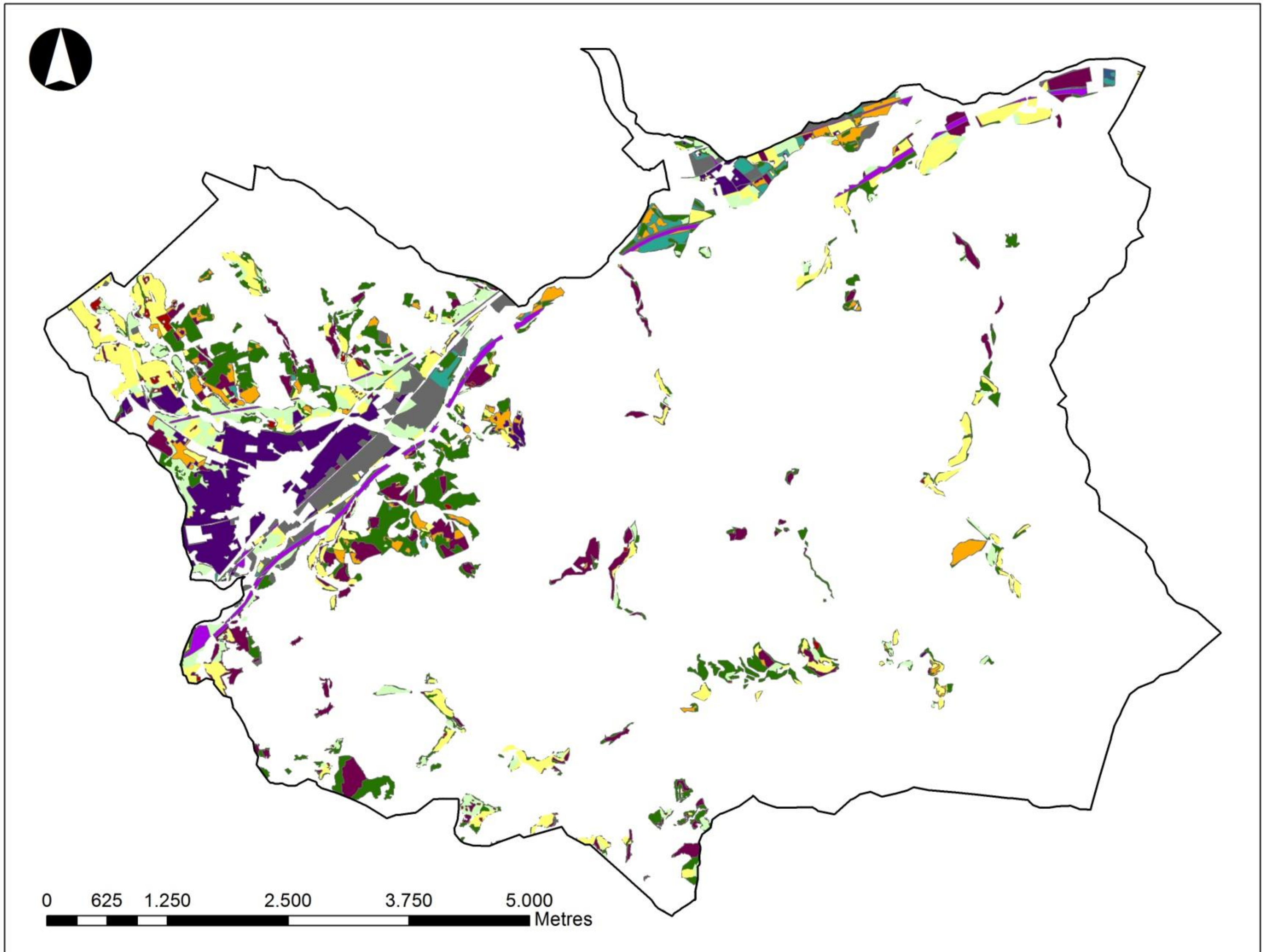
Quantitative analysis of LUCC. 1956-2010.

	1956		2010		Difference 1956-2010		
Categoria	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	**Percentage (%) 1956**
Forest	5240,24	79,87	5215,67	79,49	-24,56	-0,38	-0,47
Crops	963,28	14,68	207,15	3,16	-756,13	-11,52	-78,50
Uncultivated	35,32	0,54	177,97	2,71	142,65	2,17	403,87
Grassland	45,71	0,70	71,86	1,10	26,15	0,40	57,21
Industrial	18,98	0,29	124,15	1,89	105,17	1,60	553,94
Riverbed and surface water	58,77	0,90	20,04	0,31	-38,73	-0,59	-65,90
Scrubland	54,98	0,84	102,28	1,56	47,30	0,72	86,02
Plantation	64,48	0,98	273,31	4,17	208,83	3,18	323,88
Scattered population (farmhouses)	14,04	0,21	18,73	0,29	4,69	0,07	33,37
Urban	48,41	0,74	256,69	3,91	208,28	3,17	430,27
Communication networks (roads, train)	17,03	0,26	93,77	1,43	76,75	1,17	450,77
Total	6561,24	100,00	6561,63	100,00	0,39	0,00	0,01



Code	Class
B	Forest
C	Crops
E	Uncultivated
H	Grassland
I	Industrial
L	Riverbed and surface water
M	Scrubland
P	Plantation
PD	Scattered population (farmhouses)
U	Urban
X	Communication networks (roads, train)

Land use and cover map. Transformation of the category "Crops". 1956-2010



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Resultats

Transformation of the category “Crops” from 1956 to 2010

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Results

LUCC

Transformation of the land use/cover categories from 1956 to 2010.
In percentage over the total of each category in 1956

2010	Forest	Crops	Uncultivated	Grassland	Industrial	Riverbed and surface water	Scrubland	Plantation	Scattered Population	Urban	Communication networks (roads, train)
Forest	93.3	23.4	16.1	35.7	1.2	35.3	73.4	22.5	17.9	0.0	7.4
Crops	0.4	18.4	6.0	4.5	0.5	1.3	1.3	5.7	4.6	0.4	1.0
Uncultivated	0.7	12.0	15.4	7.0	6.8	4.0	5.1	7.6	16.5	1.4	2.7
Grassland	0.3	2.7	2.0	18.9	0.2	30.0	0.2	8.3	0.0	0.0	2.3
Industrial	0.5	7.2	8.6	10.0	51.2	6.2	1.7	1.9	1.4	4.2	2.6
Riverbed and surface water	0.1	0.2	0.1	6.3	0.0	12.7	0.1	4.9	0.0	0.0	0.6
Scrubland	0.7	5.8	3.8	6.6	0.4	3.3	4.1	2.2	4.3	0.4	0.9
Plantation	2.3	12.3	13.4	4.7	0.0	3.9	8.1	27.6	7.4	1.0	0.5
Scattered population (farmhouses)	0.0	1.0	3.0	0.0	0.0	0.0	0.7	0.0	37.0	0.0	0.1
Urban	1.3	12.5	24.2	3.4	38.5	0.1	4.0	4.5	10.9	90.5	14.9
Communication networks (roads, train)	0.4	4.5	7.4	3.0	1.4	3.3	1.3	14.9	0.1	2.0	66.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Font: elaboració pròpia

Results

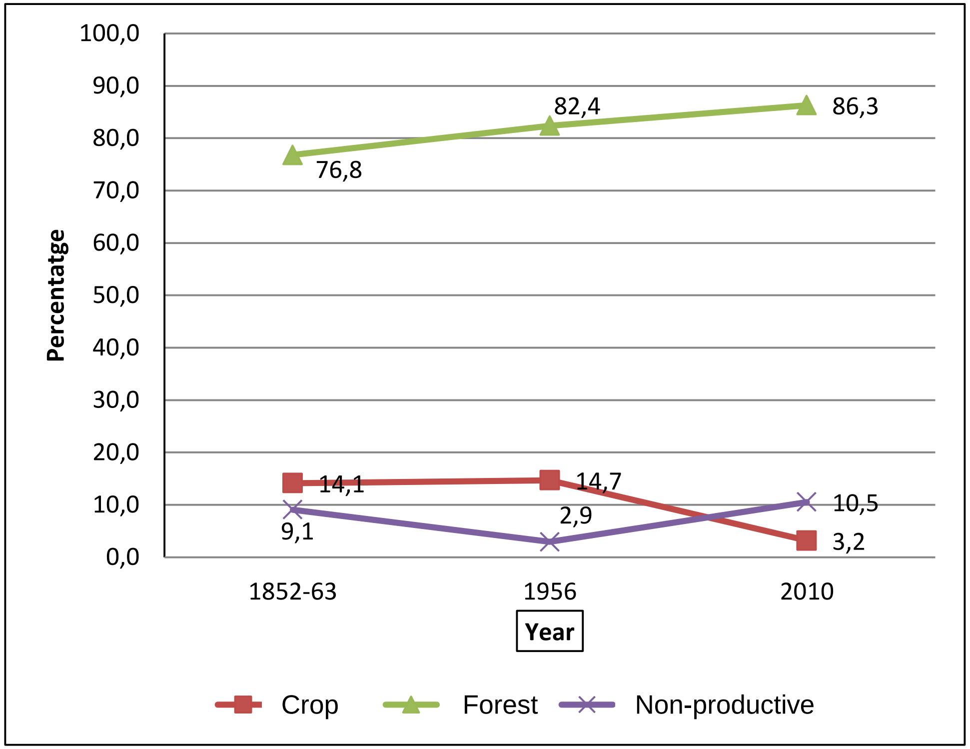
El canvi d'usos i cobertes del sòl

Procedence of the land use/cover categories in 2010 from 1956, in percentage over the total of each category in 2010

1956	Forest	Crops	Uncultivated	Grassland	Industrial	Riverbed and surface water	Scrubland	Plantation	Scattered Population	Urban	Communication networks (roads, train)
Forest	93.7	9.5	22.0	18.6	23.0	24.2	34.8	44.5	12.0	25.7	22.9
Crops	4.3	85.5	64.9	35.6	56.2	7.5	54.5	43.4	52.2	46.8	46.2
Uncultivated	0.1	1.0	3.0	1.0	2.5	0.2	1.3	1.7	5.7	3.3	2.8
Grassland	0.3	1.0	1.8	12.0	3.7	14.3	3.0	0.8	0.0	0.6	1.4
Industrial	0.0	0.0	0.7	0.1	7.9	0.0	0.1	0.0	0.0	2.9	0.3
Riverbed and surface water	0.4	0.4	1.3	24.5	2.9	37.3	1.9	0.8	0.0	0.0	2.1
Scrubland	0.8	0.4	1.6	0.1	0.8	0.1	2.2	1.6	2.1	0.8	0.8
Plantation	0.3	1.8	2.7	7.5	1.0	15.8	1.4	6.5	0.0	1.1	10.2
Scattered population (farmhouses)	0.0	0.3	1.3	0.0	0.2	0.0	0.6	0.4	28.0	0.6	0.0
Urban	0.0	0.1	0.4	0.0	1.6	0.0	0.2	0.2	0.0	17.1	1.0
Communication networks (roads, train)	0.0	0.1	0.3	0.6	0.4	0.5	0.2	0.0	0.1	1.0	12.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Results

LUCC. Comparison 1852-2010.



