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Action 3 – ECo
Report n. 2 (2013-02)
(Action ECo & ECo SI)

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Lead Partner for deliverable: UNIMOL (in Italy); SFI (in Slovenia)

Author
Italy: Daniela Tonti, Gherardo Chirici, Marco Marchetti
Slovenia: Kobler A., Kovač M., Kutnar L.

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Note:
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- Evaluation of the landscape context and land uses changes: "large" area
- Forest spatial pattern classification results: "large" area
- Evaluation of the landscape context: "small" area
- Forest spatial pattern classification results: "small" area
- Maps of landscape ecology metrics

1. Brief summary of contents

1.1. Contents from Sub-action 1 – Activities in Italy

This report refers to the annual progress report of Action Eco, particularly, to the achieved results following the analysis performed at landscape scale in 100 % of test areas (both large and small areas). This report concludes the first phase of Action Eco activities.

The main objectives of Action ECo is to use remote sensing techniques and mapping tools to assess the landscape patterns and the ecological connectivity of the test areas with the neighbouring ecosystems/landscape.

The Action will deal with the evaluation of potential remote-sensing indexes related to Sustainable Forest Management indicators such those connected to carbon stocks/sequestration and structural biodiversity and to check how the management operations may influence ecological connectivity.

Activities performed in the first phase have been mainly focused on characterising the forest landscape spatial pattern of areas subjected to forest management actions (analysed as small area) on the basis of the landscape context, including surrounding forest areas and/or other natural or semi-natural ecosystems in which they appear (analysed as large areas).

Landscape context has been characterized on the basis of indicators derived from landscape ecology analysis.

To develop this objective it was necessary: i) to define the forest/portion of forest (forest management units) subjected to the different forest management actions; ii) to define the landscape context under study (mainly based on zoological aspects); iii) to collect the necessary geographic (layers collection) and non-geographic database to model the investigated landscape area and iv) to select landscape metrics necessaries in order to analyse the landscape context around the different selected sites along the North-South transect in Italy.

In this report the topics discussed in previous annual report will be expanded to provide an overall framework of the activities performed at the end of the first phase.

In this first phase the mainly goal was to describe the landscape pattern configuration before implementing the management operations in both large (100 kmq) and small (10 kmq) areas.

These analyses will be repeated after forest treatments in simulated forest landscape.

Present report is mainly focused on: i) to describe the choice of the landscape portions within perform landscape analysis; ii) to list and describe the acquired dataset and their implementation in Geographic Information System (GIS) platform; iii) to describe the applied methodology of landscape analysis; iv) to list and describe the selected landscape metrics; v) to present achieved results of the landscape analysis for all test sites along the Italian transect.

1.2. *Contents from Sub-action 2 – Activities in Slovenia*

This report refers to the annual progress report of Action Eco-SI, the Slovenian part of the ECo action, which differs somewhat in methods from the Italian part.

The main objectives of Action Eco-SI is to use remote sensing techniques and GIS tools to compare different forest management regimes at the forest stand level (i.e., at the selected forest test sites) and to assess their impacts on forest structures, Carbon balance and biodiversity at the forest stand scale. Another objective is to analyse the forest landscape processes at the regional scale, employing landscape classification by means of metrics such as percent of forest cover, forest core area statistics, land-use pattern, landscape fragmentation, etc.

In order to implement these objectives at the forest stand scale a pre-treatment aerial lidar scanning campaign was performed over the three Slovenian test sites. The 3-D lidar data was processed into high-resolution raster maps, relating to the gradients of bare ground relief, vegetation height, and canopy cover percentage. These maps were the basis for detailed identification of gaps in canopy cover, continuity of canopy cover and forest stand productivity potential in terms of the amount of photosinthetically active canopy volume.

In fall 2013, the second (i.e., post-treatment) lidar acquisition will be followed by change detection of several lidar based indicators over the test sites in order to compare different forest management regimes and to assess their impacts at the forest stand level.

The analyses at the landscape level were done with the current forest map. The forest core area metrics were evaluated, while the landscape fragmentation / connectivity is in the process of evaluation.

The present report is mainly focused on the methodology and results at the forest stand scale using pre-treatment lidar remote sensing. In the next reporting period the post-treatment lidar data will be processed, and lidar based change decetction will be used to glean the impacts of different treatment regimes in forest stand structure. At the landscape scale the forest core area analysis is presented. Further analyses relating to landscape fragmentation / connectivity will be performed in the next reporting period.

2. Report on performed activities

2.1. Performed activity from Sub-action 1 – Activities in Italy

2.1.1. Definition of the landscape context

Test areas have been selected during Preparatory Action (PA) of the project.

The small size of foreseen forest treatments (about 3 ha for each type) inside plots (about 30 ha size) makes it difficult to identify forest spatial pattern for these sites. For this reason, to carry out the Action ECo has been proposed to extend the impact analysis caused by the different treatments at landscape scale (Figure 1).

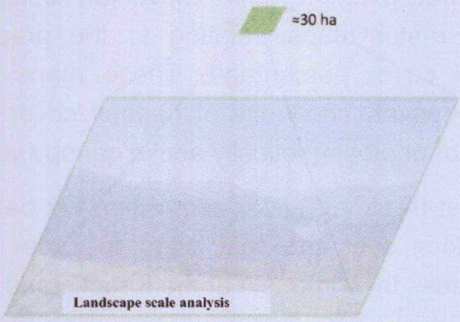


Figure 1: Relationship between the experimental plots subjected to forest management actions (size of about 30 ha) (small area) and the landscape where they appear (large area).

The proposed approach has been submitted, discussed and shared with the other LIFE parties during the PA.

Areas subject to the different forest management treatments (identified by CRA research group) have about 30 ha size and have been selected from those presents in the forest assessment plans.

In order to spatially define the landscape context under study and to make the landscape analysis comparable for all test areas, starting from centroid of each “assessment unit” (AU) (about 30 ha), two frames of different size (a big frame of 100 km^2 includes a smaller frame of 10 km^2) including the surrounding landscape have been drawn for all test sites (Figure 2).