	1852-1956	1956-2010
Forest	↑	↑
Crops	=	↓
Non productive	↓	↑

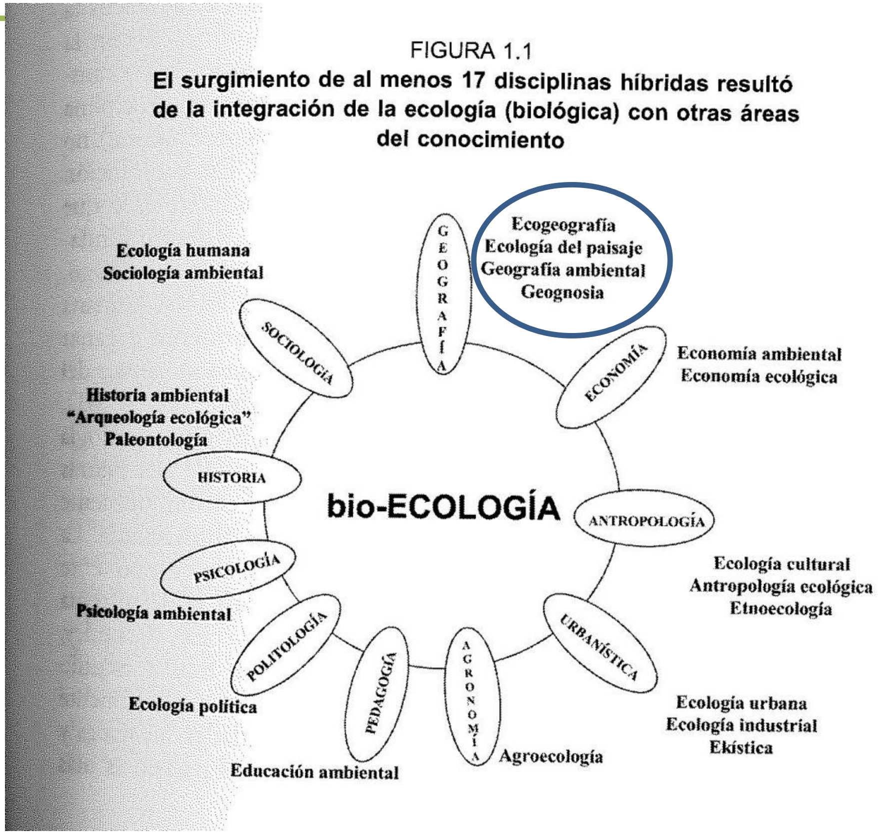
1852-63: Data obtained from "Amillaramientos". Tax documents which contained information of land use

Landscape Ecology and landscape indicators

Landscape ecology

A new integrated vision is needed to understand relationships between **nature** and **culture** (Toledo *et al.*, 1998).

Hybrid disciplines



Landscape ecology

The concept of landscape has had multiple definitions throughout history, as diverse as the disciplines converging in its study.

From the point of view of geography, landscape is very important, with the majority of definitions focusing in the dynamic relation between two elements: natural landforms, or physiographic regions, and human cultural groups.

- **Alexander von Humboldt** (19th century): landscape as “the total character of a region”.
- **Carl O. Sauer** (1925): landscape, at a regional scale, is defined as a space made of different associations of shapes, both physical and cultural.
- **Carl Troll** (1950): geographic landscape as “a part of Earth’s surface with a spatial unity that, for its external image and the joint actuation of its phenomena, equally than relations between inferior and exterior positions, has a specific character, separated from other by geographic and natural borders”.
- **Green *et al.*** (1996): landscape as a particular configuration of topography, vegetation covers, land uses and population settlement delimiting certain coherence in natural and cultural processes and activities.

Landscape ecology

Godron and Forman (1981): defined landscape from a more ecologic point of view, seeing landscape as a differentiate and measurable unit with different interesting ecological characteristics; internally, landscape is a recognizable and repeated group of ecosystems and disturbance regimes.

Patches and Structural Components for a Landscape Ecology
Author(s): Richard T. T. Forman and Michel Godron
Reviewed work(s):
Source: *BioScience*, Vol. 31, No. 10 (Nov., 1981), pp. 733-740
Published by: University of California Press on behalf of the American Institute of Biological Sciences
Stable URL: http://www.jstor.org/stable/1308780

Patches and Structural Components For A Landscape Ecology

Richard T. T. Forman and Michel Godron

Landscape ecology

Ecology: science which studies the relations between living beings and its environment.

The term was proposed by **Ernst Haeckel** in 1866.

•During the first half of the 20th century ecology develops as a functional science. Concepts like vegetal community, ecological succession or climacic vegetation are developed during this period.

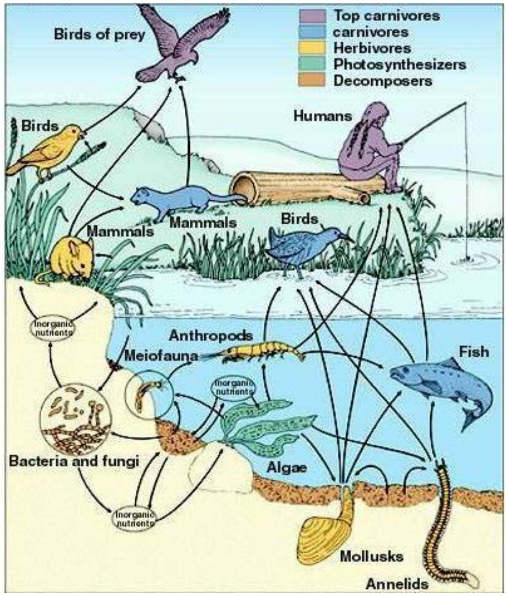
•During its development ecology expanded its scale of study from organisms to landscape.

Ecosystem: a central concept for Ecology, defined by Arthur Tansley in 1935.

“there are different types and sizes of ecosystems. They constitute a category among the many physical systems of the universe, from athoms to the universe overall”.

Since then ecosystems became the **central element** of study of Ecology, along with the vertical relations between the different components of ecosystems: climate, soil, vegetation, fauna…

Human activities constitute a highly powerful biothic factor, whose analysis must be included in Ecology (Tansley, 1935).



Landscape ecology

Advances in Ecology were soon applied to the study of landscape.

Origin of landscape ecology: **Carl Troll** (1939). Definition of landscape ecology.

Landscape ecology: discipline dedicated to the study of the whole complexity of the relations between comunities of organisms and its environmental conditions in a specific section of landscape (Troll, 1939).

Departing from Physic Geography and Ecology, the objective was to relate spatial structures with ecologic processes.

Troll adopted a holistic view, allowing to integrate relations between nature, culture, traditions, beliefs and people to understand the formation of different landscapes.

The development of aerial photographs during this period contributed to the development of the discipline

Landscape ecology

Landscape ecology consolidated as a discipline in the 1950 and 1960 decades, mainly in Central and Eastern Europe.

During this period strong links between land planning and landscape architecture were formed, receiving important contributions from other disciplines like economy, history or architecture.

Landscape ecology didn't root in North America until the decade of 1980, when the epicentre of the discipline moved from Europe to the United States.

It became an emerging research area, with important advances in the study of the structure and the dynamic of landscapes.

Theoretical advances and the development of quantitative methodologies important for the development of the discipline.

Importance of **Geographic Information Systems (GIS)**.

Aplication to the study of fragmentation and connectivity of habitats.

Landscape ecology

Two main perspectives in landscape ecology:

•More **biologic and ecologic** perspective , with a wide use of landscape indicators to analyse the spatial structure. Located mainly in United States.

•**Multifunctional** perspective of landscapes, where human dimension is more relevant and with a good integration with land planning. Located mainly in Europe.

Landscape ecology

Landscape ecology can be defined as an hybrid discipline which studies the complex interrelation between spatial structures and ecologic processes taking place in a delimited study unit called landscape.

•Landscape ecology is based in the premise that a different **composition** and **configuration** of the landscape mosaic affects ecosystems in a differentiate way (Wiens, 1995 cited by Turner et al., 2001).

•This study is made with an hybrid and integrative perspective, coming from different knowledge areas, allowing to understand the high complexity and heterogeneity of this interrelation.

•**Horizontal heterogeneity** is analyzed with a geographic perspective, focused in land distribution of the landscape.

•**Vertical heterogeneity** is analyzed with an ecologic perspective, focused in the interrelation between anthropic, biothic and abiothic elements of the landscape (Naveh and Lieberman, 1984).

Landscape ecology. Cultural landscapes

•Growing importance of human activities throughout history, responsible for the apparition of cultural landscapes.

•**Cultural landscapes** are the reflection of the evolution in the relation between society and its environment in a certain territory (Naveh, 1995).

•**Mediterranean landscapes** are a characteristic example of cultural landscapes, where the human activity has been important since remote times.

•It is crucial to integrate **anthropic elements** in the study of landscape.

Landscape ecology

Landscape ecology studies are focused in three characteristics of landscape (Forman & Godron, 1986):

•**Structure** refers to the size, number and type of elements of the landscape.

•**Functionality** refers to the interactions between this elements in therms of the exchange of energy, matter, organisms and information.

•**Change** is the alteration of structure and functionality of landscape through time.

•Structure and functionality are influenced each other.

Landscape ecology

Landscape structure and its spatial heterogeneity is responsible of the formation of **landscape mosaic**, made of the aggregation of different landscape objects or elements (Forman, 1995).
The *patch-matrix-corridor* model studies landscape mosaics through the three main elements which integrate it.
•A **patch** is defined as a relatively homogeneous non-linear area.
•A **corridor** is a strip of a particular element, different from the adjacent land, and connecting patches each other.
•A **matrix** is defined as the dominant element of the mosaic, which occupies the largest area and is better connected; usually being the dominnat element in landscape dynamics.

•In the case of patches (and corridors) it can be distinguished an **edge**, which strongly interacts with the matrix or the adjacent patches, and an interior where the interactions are much more weak (Burel & Baudry, 2002).