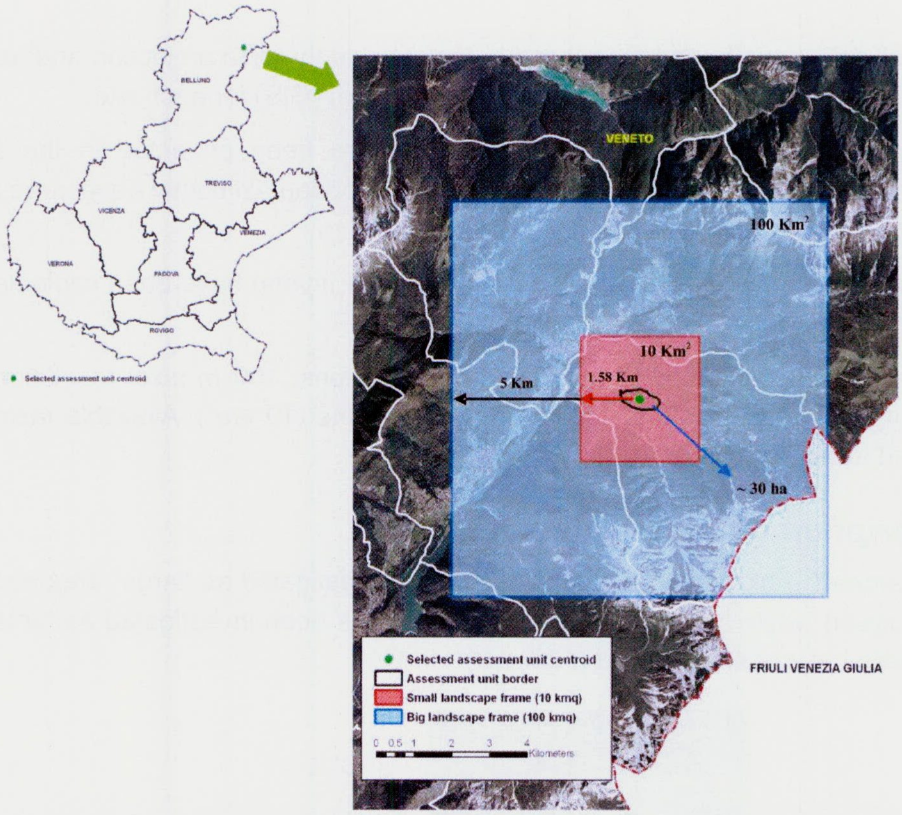


Figure 2: Example of the spatial definition of landscape investigation areas for Lorenzago di Cadore forest test area.

For each test areas the big frame (100 km^2) has been investigated as “large” area and land cover/land use maps have been analysed, while the smaller frame (10 km^2) has been investigated as “small” area and forest maps have been analysed.

2.1.2. Database availability and harmonisation

For each test areas following geographic information have been acquired:

- land cover/land use maps;
- existing forest types maps;
- digitalised forest cover maps, where non available;
- main roads and railway;
- main urban areas;
- river networks and water bodies;
- protected areas limits;
- forest assessment units limits;
- Digital Elevation Models (DEM).

For each site all data have been harmonised in terms of geographic projection and resolution and integrated in seven different Geographic Information System (GIS) for each site.

All acquired geographic layers for each test sites have been projected in the ETRS-LAEA projection: pan European CRS with datum ETRS89 in European azimuthal equal area according to the INSPIRE infrastructure.

All acquired geographic databases (both vector and raster layers) have been implemented in GIS environment.

Vector files have been rasterized at two different resolutions: 100 m pixel resolution for the big frame (100 km^2) and 10 m pixel resolution for smaller frame (10 km^2). Available raster data have been resampled at the two resolutions.

2.1.3. Description of geographic dataset

For each test areas the big frame (100 km^2) has been investigated as "large" area and CLC maps have been analysed, while the smaller frame (10 km^2) has been investigated as "small" area and forest cover maps have been analysed (Figure 3).

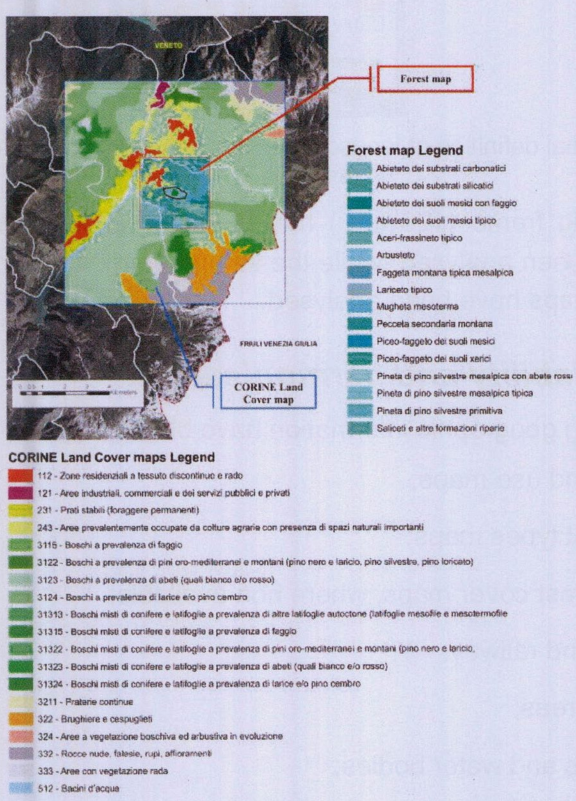


Figure 3: Example of forest and land cover maps in the Lorenzago di Cadore forest test area.

- Land use/land cover maps

Land cover/land use maps derive from Italian CORINE Land Cover (CLC) project and have been acquired at the three available date: 1990, 2000 and 2006 (scale 1:100.000). For years 2000 and 2006 a fourth classification level for natural and semi-natural areas is available.

Within the CORINE Land Cover program only Italy has produced a fourth classification level for natural and semi-natural class. Since this level is not available in other European countries, for our analysis we considered only the third level classification for each test site.

The CLC classes observed within large areas of test sites are listed in the table of Figure 4.

Level 1		Level 2		Level 3	
1	ARTIFICIAL SURFACES				
		1	Urban fabric		
				1.1.2	Continuous urban fabric
		1	Industrial, commercial and transport units		
				1.2.1	Industrial or commercial units
				1.2.2	Road and rail networks and associated land
		1	Mine, dump and construction sites		
				1.3.1	Mineral extraction sites
				1.3.3	Construction sites
2	AGRICULTURAL AREAS				
		2	Arable land		
				2.1.1	Non-irrigated arable land
		2	Permanent crops		
				2.2.1	Vineyards
				2.2.3	Olive groves
		2	Pastures		
				2.3.1	Pastures
		2	Heterogeneous agricultural areas		
				2.4.1	Annual crops associated with permanent crops
				2.4.2	Complex cultivation patterns
				2.4.3	Land principally occupied by agriculture, with significant areas of natural vegetation
3	FOREST AND SEMI NATURAL AREAS				
		3	Forests		
				3.1.1	Broad-leaved forest
				3.1.2	Coniferous forest
				3.1.3	Mixed forest
		3	Scrub and/or herbaceous vegetation associations		
				3.2.1	Natural grasslands
				3.2.2	Moors and heathland
				3.2.3	Sclerophyllous vegetation
				3.2.4	Transitional woodland-shrub
		3	Open spaces with little or no vegetation		
				3.3.2	Bare rocks
				3.3.3	Sparsely vegetated areas
5	WATER BODIES				
		5	Inland waters		
				5.1.2	Water bodies

Figure 4: CORINE Land Cover classes (third level) observed within test sites.

- Forest maps

Forest maps (at various spatial scales and reference years) deriving from regional project and with a forest types level classification were available only for five sites (the available maps are listed in Table 1).

Test area	Region	Province	Resolution	Year
Tarvisio Forest	Friuli Venezia Giulia	Udine	1:10.000	1998
Lorenzago di Cadore Forest	Veneto	Belluno	1:10.000	2006 and 2005 (cover <30%)
Cansiglio Forest	Veneto	Treviso	1:10.000	2006 and 2005 (cover <30%)
Chiarano-Sparvera Regional Forest	Abruzzo	L'Aquila	1:10.000	2009
Pennataro Forest	Molise	Isernia	1:10.000	2009
Vallombrosa Forest	Toscana	Firenze	Not available	
Mongiana	Calabria	Vibo Valentia	Not available	

Table 1: Available regional forest maps.

For Tuscany site (Vallombrosa forest) and for Calabria site (Mongiana), forest cover maps were not available.

For small areas (10 km^2 size) of this two sites it was necessary to produce two new forest cover maps. The methodology applied is explained for both Vallombrosa and Mongiana sites.

- Digitalised forest cover maps

- *Forest cover map of Vallombrosa Forest small area (10 km^2)*

For Tuscany Region in 1999 have been produced a vegetation forest map (Arrigoni et al., 1999) (1:250.000) on the basis of field surveys carried out in a sample grid which plot have 205 x 250 m size. To each forest area of 250 x 250 m size has been assigned the code of the dominant species, with coverage over 50 % and, in the case no species reached this level of coverage, has been assigned codes of the most common species (Figure 5).

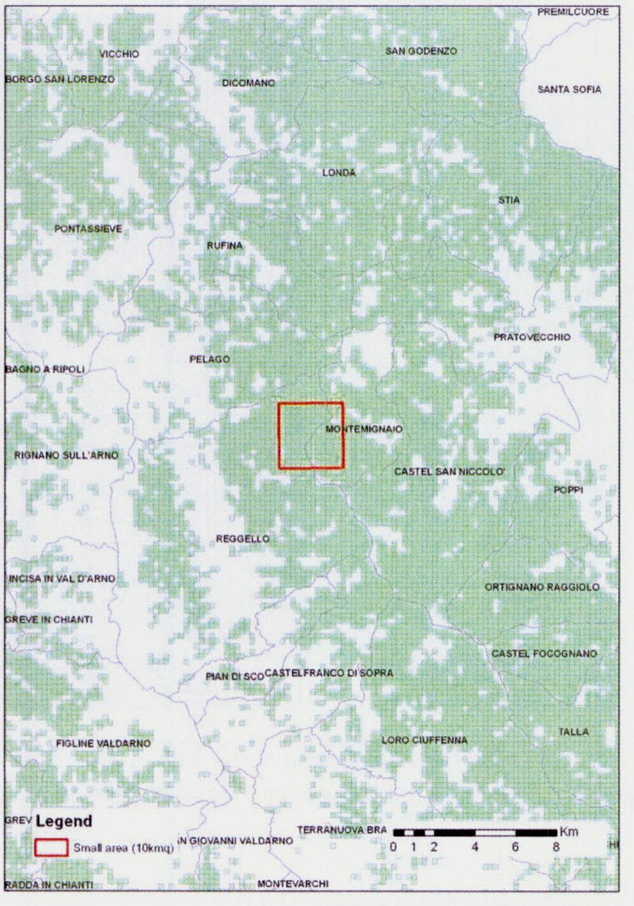


Figure 5: Example of the vegetation forest map of Tuscany Region. The red line is the small (10 kmq) frame of ManForCBD landscape analysis.

On the basis on orthophotos of year 2006 available on the Italian national mapping portal (Portale Cartografico Nazionale - http://www.pcn.minambiente.it/viewer/index.php?services=ortofoto_colore_06.map), a visual interpretation of land forest cover have been produced. To each polygon of the resulting vector layer has been assigned a code according to the forest cover map of Tuscany Region (Figure 6).