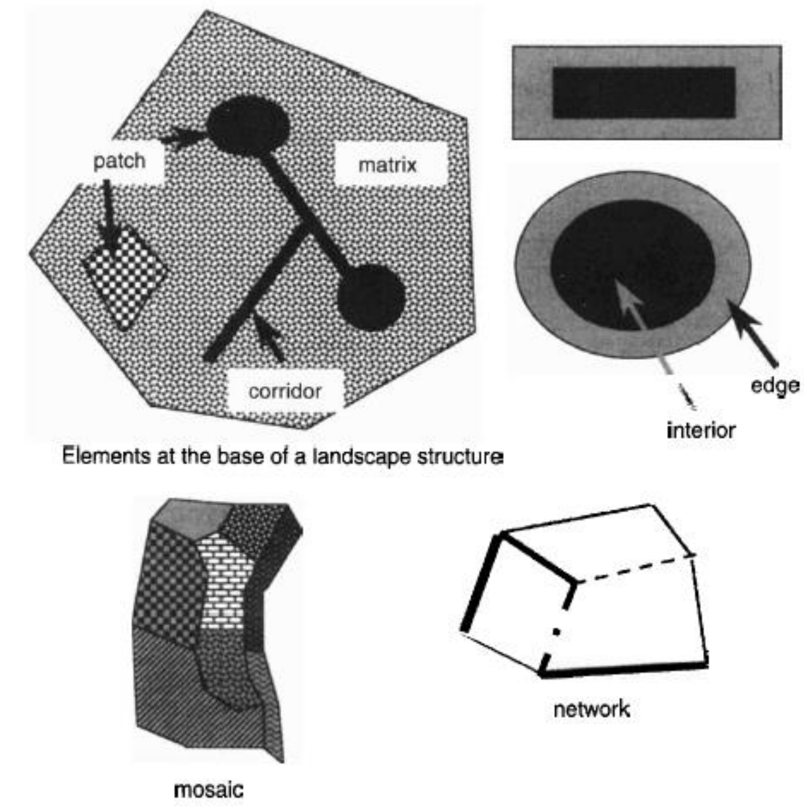


Fig. 1. Categories of landscape elements

Burel & Baudry, 2002

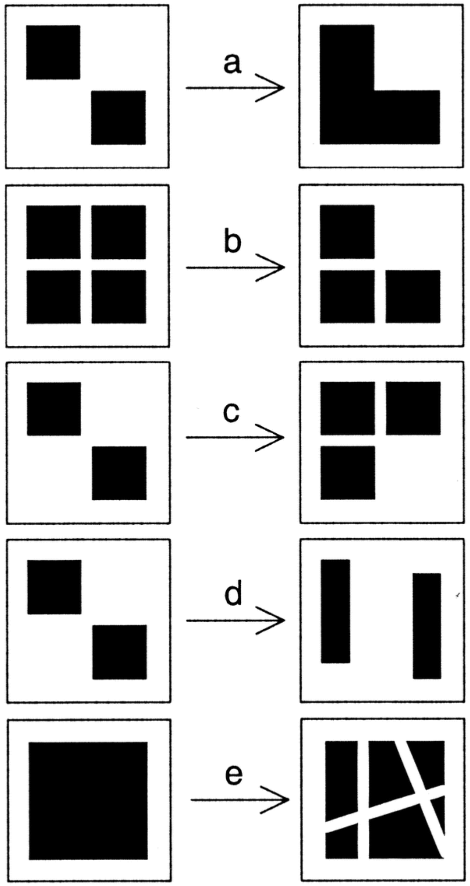
Landscape ecology

When describing landscape spatial structure, two main dimensions can be distingished (Botequilha *et al.*, 2006):

Composition: landscape composition refers to its variety (number of classes of the landscape or, in a wider sense, the number of land use and cover categories) and its abundance (area, relative proportion of each class or category) without explicitly consider its spatial distribution.
Configuration: landscape configuration refers to the spatial distribution of landscape elements, considering measures like patch form or distances between them.

Landscape ecology. Spatial processes of landscape transformation

To analyze landscape **transformation** in a certain period of time it is very important to analyze the spatial processes produced in its structure, both in composition and configuration.
Ten main spatial processes between a class and its enviroment, the matrix (Bogaert *et al.*, 2004):



Bogaert *et al.*, 2004

- **Aggregation (a)**: process of union of different patches to form a single one.

- **Attrition (b)**: the reduction or decrease in the number of patches, dissappearance of patches.

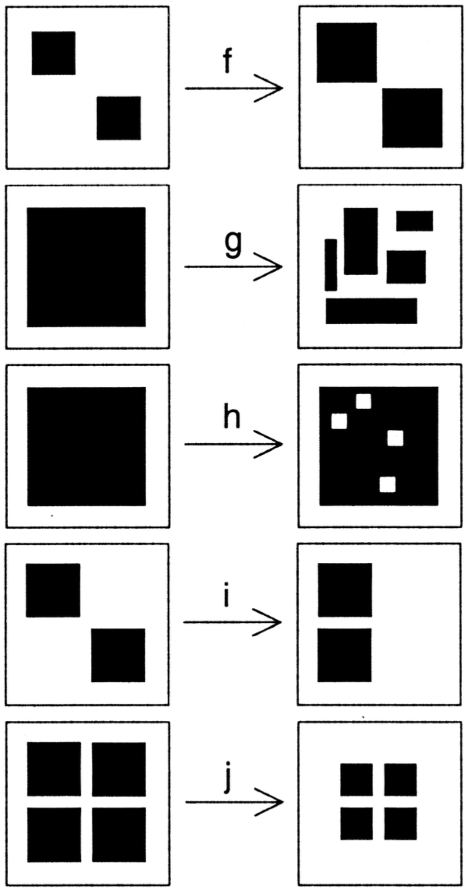
- **Creation (c)**: the formation of new patches, which results in an increase of the total number of patches; the act of causing to exist of patches; patch genesis.

- **Deformation (d)**: the change of patch shape, without patch size change; patch disfigurement.

- **Dissection (e)**: the carving up or subdividing of an area or patch using equal-width lines; sectioning of an area or patch; area or patch (sub)division.

Landscape ecology

To analyze landscape transformation in a certain period of time it is very important to analyze the spatial processes produced in its structure, both in composition and configuration.
Ten main spatial processes between a class and its enviroment, the matrix (Bogaert *et al.*, 2004):



Bogaert *et al.*, 2004

•**Enlargement (f)**: the increase of patch size; patch size expansion.

•**Fragmentation (g)**: the breaking up of an area into smaller parcels, resulting in unevenly separated patches; the breaking up of extensive landscape features into disjunt, isolated, or semi-isolated patches.

•**Perforation (h)**: the process of making holes in an area or patch; gap formation; interruption of land cover continuity by formation of openings.

•**Shift (i)**: patch repositioning; patch translocation.

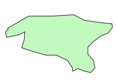
•**Shrinkage (j)**: the decrease or reduction in size of patches, without “attrition”; progressive reduction of the initial land cover patch, ideally maintaining its original shape.

Landscape ecology

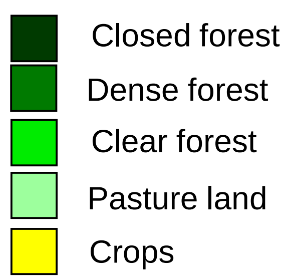
Quantitative methods in landscape ecology. Landscape indices
Landscape composition and configuration can be analyzed through quantitative methods, which have experienced sgnificant advances since the 1980s decade.

Landscape indices
Quantify different measures related with composition and configuration. Its use allows to compare different landscapes or the same landscape in different moments.

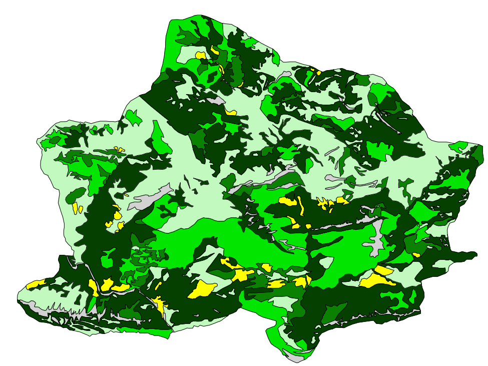
Landscape indices can be applied at different levels (McGarigal & Marks, 1995):
•**Patch**: a single value is obtained for each element.
•**Class**: a set of patches of the same type, obtaining a value for each class.
•**Landscape**: it is obtained a single value for the whole set of patches of a landscape.



Patch



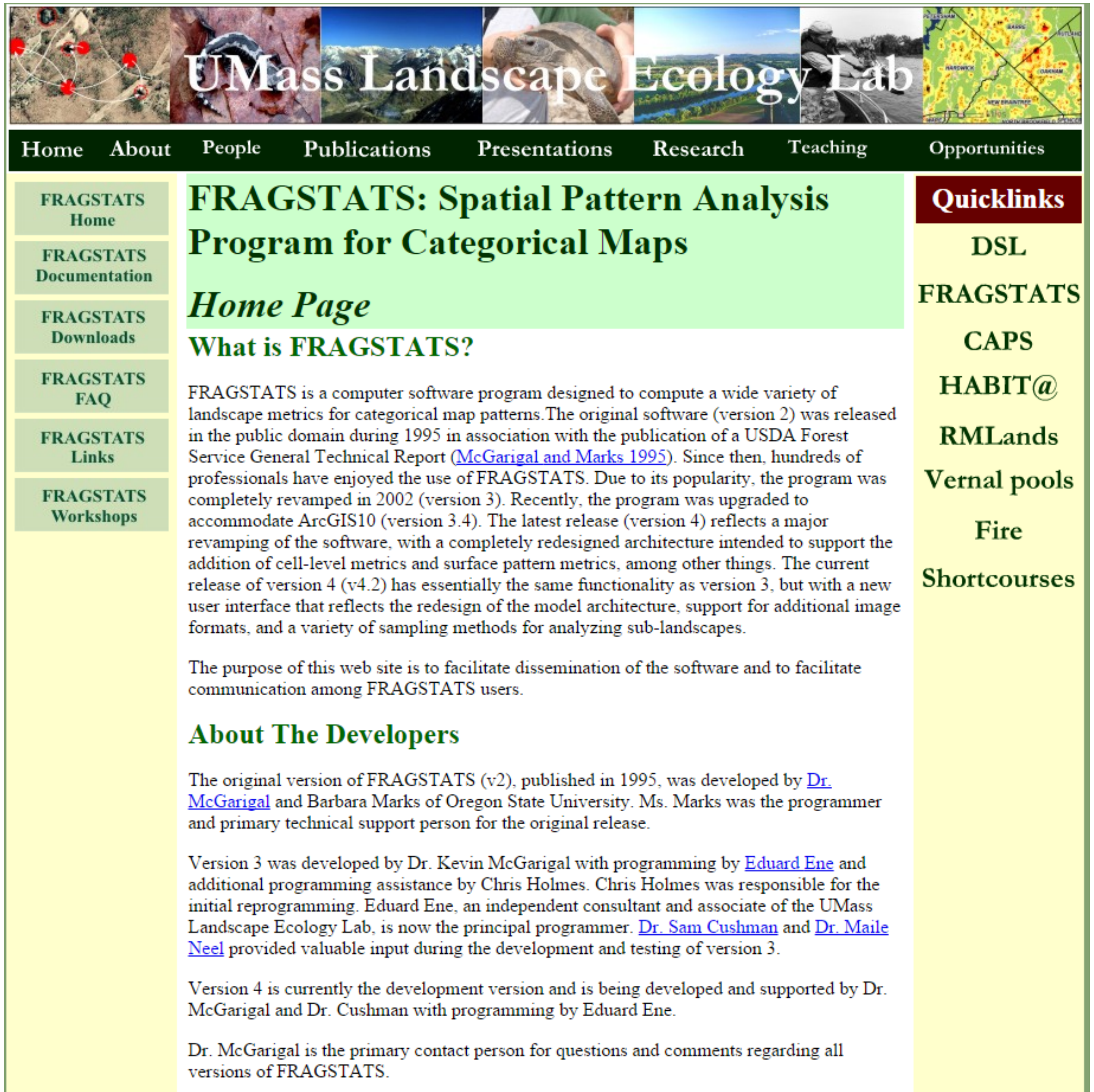
Class



Landscape

Landscape ecology

Use of Fragstats to calculate landscape indices
Downloadable at: http://www.umass.edu/landeco/research/fragstats/fragstats.html


UMass Landscape Ecology Lab

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FRAGSTATS Home
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FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps

Home Page

What is FRAGSTATS?

FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns.The original software (version 2) was released in the public domain during 1995 in association with the publication of a USDA Forest Service General Technical Report (McGarigal and Marks 1995). Since then, hundreds of professionals have enjoyed the use of FRAGSTATS. Due to its popularity, the program was completely revamped in 2002 (version 3). Recently, the program was upgraded to accommodate ArcGIS10 (version 3.4). The latest release (version 4) reflects a major revamping of the software, with a completely redesigned architecture intended to support the addition of cell-level metrics and surface pattern metrics, among other things. The current release of version 4 (v4.2) has essentially the same functionality as version 3, but with a new user interface that reflects the redesign of the model architecture, support for additional image formats, and a variety of sampling methods for analyzing sub-landscapes.

The purpose of this web site is to facilitate dissemination of the software and to facilitate communication among FRAGSTATS users.

About The Developers

The original version of FRAGSTATS (v2), published in 1995, was developed by Dr. McGarigal and Barbara Marks of Oregon State University. Ms. Marks was the programmer and primary technical support person for the original release.

Version 3 was developed by Dr. Kevin McGarigal with programming by Eduard Ene and additional programming assistance by Chris Holmes. Chris Holmes was responsible for the initial reprogramming. Eduard Ene, an independent consultant and associate of the UMass Landscape Ecology Lab, is now the principal programmer. Dr. Sam Cushman and Dr. Maile Neel provided valuable input during the development and testing of version 3.

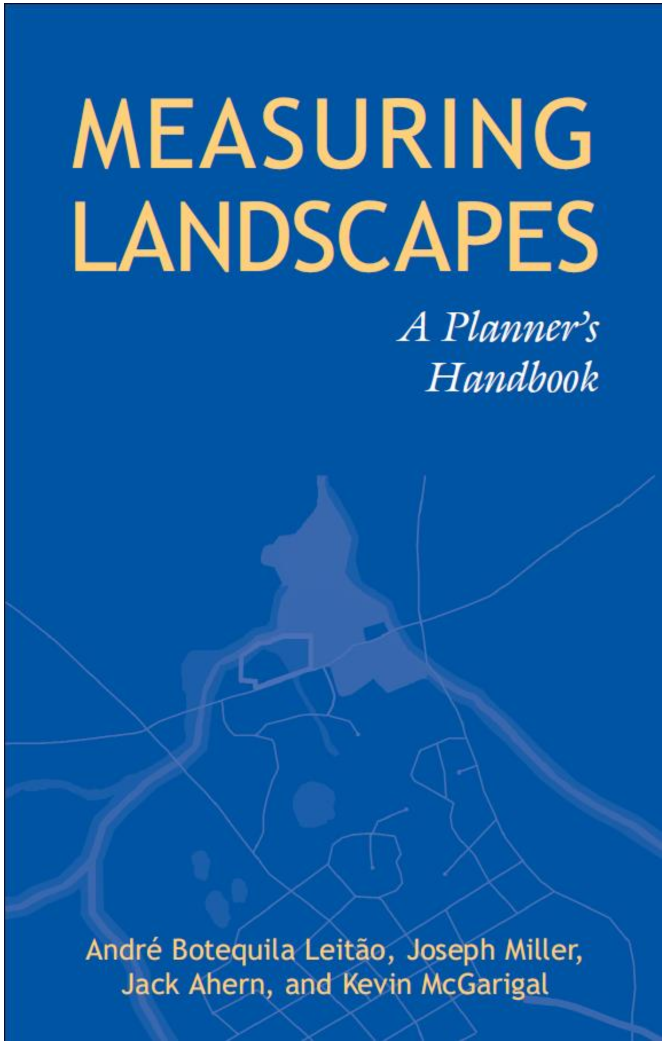
Version 4 is currently the development version and is being developed and supported by Dr. McGarigal and Dr. Cushman with programming by Eduard Ene.

Dr. McGarigal is the primary contact person for questions and comments regarding all versions of FRAGSTATS.

Quicklinks
DSL
FRAGSTATS
CAPS
HABIT@
RMLands
Vernal pools
Fire
Shortcourses

This program works mainly from raster maps and is considered the most complete due to the amount and diversity of landscape indices calculated, including the majority of the indices used in the scientific literature (McGarigal 1995; Botequilha et al ., 2006; Varga, 2007).

Landscape ecology



FRAGSTATS

SPATIAL PATTERN ANALYSIS PROGRAM

FOR

QUANTIFYING LANDSCAPE STRUCTURE

Version 2.0

by

KEVIN MCGARIGAL[1]

Forest Science Department, Oregon State University, Corvallis, OR 97331
(303) 882-2114

BARBARA J. MARKS

Forest Science Department, Oregon State University, Corvallis, OR 97331
(503) 750-7287

March, 1994

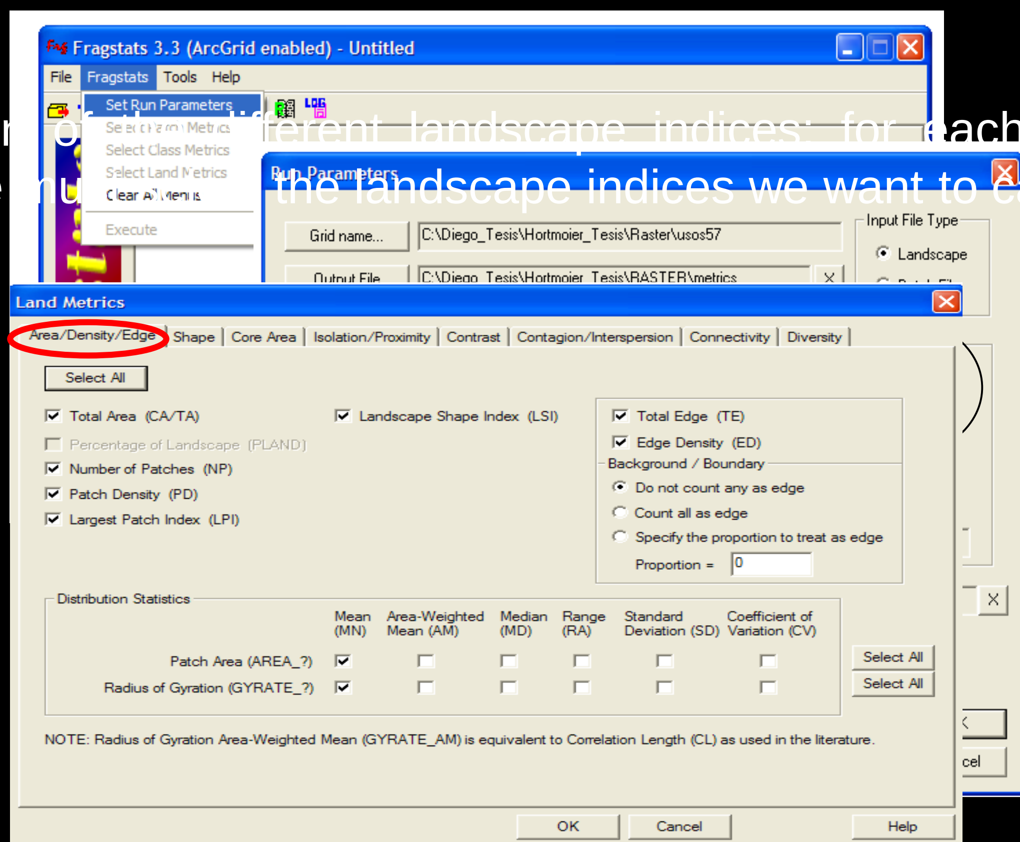
[1]Present address: P.O. Box 606, Dolores, Colorado 81323-9998 [(303) 882-2114]

Use of Fragstats to calculate landscape indices

Landscape analysis with FRAGSTATS incudes two main phases:

— Configuration of the parameters (Set Run Parameters).

— Selection of the different landscape indices: for each level of analysis we mu[illegible] the landscape indices we want to calculate.



3.Metodologia

Landscape ecology

When analyzing the results for different indices of the landscape is important to **interpret** them appropriately for each level.
Also, keep in mind that not all landscape indexes are applied to the three levels, they only have some relevance in terms of class or landscape level.
We must consider how to calculate the indices, as some are not calculated from patches but from cells, like contagion(Botequilha et al., 2006).

Landscape Ecology **19:** 389–399, 2004.
389

Research article

Use and misuse of landscape indices

Harbin Li[1,*] and Jianguo Wu[2]
*[1]USDA Forest Service Southern Research Station, Center for Forested Wetlands Research, 2730 Savannah Highway, Charleston, SC 29414, USA; [2]Faculty of Ecology, Evolution, and Environmental Science, School of Life Sciences, Arizona State University, Tempe, AZ 85287-4501, USA; *Author for correspondence (e-mail: hli@fs.fed.us)*

Received 29 May 2001; accepted in revised form 18 August 2003

Key words: Conceptual flaws, GIS and map data, Landscape pattern analysis, Pattern and process, Scale

Abstract

Landscape ecology has generated much excitement in the past two decades. One reason was that it brought spatial analysis and modeling to the forefront of ecological research. However, high expectations for landscape analysis to improve our understanding and prediction of ecological processes have largely been unfulfilled. We identified three kinds of critical issues: conceptual flaws in landscape pattern analysis, inherent limitations of landscape indices, and improper use of pattern indices. For example, many landscape analyses treat quantitative description of spatial pattern as an end itself and fail to explore relationships between pattern and process. Landscape indices and map data are sometimes used without testing their ecological relevance, which may not only confound interpretation of results, but also lead to meaningless results. In addition, correlation analysis with indices is impeded by the lack of data because of difficulties in large-scale experimentation and by complicated behavior of indices because of their varying responses to changes in scale and spatial pattern. These problems represent significant challenges to landscape pattern analysis, especially in terms of relating pattern to process. In this perspective paper, we examine the underlying problems of these challenges and offer some solutions.

•Use only the landscape indices meaningful for our research.

•Interpretation of the results is the key aspect in using landscape indices.

Landscape ecology

Selected class indices

Area/Density/Edge	***Isolation/Proximity***
Patch Density (PD). Largest Patch Index (LPI). Edge Density (ED). Landscape Shape Index (LSI). Patch Area. Area-Weighted Mean (AREA_AM).	Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM). ***Contagion/Interspersion*** Proportion of Like Adjacencies (PLADJ). Interspersion Juxtaposition Index (IJI).
Shape	***Connectivity***
Fractal Dimension Index. Area-Weighted Mean (FRAC_AM).	Patch Cohesion Index (COHESION).

Landscape ecology

Area/Density/Edge

Patch Density (PD): the number or density of discrete patches in the landscape or of a particular patch type (or class).