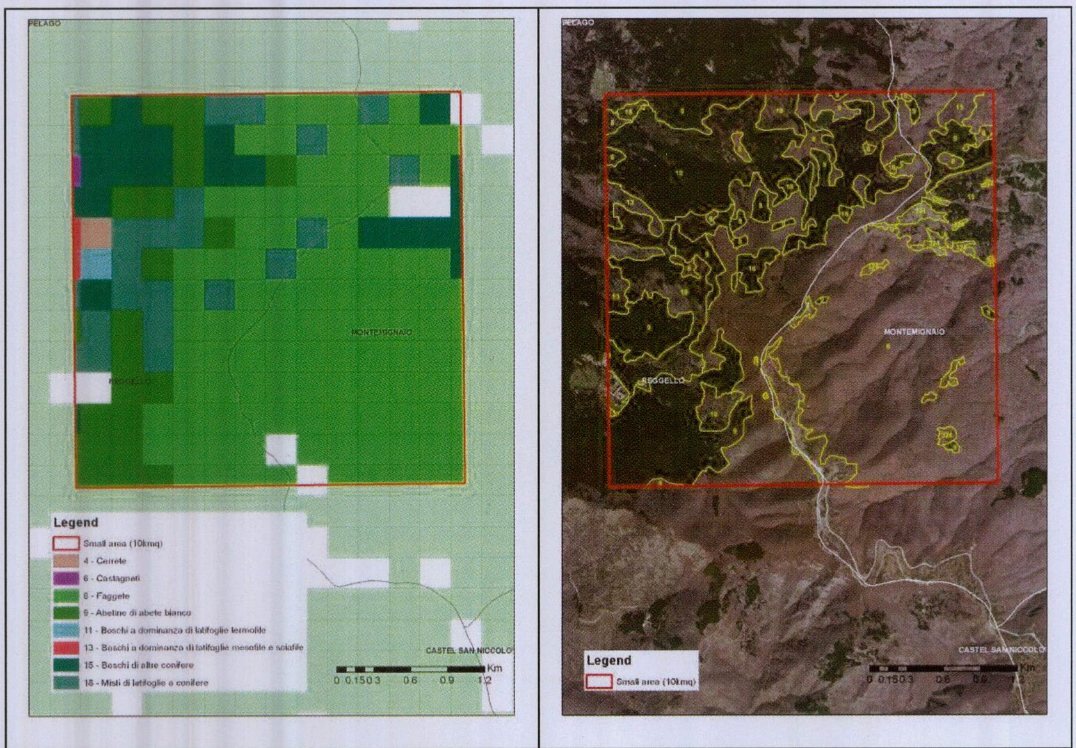


Figure 6: Production of forest cover map for Vallombrosa small area. To the left of the picture: forest cover map of Tuscany Region; to the right of the picture: the visual interpretation result for small area.

- *Forest cover map of Mongiana small area (10 km^2)*

For Calabria Region forest cover map was not available.

On the basis of SPOT-5 satellite image, a preliminary segmentation process has been applied. This procedure (performed by IDRISI Taiga software), groups adjacent pixels into image segments according to their spectral similarity. Results are vector layers of the different levels of selected pixel aggregation algorithm (Figure 7).

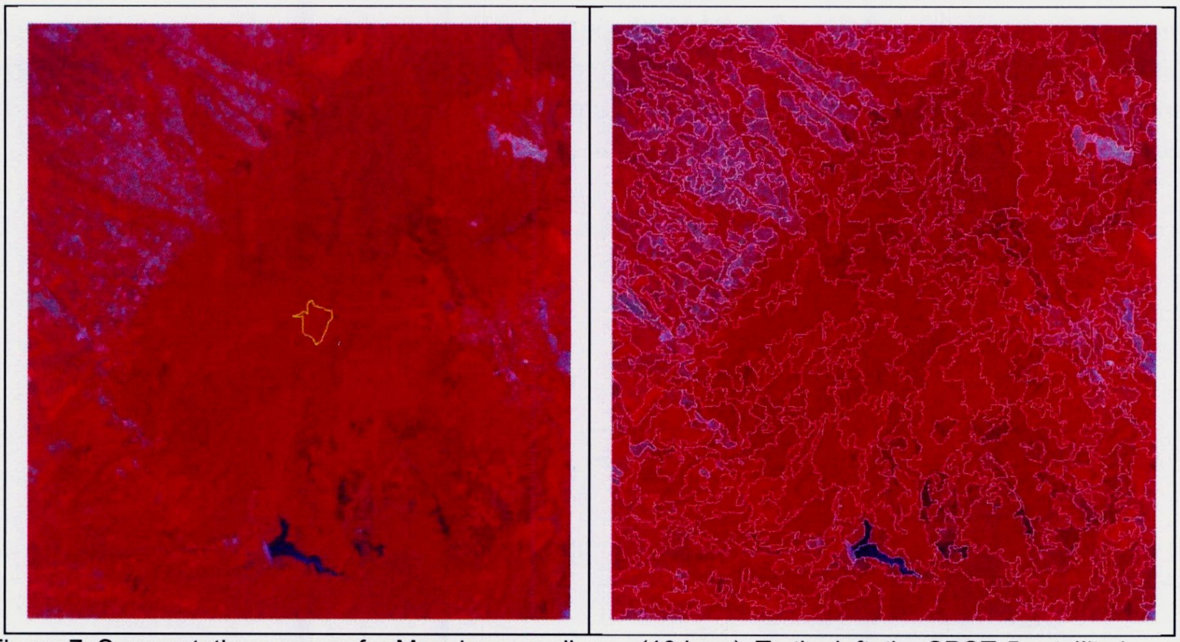


Figure 7: Segmentation process for Mongiana small area (10 kmq). To the left: the SPOT-5 satellite image (frame of 10 kmq size) in false colour (321) of the Mongiana site (Assessment unit is the yellow line); to the right: the segmentation process result.

The segmentation process result have been then used as basis to produce the forest/land cover map throughout the visual interpretation of orthophotos of year 2006 available on the Italian national mapping portal (Portale Cartografico Nazionale - http://www.pcn.minambiente.it/viewer/index.php?services=ortofoto_colore_06.map). To each polygon a CLC third level code has been assigned (Figure 8).

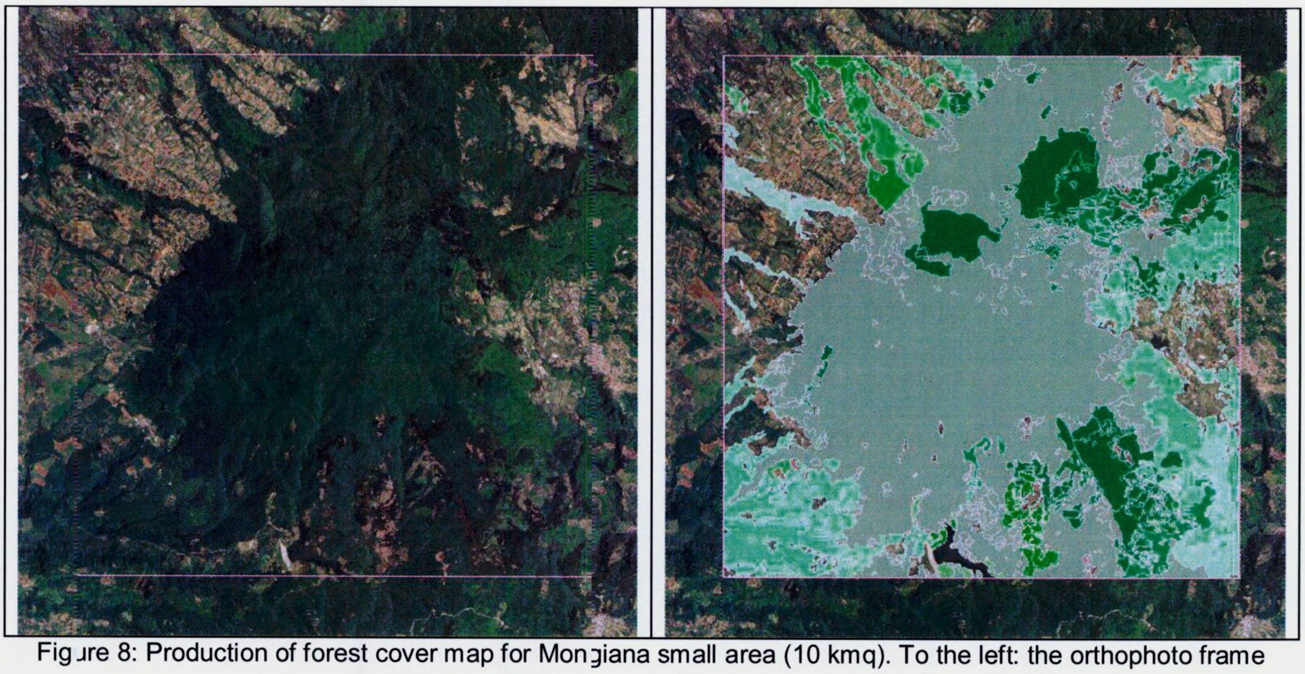


Figure 8: Production of forest cover map for Mongiana small area (10 kmq). To the left: the orthophoto frame of the small area; to the right: result of the visual interpretation process.

In order to compare the different forest landscape along the Italian (North-South) and Slovenian (East-West) transects, for each Italian test site forest cover maps (available for small area) have been reclassified on the basis of the European Forest Types nomenclature system (EEA 2006), at level of forest types where possible (Figure 9).

Table 4.1 European forest types classes

Categories	Types
1. Boreal forest	1.1 Spruce and spruce-birch boreal forest 1.2 Pine and pine-birch boreal forest
2. Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest	2.1 Hemiboreal forest 2.2 Nemoral Scots pine forest 2.3 Nemoral spruce forest 2.4 Nemoral Black pine forest 2.5 Mixed Scots pine-birch forest 2.6 Mixed Scots pine-pedunculate oak forest
3. Alpine coniferous forest	3.1 Subalpine larch-arolla pine and dwarf pine forest 3.2 Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest 3.3 Alpine Scots pine and Black pine forest
4. Acidophilous oak and oak-birch forest	4.1 Acidophilous oakwood 4.2 Oak-birch forest
5. Mesophytic deciduous forest	5.1 Pedunculate oak-hornbeam forest 5.2 Sessile oak-hornbeam forest 5.3 Ashwood and oak-ash forest 5.4 Maple-oak forest 5.5 Lime-oak forest 5.6 Maple-lime forest 5.7 Lime forest 5.8 Ravine and slope forest 5.9 Other mesophytic deciduous forests
6. Beech forest	6.1 Lowland beech forest of southern Scandinavia and north central Europe 6.2 Atlantic and subatlantic lowland beech forest 6.3 Subatlantic submountainous beech forest 6.4 Central European submountainous beech forest 6.5 Carpathian submountainous beech forest 6.6 Illyrian submountainous beech forest 6.7 Moesian submountainous beech forest
7. Mountainous beech forest	7.1 South western European mountainous beech forest (Cantabrians, Pyrenees, central Massif, south western Alps) 7.2 Central European mountainous beech forest 7.3 Apennine-Corsican mountainous beech forest 7.4 Illyrian mountainous beech forest 7.5 Carpathian mountainous beech forest 7.6 Moesian mountainous beech forest 7.7 Crimean mountainous beech forest 7.8 Oriental beech and hornbeam-oriental beech forest
8. Thermophilous deciduous forest	8.1 Downy oak forest 8.2 Turkey oak, Hungarian oak and Sessile oak forest 8.3 Pyrenean oak forest 8.4 Portuguese oak and Mirbeck's oak Iberian forest 8.5 Macedonian oak forest 8.6 Valonia oak forest 8.7 Chestnut forest 8.8 Other thermophilous deciduous forests
9. Broadleaved evergreen forest	9.1 Mediterranean evergreen oak forest 9.2 Olive-carob forest 9.3 Palm groves 9.4 Macaronesian laurisilva 9.5 Other sclerophlyllous forests
10. Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	10.1 Mediterranean pine forest 10.2 Mediterranean and Anatolian Black pine forest 10.3 Canarian pine forest 10.4 Mediterranean and Anatolian Scots pine forest 10.5 Alti-Mediterranean pine forest 10.6 Mediterranean and Anatolian fir forest 10.7 Juniper forest 10.8 Cypress forest 10.9 Cedar forest 10.10 *Tetraclinis articulata* stands 10.11 Mediterranean yew stands
11. Mire and swamp forest	11.1 Conifer dominated or mixed mire forest 11.2 Alder swamp forest 11.3 Birch swamp forest 11.4 Pedunculate oak swamp forest 11.5 Aspen swamp forest
12. Floodplain forest	12.1 Riparian forest 12.2 Fluvial forest 12.3 Mediterranean and Macaronesian riparian forest
13. Non riverine alder, birch, or aspen forest	13.1 Alder forest 13.2 Italian alder forest 13.3 Boreal birch forest 13.4 Southern boreal birch forest 13.5 Aspen forest
14. Plantations and self sown exotic forest	14.1 Plantations of site-native species 14.2 Plantations of not-site-native species and self-sown exotic forest

Figure 9: European Forest Types classes (source: EEA 2006).