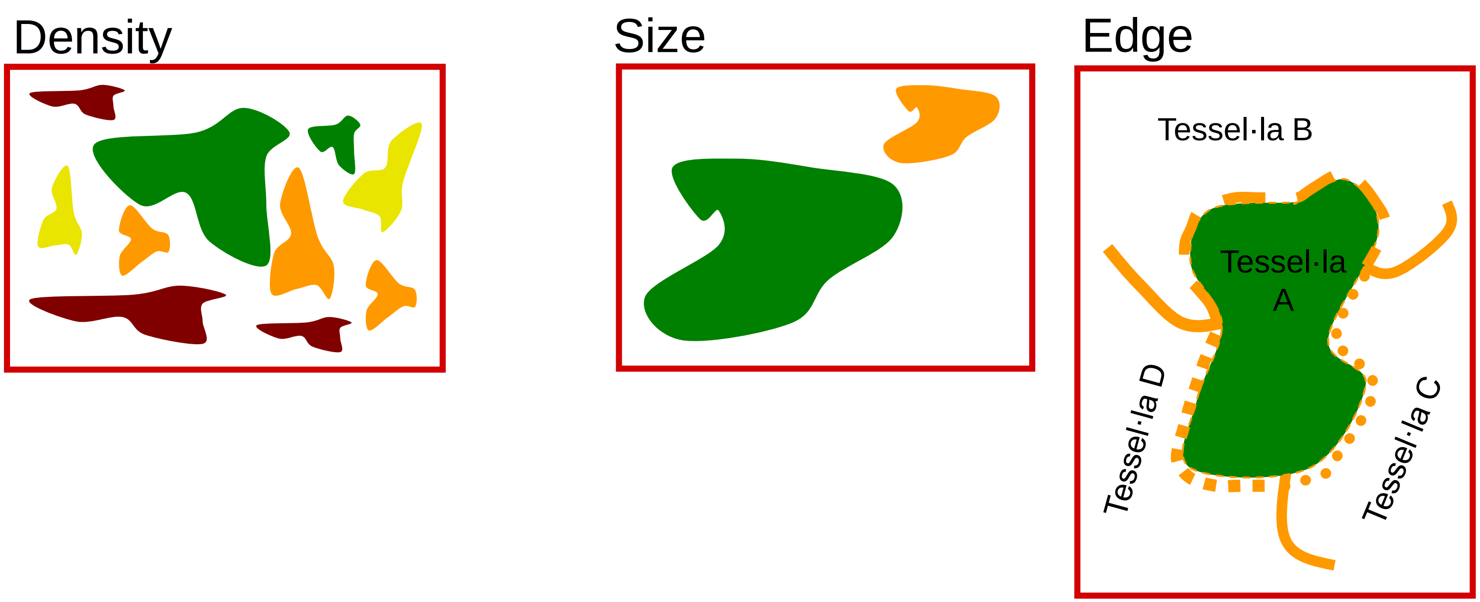
Levels: class, landscape.

$PD = \frac{n_i}{A} \cdot 10.000 \cdot 100$	n_i = number of patches of the class i in the landscape A = total area of the landscape (m^2).

Description: is equal to the number of patches of a certain class divided by the total ara of the landscape (m^2), multiplied by 10.000 (to convert into hectares) and by 100.

Units: number by 100 hectares

Range: PD > 0.



Landscape ecology

Largest Patch Index (LPI):

Levels: class, landscape.

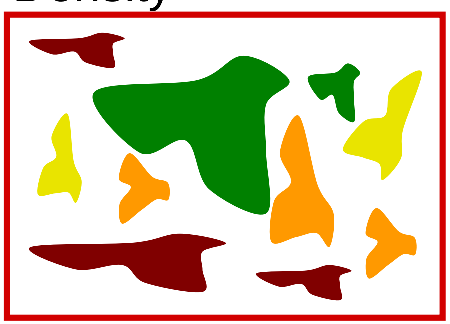
$LPI = \dfrac{\max\limits_{j=1}(a_{ij})}{A} \cdot 100$	a_{ij} = area (m^2) of a patch j belonging to a class i. A = total área of a landscape (m^2).

Description: is equal to the area of the largest patch belonging to a certain class i, divided by the total area of the landscape(m^2) and multiplied by 100 to convert it into a percentatge. Indicates and measures dominance in a landscape.

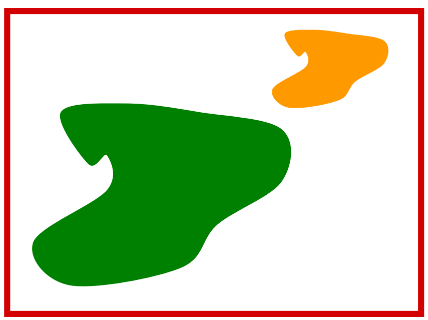
Units. Percentage (%):

Range: $0 < LPI \leq 100$

Density



Size



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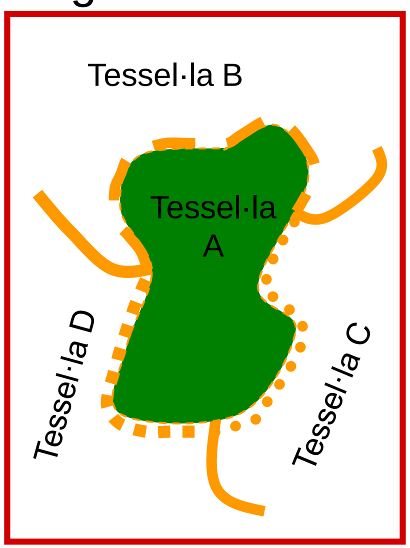


Landscape ecology

Edge Density (ED):

Levels: class, landscape.

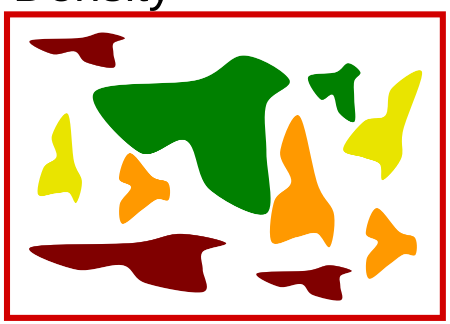
$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A} \cdot 10.000$	e_{ik} = total length (m) of the edge of all the patches of a certain type (class). A = total area of the landscape (m^2).

Description: it is equal to the sum of the lengths of the edges of all the patches of a certain class divided by the total area of the landscape (m^2) and multiplied by 10.000 to convert it into hectares.

Unitats: meters per hectarea (m/ha).

Range: ED ≥ 0, without limit.

Density



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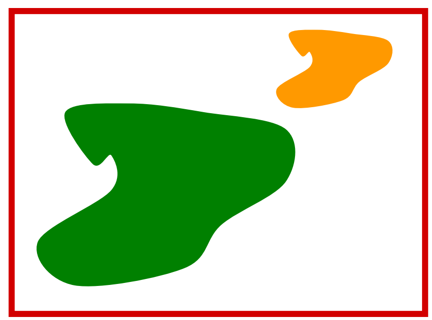
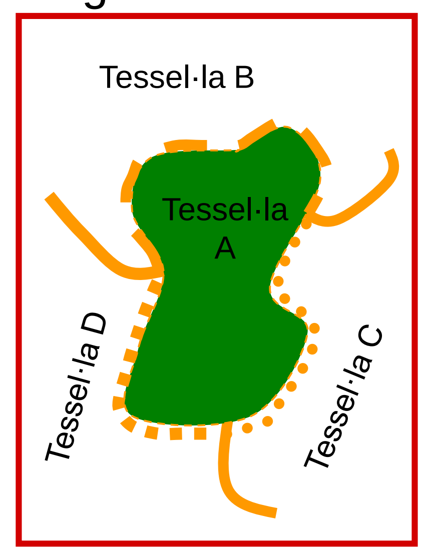


Edge

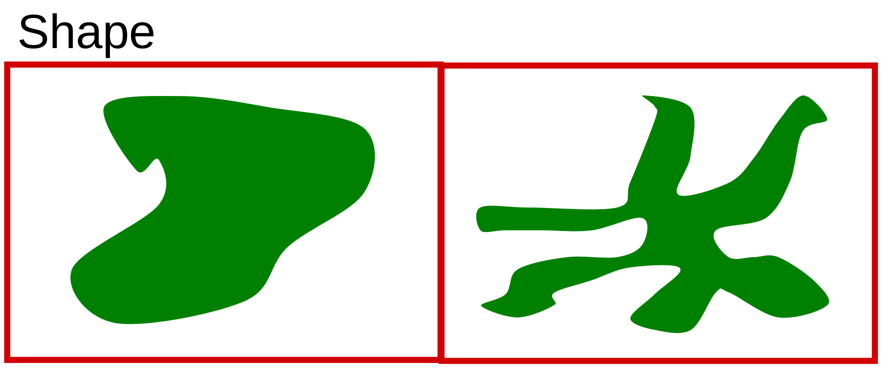


Landscape Shape Index (LSI):

Description: it is equal to the total length of the edges of a certain class i, divided by the minimum possible edge length to maximize class aggregation.
Units: none.

Range:
•LSI = 1 when a unique patch of a certain class being the màximum compact possible, constitutes the totality of the landscape.
•LSI ≥ 1, without límit. Its growth shows a bigger disaggregation of the patches of a certain class.

$LSI = \frac{e_i}{min\, e_i}$	e_i = total edge length of the class i. min e_i = minimum edge length of the class i.



Landscape ecology

Patch Area. Area-Weighted Mean (AREA_AM):

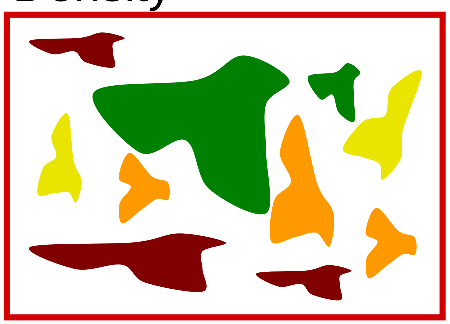
Description: it is equal to the sum, for all the patches of a certain class, of the patch area multiplied by the relative abundance of each patch, in this case the patch area (m^2) divided by the sum of the areas of all the patches of a certain class, and multiplied by 10.000 to convert it into hectares.

Units: hectares (ha).

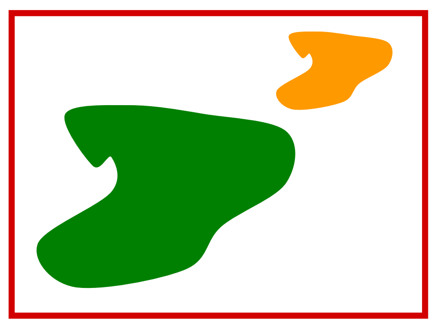
Range: AREA_AM>0, without limit.

$$\mathrm{AREA\_AM} = \sum_{j=1}^{n} \left[a_{ij} \cdot \left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \right) \cdot 10.000 \right]$$	a_{ij} = area (m^2) of a patch j belonging to a class i. n_i = number of patches in the landscape belonging to class i.