From Figure 10 to Figure 16, forest cover classes and corresponding European Forest Categories/Types reclassification have been reported for the seven test sites: Tarvisio Forest, Cansiglio Forest, Lorenzago di Cadore Forest, Vallombrosa Forest, Chiarano-Saprvera Regional Forest, Pennataro Forest and Mongiana.

TARVISIO		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	**EFT code**	**EFT description**
Pic-fagg suoli mesici carbonatici montano	31	Subalpine larch arolla pine and dwarf pine forest
Pic-fagg primitivo	31	Subalpine larch arolla pine and dwarf pine forest
Rimbosch di abete rosso su pic-fagg dei suoli mesici carbonatici montano	141	Plantations of site-native species
Pecceta secondaria montana	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pic-fagg suoli mesici montano	31	Subalpine larch arolla pine and dwarf pine forest
Rimbosch di abete rosso	141	Plantations of site-native species
Aceri-frassi tipic var. esalp interna	54	Maple oak forest
Pic-fagg dei suoli xerici	31	Subalpine larch arolla pine and dwarf pine forest
Pecceta di sostituzione dei suoli mesici	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Mugh microterma dei suoli basici	31	Subalpine larch arolla pine and dwarf pine forest
Pin pino nero primitiva di rupe	33	Alpine Scots pine and Black pine forest
Pin pino nero tipica	33	Alpine Scots pine and Black pine forest
Lariceto tipico dei substr carbonatici	31	Subalpine larch arolla pine and dwarf pine forest
Castagneto dei suoli mesici	87	Chestnut forest
Pin pino silvestre mesalpica con faggio e abete rosso	31	Subalpine larch arolla pine and dwarf pine forest
Betuleto	134	Other birch forest
Rimboschimento di larice su pecceta secondaria montana	141	Plantations of site-native species
Pecceta dei substrati carbonatici altimontana	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pin pino silvestre mesalpica tipica/primitiva	31	Subalpine larch arolla pine and dwarf pine forest
Pecceta azonale su alluvioni	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Abieti-piceo-fagg dei substrati carbonatici montano	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Neocoloniz mesalpica tendente alla pin di pino silv mesalpica con fagg e ab rosso	3	NA* ("Alpine coniferous forest")
Pic-abiet suoli acidi mont var bassomontana	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Neocoloniz avanalpica tendente al castagneto dei suoli mesici	87	Chestnut forest
Pic-abiet dei suoli acidi	31	Subalpine larch arolla pine and dwarf pine forest
Pic-fagg suoli mesici carbo mont var con abete bianco	31	Subalpine larch arolla pine and dwarf pine forest
Neocoloniz a prev di abete rosso	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pic-fagg suoli mesici carbo mont var con larice	31	Subalpine larch arolla pine and dwarf pine forest
Neocoloniz mesalpica	8	NA* ("Thermophilous deciduous forest")
Mugh mesoterma mesoendalpica	31	Subalpine larch arolla pine and dwarf pine forest
Abieti-piceo-fagg suoli mes mont	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pic-abiet suoli mesici montano	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Fagg mont tipica esalpica	74	Illyrian mountainous beech forest
Pic-fagg suoli mesici montano var bassomontana	31	Subalpine larch arolla pine and dwarf pine forest
Ab- pi-fagg alti suoli acidi var. montana	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Ab- pi-fagg alti suoli acidi	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pic-abiet dei suoli mesici carbonatici altimontano	31	Subalpine larch arolla pine and dwarf pine forest
Fagg submont con ostria	66	Illyrian submountainous beech forest
Pecceta altimontana e subalp substr silicatici	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pecceta dei substrati carbonatici altimontana var con larice	31	Subalpine larch arolla pine and dwarf pine forest

* NA (not available): the classification was possible only at EFC level.

Figure 10: European Forest Types nomenclature for Tarvisio forest cover map within small area (10 kmq).

CANSIGLIO		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
Arbusteto	NA*	"Shrubs formation"
Faggeta altimontana	74	Illyrian mountainous beech forest
Faggeta montana tipica esalpica	74	Illyrian mountainous beech forest
For antr di conif su fagg mont tip esalpica	141	Plantations of site-native species
For antr di conif Pecceta su fagg mont tip esalpica	141	Plantations of site-native species

* NA (not available): the classification was possible only at EFC level.

Figure 11: European Forest Types nomenclature for Cansiglio forest cover map within small area (10 kmq).

LORENZAGO DI CADORE		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
Arbusteto	NA*	"Shrubs formation"
Aceri-frassineto tipico	54	Maple oak forest
Saliceti e altre formazioni riparie	121	Riparian forest
Pecceta secondaria montana	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Pineta di pino silvestre mesalpica con abete rosso	31	Subalpine larch arolla pine and dwarf pine forest
Lariceto tipico	31	Subalpine larch arolla pine and dwarf pine forest
Pineta di pino silvestre primitiva	31	Subalpine larch arolla pine and dwarf pine forest
Abieteto dei substrati carbonatici	32	Subalpine and mountainous spruce and mountainous mixed spruce- silver fir forest
Abieteto dei substrati silicatici	32	Subalpine and mountainous spruce and mountainous mixed spruce- silver fir forest
Abieteto dei suoli mesici tipico	32	Subalpine and mountainous spruce and mountainous mixed spruce- silver fir forest
Pineta di pino silvestre mesalpica tipica	31	Subalpine larch arolla pine and dwarf pine forest
Piceo-faggeto dei suoli xerici	31	Subalpine larch arolla pine and dwarf pine forest
Mugheta mesoterma	31	Subalpine larch arolla pine and dwarf pine forest
Abieteto dei suoli mesici con faggio	32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest
Piceo-faggeto dei suoli mesici	31	Subalpine larch arolla pine and dwarf pine forest
Faggeta montana tipica mesalpica	74	Illyrian mountainous beech forest

* NA (not available): the classification was possible only at EFC level.