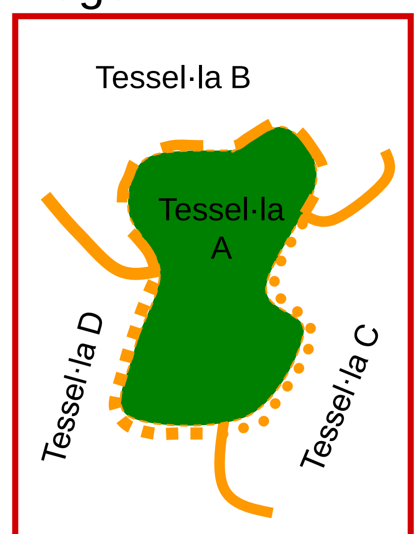
Density



Size



Edge



Landscape ecology

Shape

Fractal Dimension Index. Area-Weighted Mean (FRAC_AM):

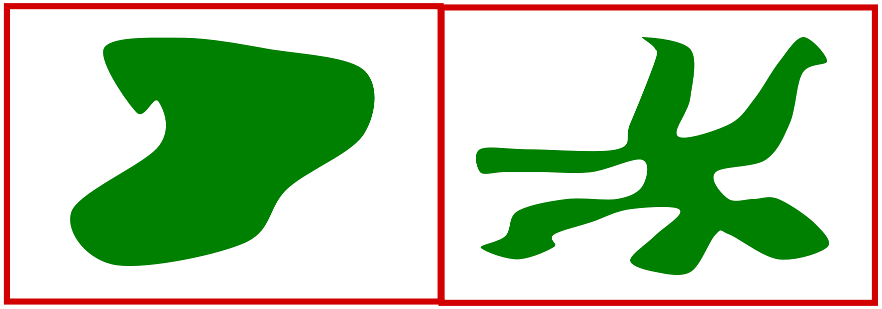
Description: it is equal to the sum, for all the patches of a certain class, of 2 times the logarithm of the perimeter of the patch (m), divided by the logarithm of the patch area (m^2), multiplied by the área of the patch (m^2)n and divided by the total área of the class. The patch perimeter is multiplied by 0.25 to correct the error in the perimeter caused by the conversión to raster (McGarigal & Marks, 1995).

Units: none.

Range: 1≤ FRAC_AM ≤ 2

$\mathrm{FRAC\_AM} = \sum_{j=1}^{n}\left[\frac{2\ln(0{,}25p_{ij})}{\ln a_{ij}} \cdot \left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$	Pij = perimeter (m) of a patch j belonging to a class i. a_{ij} = area (m^2) of a patch j belonging to a class i.

Shape



Landscape ecology

Isolation/Proximity

Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM):

Description: it is equal to the sum, for all the patches of a certain class, of the shortest distance to the closest neighbor of each patch multiplied by the relative abundance of each patch, in this case the patch area (m^2) divided by the sum of the patches area of a certain class.

Units: meters (m).

Range: ENN_AM>0

$$ENN\_AM = \sum_{j=1}^{n}\left[h_{ij}\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$$	h_{ij} = shortest distance (m) to the closest neighbor of a patch j belonging to a class i, calculated taking as a reference the center of each patch. a_{ij} = area(m^2) of a patch j belonging to a class i.

How do the actual distances between patches relate to ecological factors such as the dispersal distance of a particular wildlife species? The increased distance between patches further reduces the probability of interpatch dispersal, migration, and colonization.

Landscape ecology

Contagion/Interspersion

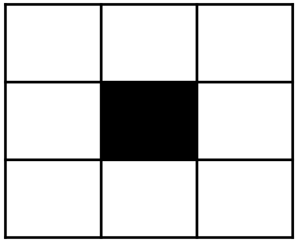
Proportion of Like Adjacencies (PLADJ):

Description: it is equal to the number of similar adjacencies of a certain class divided by the total number of adjacencies of this class, multiplied by 100 to convert the result in a percentage

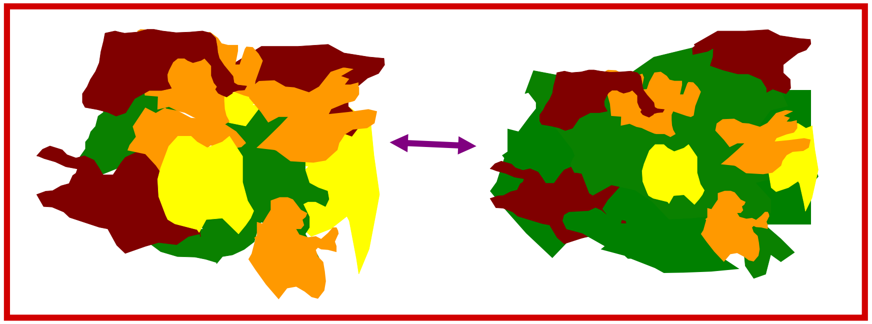
Units: Percentage.

Rang: 0 ≤ PLADJ ≤ 100

$$PLADJ = \left(\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}}\right) \cdot 100$$	g_{ii} = number of like adjacencies (belonging to the same class) between pixels of the class i. g_{ik} = number of adjacencies between pixels of the classes *i* and *k*.



Contagion



Landscape ecology

Interspersion Juxtaposition Index (IJI): expresses observed interspersion over the maximum possible interspersion for the given number of LULC classes.

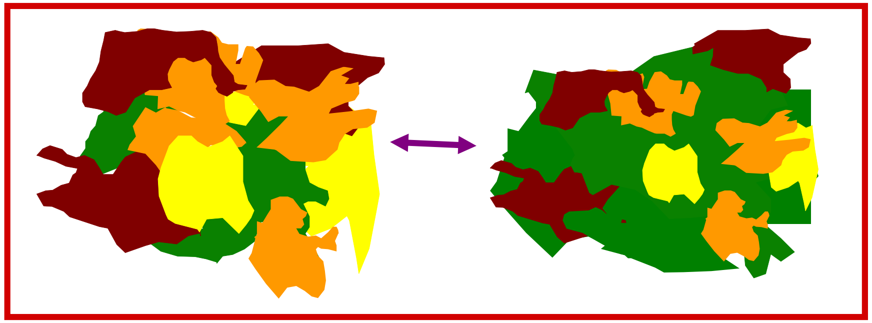
Description: IJI equals minus the sum of the length (m) of each unique edge type divided by the total landscape edge (m), multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch types times the number of patch types minus 1; multiplied by 100 (to convert to a percentage).
In other words, the observed interspersion over the maximum possible interspersion for the given number of patch types.
Units: Percentage.

Range: 0 < IJI ≤ 100

IJI approaches 0 when the distribution of adjacencies among unique patch types becomes increasingly uneven.
IJI = 100 when all patch types are equally adjacent to all other patch types (i.e., maximum interspersion and juxtaposition).

$IJI = \frac{-\sum_{k=1}^{m}\left[\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\ln\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\right]}{\ln(m-1)} \cdot 100$	e_{ik} = total length (m) of edge in landscape between patch types (classes) i and k. m = number of patch types (classes) present in the landscape, including the landscape border, if present.

Contagion



Intermixing of classes

Landscape ecology

Connectivity
Patch Cohesion Index (COHESION)

Description: Equal to one minus the sum of the perimeter of the patches of a certain class divided by the sum of the perimeters multiplied by the square root of the area of the patch, divided by one less the inverse of the root square of the total area of the landscape, multiplied by a hundred to make it a percentage

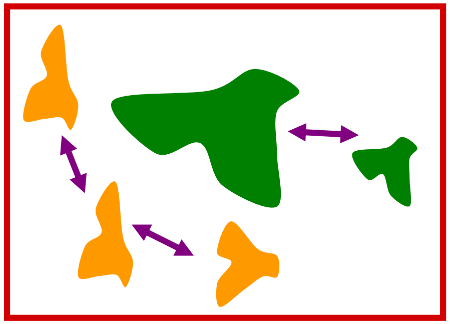
Unitats: none.

Range: $0 \leq COHESION < 100$.

COHESION approaches 0 as the proportion of the landscape comprised of the focal class decreases and becomes increasingly subdivided and less physically connected. COHESION increases as the proportion of the landscape comprised of the focal class increases. COHESION is given as 0 if the landscape consists of a single non-background cell.

$COHESION = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right] \cdot \left[1 - \frac{1}{\sqrt{A}}\right]^{-1} \cdot 100$	p_{ij} = perimeter of the patch j belonging to the class i (m). a_{ij} = area of a patch j belonging to the class i. A = total area of the landscape

Connectivity



Landscape ecology

Selected landscape indices

Area/Density/Edge	***Isolation/Proximity***
Total Area (TA).	Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM).
Patch Density (PD).	***Contagion/Interspersion***
Largest Patch Index (LPI).	Contagion (CONTAG).
Edge Density (ED).	***Connectivity***
Landscape Shape Index (LSI).	Patch Cohesion Index (COHESION).
Patch Area. Area-Weighted Mean (AREA_AM).	***Diversity***
Shape	Shannon's Diversity Index (SHDI).
Fractal Dimension Index. Area-Weighted Mean (FRAC_AM).	Shannon's Evenness Index (SHEI).

Landscape ecology

Contagion/Interspersion

Contagion (CONTAG):

Description: it is equal to the sum of the proportional abundance of each patch type (class) multiplied by the proportion of adjacencies between cells (number of shared pixel sides) of this class and other classes, summed by each type of adjacency and each patch class; divided two times by the logarithm of the number of patch classes; and multiplied by 100 to obtain a percentage.

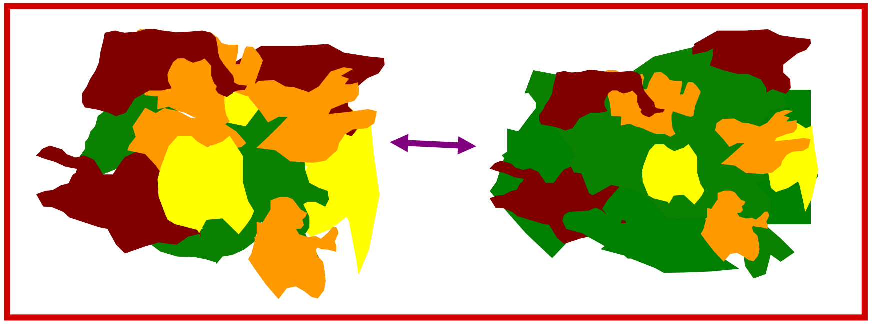
This index is inversely proportional to edge density (ED).
Also it is affected by class dispersion and Interspersion. Low levels in PLADJ and IJI mean a higher value of CONTAG, and inversely.

Units: percentage.

Range: 0 < CONTAG ≤ 100

$CONTAG = \left[1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\ln(m)}\right] \cdot 100$	P_i = proportion of landscape occupied by the patch type (class) i. g_{ik} = number of adjacencies between cells of a certain class. m= number of patch classes.

Contagion



Landscape ecology

Diversity
Shannon's Diversity Index (SHDI).

Description: SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by the logarithm of that proportion.
This index refers to the composition and structure diversity if the landscape. Its values is higher when the number of classes is higher and/or the proportional distribution of the area of each class is more equitative.

The *Shannon's diversity index* is a popular measure of diversity in community ecology, applied here to landscapes.

Units: none.
Range:
•SHDI ≥ 0, without limit.
•SHDI= 0, when the landscape only contains one patch.

$SHDI = -\sum_{i=1}^{m}(P_i \cdot \ln P_i)$	P_i= proportion of the landscape occupied by patch type (class) i.

Landscape ecology

Shannon's Evenness Index (SHEI).

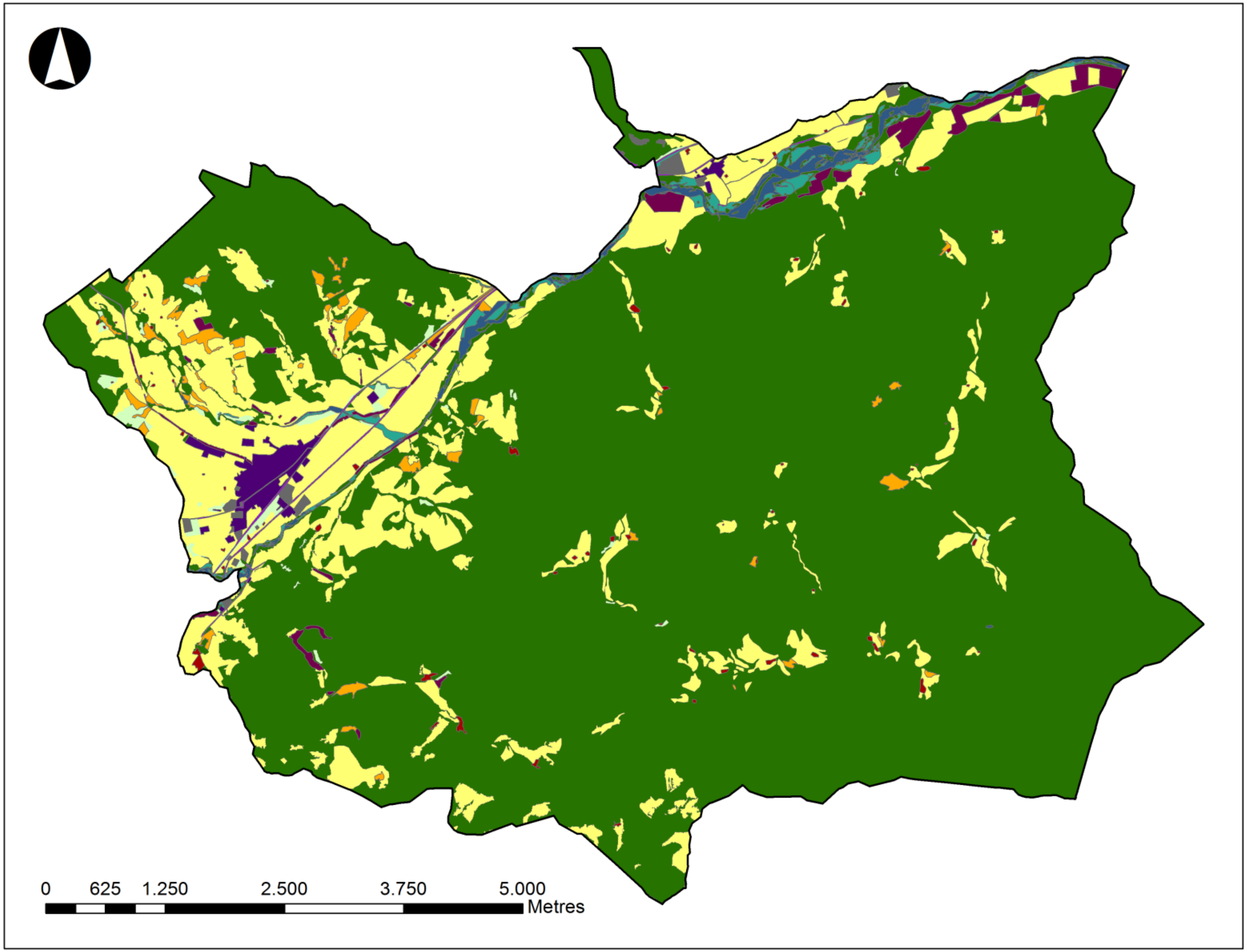
Description: equals the negative of the sum, for all the classes, of the relative abundance of each one, multiplied by its logarithm, divided by the logarithm of the number of classes. It is equivalent to divide the observed Shannon's diversity index by the maximum Shannon's diversity index possible for the number of classes of the landscape.
Units: none.
Range: $0 \leq SHEI \leq 1$
The index aproximates 1 when the landscape is uniform ,and aproximates 0 when there is no spatial regularity.

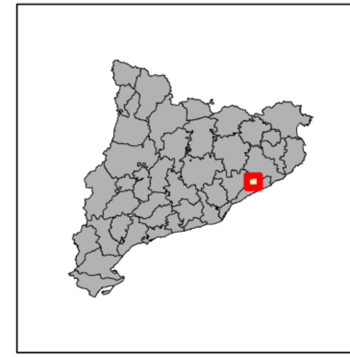
$SHEI = \frac{-\sum_{i=1}^{m}(P_i \cdot \ln P_i)}{\ln m}$	P_i= proportion of landscape occupied by each class. m= number of patch types (classes).

Study Case

Global Change Manifestations in Mediterranean mountain areas:
a study case in Baix Montseny

Land use and cover map.1956





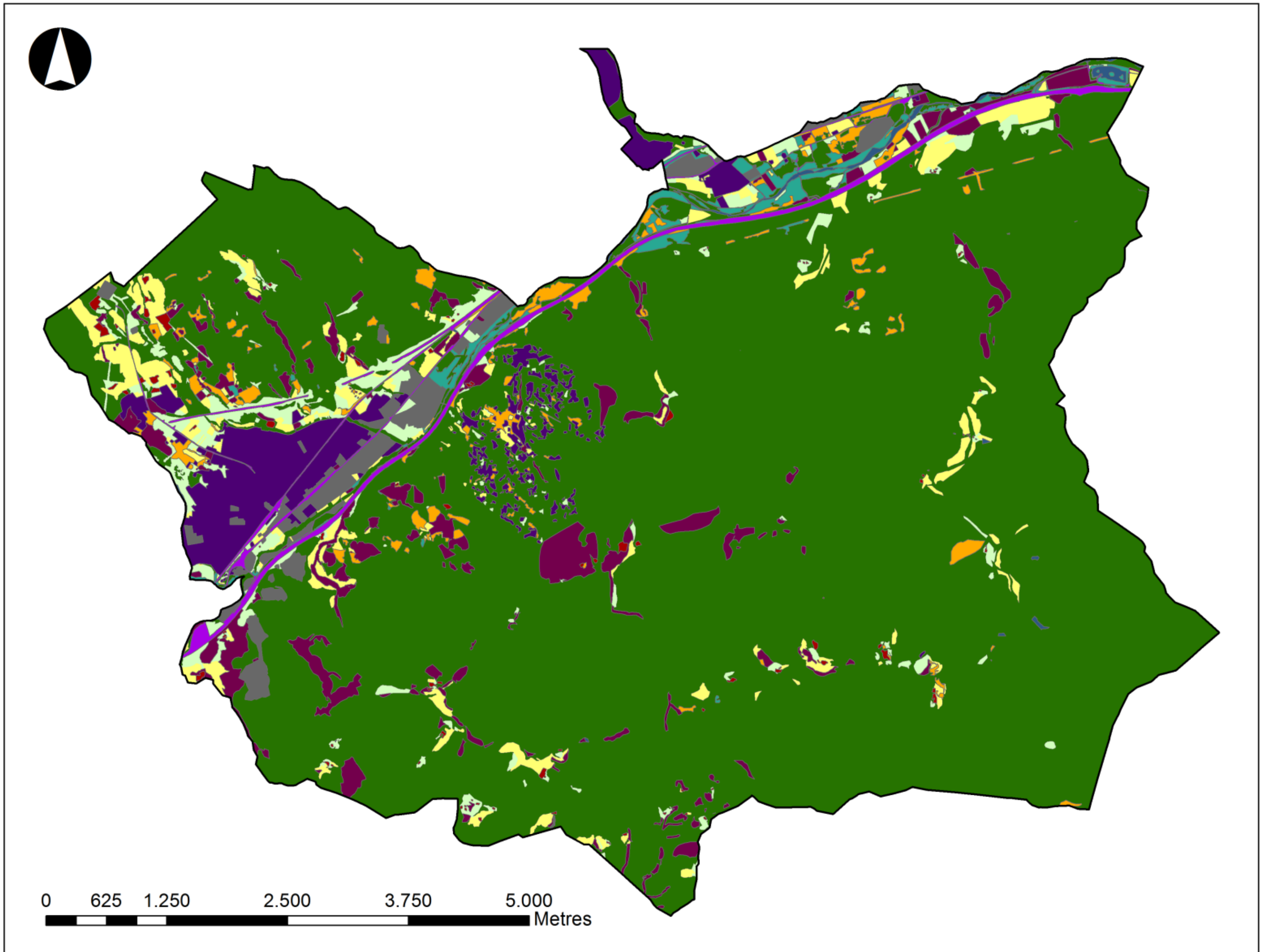
Lleg

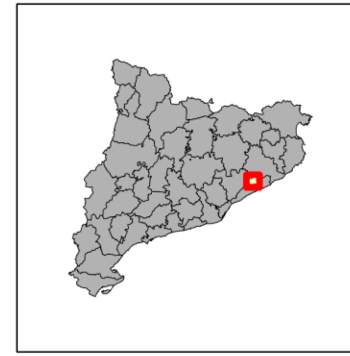
Class

- Forest
- Crops
- Uncultivated
- Grassland
- Industrial
- Riverbed and surface water
- Scrubland
- Plantation
- Scattered population (farmhouses)
- Urban
- Communication networks (roads, trai