Figure 12: European Forest Types nomenclature for Lorenzago di Cadore forest cover map within small area (10 kmq).

VALLOMBROSA		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
Abetine di abete bianco	106	Mediterranean and Anatolian fir forest
Boschi di altre conifere	141	Plantations of site-native species
Misti di latifoglie e conifere	73	Apennine Corsican mountainous beech forest
Faggete	73	Apennine Corsican mountainous beech forest
Castagneti	87	Chestnut forest
Boschi a dominanza di latifoglie mesofile e sciafile	73	Apennine Corsican mountainous beech forest
Aree in evoluzione	NA*	"Shrubs formation"

* NA (not available): the classification was possible only at EFC level.

Figure 13: European Forest Types nomenclature for Vallombrosa forest cover map within small area (10 kmq).

CHIARANO-SPARVERA		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
Boscaglia faggeta	73	Apennine Corsican mountainous beech forest
Rim di conifere	141	Plantations of site-native species
Arbusteto a prev di rose e prugnolo	NA*	"Shrubs formation"

* NA (not available): the classification was possible only at EFC level.

Figure 14: European Forest Types nomenclature for Chiarano-Sparvera forest cover map within small area (10 kmq).

PENNATARO		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
cerreta mesofila	81	Downy oak forest
faggeta submontana	63	Subatlantic submountainous beech forest
faggeta montana	73	Apennine-Corsican mountainous beech
arbusteto a rose prugnolo e rovo	NA*	"Shrubs formation"
pioppo saliceto ripariale	121	Riparian forest
latifoglie di invasione miste e varie	141	Plantations of site-native species
cerreta mesoxerofila	81	Downy oak forest

* NA (not available): the classification was possible only at EFC level.

Figure 15: European Forest Types nomenclature for Pennataro forest cover map within small area (10 kmq).

MONGIANA		
European Forest Types classification of forest cover map classes within small area (10 kmq)		
TYPE	EFT code	EFT description
Boschi misti di conifere e latifoglie a prevalenza di faggio	73	Apennine-Corsican mountainous beech
Boschi a prevalenza di faggio	63	Subatlantic submountainous beech forest
Boschi misti di conifere e latifoglie a prevalenza di pini montani e oromediterranei	102	Mediterranean and Anatolian Black pine forest

Figure 16: European Forest Types nomenclature for Mongiana forest cover map within small area (10 kmq).

- Settlements and communication networks

For each test sites, vector files of main towns and cities and main roads and railway network have been also acquired.

Settlements localization have been extracted by CORINE Land Cover maps and communication networks have been acquired from national and, where available, regional geographic informations.

These informations will be used to evaluate the potential anthropogenic disturbances on forest biodiversity (with emphasis on forest fauna), after the identification of connected zoological aspects (related to the selected fauna indicator species) that will be defined in future phases of the action ECo and ForBD.

- River networks and water bodies

Water bodies and main river network have been derived mainly from CORINE Land Cover maps and if available, from regional informations and have been acquired for each site.

Their localization will be used in the future action activities to identify potential geographic barriers to fauna species movement.

- Protected areas

Protected areas limits presents in each test sites have been also acquired.

Localization of protected areas will be take into consideration in the future planning of the good practices of Sustainable Forest Management (SFM) linked to biodiversity at landscape level and to the ecological functions of managed areas.

- Forest assessment units

Geographic localization of forest assessment units have been acquired from forest assessment plans for each site.

The “assessment units” (AU), of about 30 ha size, are sites where forest managements treatments will be implement. From centroid of each AU (or from the centroid between near assessment units in the case of they were more then one) the landscape context dimension in which to develop landscape spatial pattern analysis has been spatially defined.

A brief description of the three AU is reported in Table 2.

Site name	*Geographic localization*		*Size (ha)*	*Regional forest types*
	*Geographic Coordinates (ETRS89-LAEA)**			
	East	*North*		
Tarvisio forest	4597793	2603880	25.9	Mountain spruce (Picea-abies) and silver fir (Abies alba) forests and spuce and beech (*Fagus sylvatica*) forests
Cansiglio forest	4505270	2550700	43.5	Mountain beach forest
Lorenzago di Cadore forest	4510890	2598250	38.3	Abies alba forest on carbonatic substrate
Vallombrosa forest (AU n. 31)	4448281	2293570	16.4	Beech (*Fagus sylvatica*) forest
Vallombrosa forest (AU n. 37)			11.4	
Chiarano-Sparvera regional forest (AU n. 28)	4651860	2091600	25.5	Beach forest
Chiarano-Sparvera regional forest (AU n. 29)			18.1	Beach forest
Pennataro forest	4671003	2080450	31.5	Thermophilous deciduous forests (*Quercus cerris*) and beech forests
Mongiana	4868427	1735067	20.3	Beach forest
* Coordinates refers to the AU centroids.				

Table 2: Description of the identified assessment units (AU).

Figure 17: Test areas localization.

- Digital elevation models (DEM)

Digital elevation models (DEM) have been acquired for each test site. Where available, DEM with high resolution levels have been preferred (pixel wide: 5 m), otherwise, a DEM at national scale with 20 m pixel resolution has been acquired.

Altitudes and slopes informations will be taking into consideration in the future planning of the good practices of SFM and forest functions.

2.1.4. Applied methodology in the investigation of test areas

Landscape context and landscape indexes to calculate in order to describe the ex-ante situation of study areas have been defined considering aspects investigated within the European project: "Linking and harmonizing the forest spatial pattern analyses at European, national and regional scales for a better characterization of the forests vulnerability and resilience" related to the existing linking between the forest landscape spatial pattern characteristics (with emphasis on habitat fragmentation and connectivity) and the forest fauna biodiversity. This European project (contract 382391 FISC following Tender 176-174131), launched by the Joint Research Centre of the European Commission, Institute for Environment an Sustainability (JRC-IES) located in Ispra (Varese-Italy), entered in force in November 2006 and ended in March 2009, has been coordinated by the UNIMOL. The complete report is available at URL: http://publications.jrc.ec.europa.eu/repository/handle/111111111/13606.