Font: elaboració pròpia

Land use and cover map. 2010





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Results

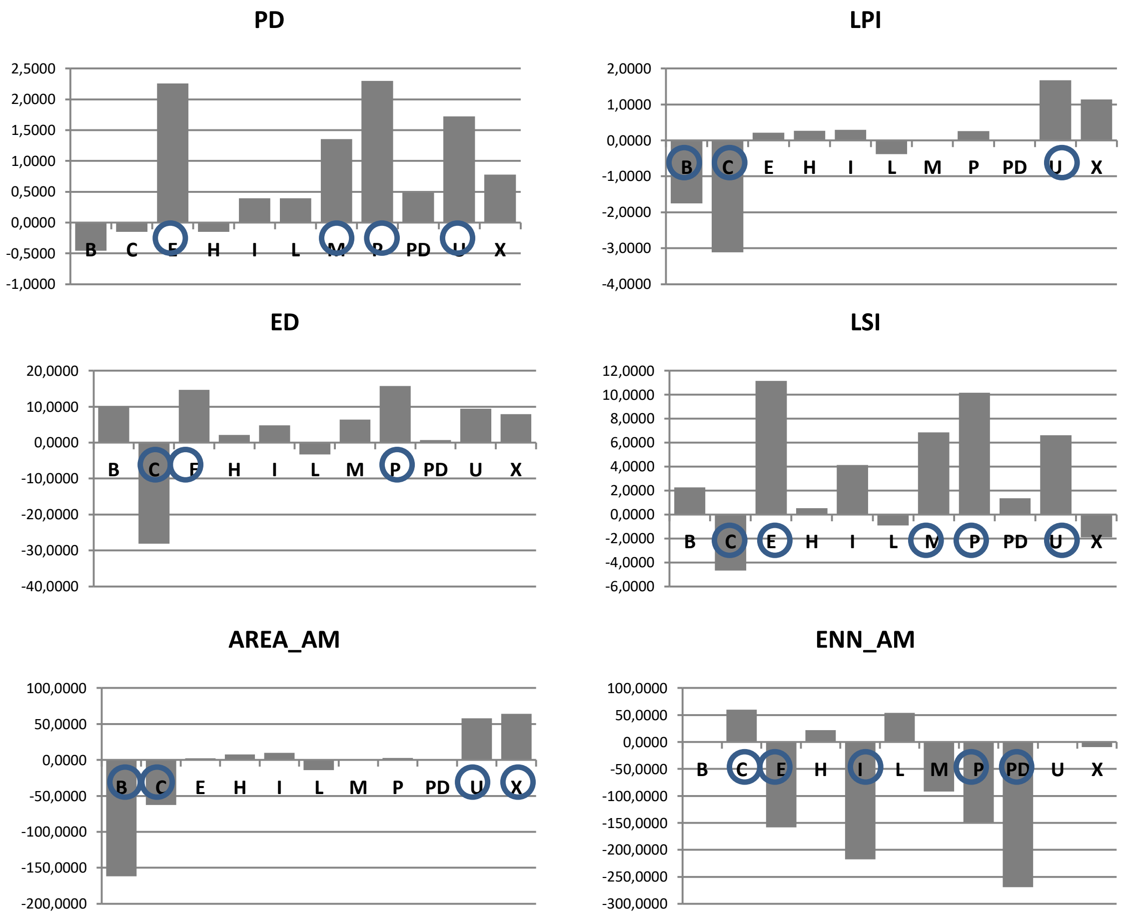
Changes in class indices (1956-2010)

Code	Class	PD	LPI	ED	LSI	AREA_AM
B	Forest	-0,4573	-1,7565	10,0236	2,2588	-161,7426
C	Crops	-0,1526	-3,1122	-28,0738	-4,6822	-62,6431
E	Uncultivated	2,2555	0,2100	14,6577	11,1618	2,4594
H	Grassland	-0,1525	0,2695	2,1637	0,5412	7,6710
I	Industrial	0,3962	0,2897	4,8081	4,1270	9,8890
L	Riverbed and surface water	0,3962	-0,3800	-3,3136	-0,9072	-14,1744
M	Scrubland	1,3563	0,0259	6,3883	6,8664	0,3783
P	Plantation	2,3012	0,2543	15,7641	10,1592	2,5854
PD	Scattered population (farmhouses)	0,4876	-0,0003	0,7253	1,3552	0,0373
U	Urban	1,7221	1,6695	9,4350	6,6181	58,0808
X	Communication networks (roads, train)	0,7771	1,1426	7,9549	-1,8998	64,2911

Code	Class	ENN_AM	PLADJ	IJI	COHESION
B	Forest	-0,0230	-0,3173	35,5285	0,0015
C	Crops	59,7426	-5,8983	14,8924	-4,8490
E	Uncultivated	-158,2127	3,3508	1,4805	2,1177
H	Grassland	22,0198	4,4621	11,9315	4,9852
I	Industrial	-217,7439	3,9663	5,9261	5,0815
L	Riverbed and surface water	54,0430	-12,6678	7,0589	-6,4023
M	Scrubland	-91,9193	-1,9618	13,4867	-0,0318
P	Plantation	-148,8166	1,2130	-4,0258	0,7493
PD	Scattered population (farmhouses)	-269,3671	0,7303	22,1451	-0,0787
U	Urban	0,1245	1,0540	7,9314	-0,1135
X	Communication networks (roads, train)	-9,3993	39,1843	6,9765	9,0477

Results

Changes in class indices (1956-2010)



Code	Class
B	Forest
C	Crops
E	Uncultivated
H	Grassland
I	Industrial
L	Riverbed and surface water
M	Scrubland
P	Plantation
PD	Scattered population (farmhouses)
U	Urban
X	Communication networks (roads, train)

Area/Density/Edge

Patch Density (PD).
Largest Patch Index (LPI).
Edge Density (ED).
Landscape Shape Index (LSI).
Patch Area. Area-Weighted Mean (AREA_AM).

Shape

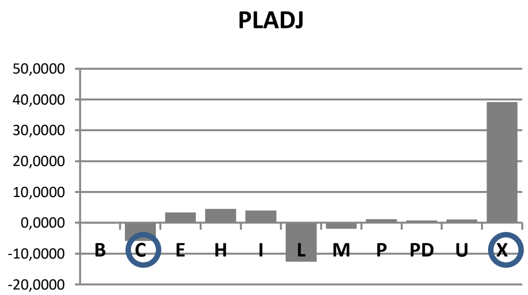
Fractal Dimension Index. Area-Weighted Mean (FRAC_AM).

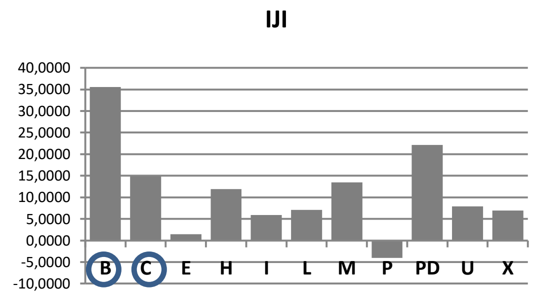
Isolation/Proximity

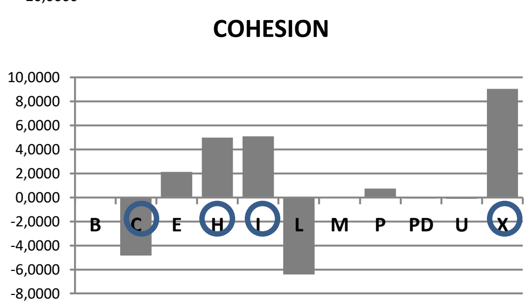
Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM).

Results

Changes in class indices (1956-2010)







Contagion/Interspersion

Proportion of Like Adjacencies (PLADJ).
Interspersion Juxtaposition Index (IJI).

Connectivity

Patch Cohesion Index (COHESION).

Code	Class
B	Forest
C	Crops
E	Uncultivated
H	Grassland
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L	Riverbed and surface water
M	Scrubland
P	Plantation
PD	Scattered population (farmhouses)
U	Urban
X	Communication networks (roads, train)

Results

Class indexes

Area/Density/Edge	***Isolation/Proximity***
Patch Density (PD). Largest Patch Index (LPI). Edge Density (ED). Landscape Shape Index (LSI). Patch Area. Area-Weighted Mean (AREA_AM).	Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM). ***Contagion/Interspersion*** Proportion of Like Adjacencies (PLADJ). Interspersion Juxtaposition Index (IJI).
Shape	***Connectivity***
Fractal Dimension Index. Area-Weighted Mean (FRAC_AM).	Patch Cohesion Index (COHESION).

Class	Δ 1956-2010	Descripció
Forest	⇑IJI ⇑ PLADJ ⇑ COHESION	Matrix of the landscape. Increase in cohesion. (1956 i 2010).High contagion and connectivity.
Crops	⇓PD ⇓ED ⇓LPI ⇓AREA_AM ⇑ENN_AM ⇓COHESION	Regression in area. Regression in connectivity.

Results

Landscape indices

Increase in landscape fragmentation	⇑PD ⇑ED ⇓AREA_AM ⇑ENN_AM
Increase in the complexity of the forms of the shapes (uncultivated, scrubland, plantation, urban).	⇑LSI
Decrease in landscape aggregation	⇓CONTAG
Increase in landscape heterogeneity.	⇑SHDI

Changes in landscape indices (1956-2010)

Year	PD	LPI	ED	LSI	AREA_AM
1956	13,8694	71,3337	67,1936	15,4025	3371,2731
2010	22,7993	69,5772	87,4604	19,5040	3221,4625
Change	8,9299	-1,7565	20,2668	4,1015	-149,8106

Year	FRAC_AM	ENN_AM	CONTAG	SHDI	SHEI
1956	1,2191	30,2770	81,1581	0,7336	0,3059
2010	1,2323	32,9055	75,7353	0,9331	0,3891
Change	0,0132	2,6285	-5,4228	0,1995	0,0832

Àrea/Density/Edge

Total Area (TA).

Patch Density (PD).

Largest Patch Index (LPI).

Edge Density (ED).

Landscape Shape Index (LSI).

Patch Area. Area-Weighted Mean (AREA_AM).

Shape

Fractal Dimension Index. Area-Weighted Mean (FRAC_AM).

Isolation/Proximity

Euclidean Nearest Neighbor. Area-Weighted Mean (ENN_AM).

Contagion/Interspersion

Contagion (CONTAG).

Connectivity

Patch Cohesion Index (COHESION).

Diversity

Shannon's Diversity Index (SHDI).

Shannon's Evenness Index (SHEI).

Conclusions

Land Use and Land Cover Change

- The results obtained show the marked forest dominance in the study area. The forest area has remained stable between 1956 and 2010, while the plantation and scrubland categories have increased significantly.

- Between 1956 and 2010, the most important change in land use and cover has been the large regression of the croplands (-78.50%), mainly transformed into forest (23.4%), new urban area (12.5%), plantations (12.3%) and uncultivated (12.0%). This process means a significant decrease in open spaces, with negative effects on the fauna typical of these environments. The comparison with the land use data from amillaraments, however, shows how the agricultural surface remained stable between the mid-nineteenth century and the year 1956, so that the beginning of this process would be after this last year.
- Another important change in land use and cover between 1956 and 2010 was the growth of the categories corresponding to urbanized areas, with the exception of the dispersed population in farms: urban (+3.17% of study area), industrial and commercial (+ 1.89%) and communications network (+1.17%). These changes are the result of the industrialization and tertiarisation of the economy, and its associated demographic growth.

Landscape Ecology and landscape indicators

- The results obtained at the landscape level show an increase in fragmentation between 1956 and 2010, through the increase in patch density (PD) and edge density (ED). There is also a certain decrease in the contagion (CONTAG), indicative of a decrease in the aggregation of the landscape.
- At the class level, the forest category has been identified as the landscape matrix of both 1956 and 2010, since it is the dominant class at the surface level, having the highest value of the largest patch index (LPI), and high levels of contagion and connectivity. The regression of the uncultivated category is reflected in the decrease in patch density (PD), edge density (ED) and patch area (AREA_AM) of this category between 1956 and 2010.
- A decrease in structural and functional connectivity has been identified in the whole studyarea , related to the development of the communication network, which dissect the rest of the categories, including forest and open spaces.

Master in Interdisciplinary Studies in Environmental, Economic and Social Sustainability

Analysis and Management of Natural Landscapes. 2018/19

Dr. Josep Antoni Pujantell Albós

Josepantoni.Pujantell@uab.cat
@JosepPujantell

Institute of Environmental Science and Tecnology (ICTA)

Universitat Autònoma de Barcelona

UAB
Universitat Autònoma
de Barcelona

icta
Institut de Ciència
i Tecnologia Ambientals • UAB