The protocol of landscape analysis has been tested before in one single site ("Lorenzago di Cadore" forest site) and then implements in all sites.

This methodology was applied to describe the ex-ante landscape spatial pattern situation and will be replicated after forest treatments application within simulated landscapes.

In order to evaluate the landscape context in which each forest study areas appear, landscape analysis have been applied and landscape ecology metrics have been calculated.

In each study areas landscape has been investigated at two spatial scale levels: low detail level, within the big frame (of 100 km^2 size), where the landscape context around each forest study areas have been analysed on CLC raster dataset (100 m pixel resolution); high detail level, within the smaller frame (of 10 km^2 size) where landscape has been analysed on forest cover raster dataset (10 m pixel resolution) for each test areas.

In order to correlate the landscape composition to the topographic characteristics, altitudes and slopes features (expressed in percentage) have been extracted for both large and small areas from the acquired national digital elevation model (DEM) at 20 meters resolution.

The slope features have been grouped in six classes (Table 3):

Class	*Description*	*Slope (%)*
1	Flat lands	< 3%
2	Gently undulating slopes	3 - 10 %
3	Moderate slopes	10 - 20 %
4	Moderately steep slopes	20 - 30 %
5	Very steep slope	30 - 50 %
6	Steeps	> 50 %

Table 3: Description of slope classes.

For large areas (100 km^2) topographic characteristics have been referred to the year 2006.

In action ECo different landscape metrics have been computed by FRAGSTAT software (McGarigal & Marks 1995). Each calculated metric have been mapped for each test site (both for large and small area).

Landscape metrics aim to numerically describes geometrics and spatial characteristics of landscapes allowing comparisons in term of composition and configuration of the elements characterising different landscape mosaics.

Each selected landscape metric has a specific ecological utility, in particular for fauna species investigations.

Metrics analysis allowed to evaluate the landscape composition of both defined large and small areas for each test site.

For large areas (100 km^2) only, landscape composition changes between the available dates of CLC data (1990, 2000 and 2006) have been also evaluated and a Cross-Tabulation (CROSSTAB) operation by *Idrisi Selva* software (Eastman, 2003) has been performed for the time period 1990-

2006. This operation has generated a cross tabulation matrix (or contingency matrix) which shows change rates of each land use class within the large area landscape.

Forest landscape level forest spatial pattern has been also investigated at the two spatial scale levels and at temporal scale level (for large areas only).

Landscape level forest spatial pattern refers to the spatial arrangement or configuration of forested ecosystems across the landscape and has been mapped by applying the mathematical morphology based freeware GUIDOS (Graphical User Interface for the Detection of Objects and Shapes) software (developed by the JRC-IES and available at URL: http://forest.jrc.ec.europa.eu/download/software/guidos), on all binary forest (forest type)/non forest maps.

Performed landscape analysis allowed quantitative evaluations of the landscape context in pre-treatments conditions and will be repeated in the second phase of the project to analyse the forest landscape spatial pattern and its possible changes in the post-treatments conditions in each test area.

2.1.5. Applied landscape ecology metrics

Within the main groups of metrics available in FRAGSTATS have been selected those described below.

Area metrics

Area metrics quantify landscape composition, not landscape configuration.

Follow metrics have been calculated:

- *Patch area metric* (AREA) (*per patch*). The area of each patch comprising a landscape mosaic is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but patch area has a great deal of ecological utility in its own right (McGarigal & Marks 1995).

AREA equals the area (m^2) of the patch (divided by 10000 to convert to hectares):

$$(1)\ AREA = a_{ij}\left(\frac{1}{10000}\right)$$

Where:

a_{ij} = area (m^2) of patch *ij*

The range is AREA > 0, without limit.

The range in AREA is limited by the grain and extent of the image. In a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain (McGarigal & Marks 1995).

- *Class area* (CA) (*per class*). Is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type. In addition to its direct interpretive value, class area is used in the computations for many of the class and landscape metrics.

CA equals the sum of the areas (m^2) of all patches of the corresponding patch type (divided by 10000 to convert to hectares), that is, "total class area" (TA) (McGarigal & Marks 1995):

$$(2)\ CA = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10000}\right)$$

Where

a_{ij} = area (m^2) of patch *ij*

The range is CA > 0, without limit.

CA approaches 0 as the patch type becomes increasing rare in the landscape. CA = TA when the entire landscape consists of a single patch type (that is, when the entire image is comprised of a single patch) (McGarigal & Marks 1995).

- *Mean patch size* (AREA_MN) (*per class*). Is equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by the number of patches of the same type, divided by 10000 (to convert to hectares).

$$(3)\ AREA\_MN = \frac{\sum_{j=1}^{n} a_{ij}}{n_i} \left(\frac{1}{10000}\right)$$

Where

n_i = number of patches in the landscape of class type *i*

The range is AREA_MN > 0, without limit.

The range in AREA_MN is limited by the grain and extent of the image and the minimum patch size in the same manner as patch area (AREA).

- *Percentage of landscape* (PLAND) (*per class*). Is the percentage of landscape occupied by each patch type. PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, PLAND equals the percentage the landscape comprised of the corresponding patch type (McGarigal & Marks 1995):

$$(4)\ PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$$

Where:

P_i = proportion of the landscape occupied by patch type (class) *i*.

a_{ij} = area (m^2) of patch *ij*.

A = total landscape area (m^2).

The range is $0 < PLAND \le 100$.

PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch (McGarigal & Marks 1995).

- *Largest patch index* (LPI) (*per class*). Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance (McGarigal & Marks 1995).

LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch (McGarigal & Marks 1995).

$$(5)\ LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$$

Where

a_{ij} = area (m^2) of patch *ij*.

A = total landscape area (m^2).

LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.

Edge metrics

Edge effect is highly variable and dependent upon habitat type, the composition of adjacent patches and the species under examination (Betts 2000). The perimeter has been identified by GUIDOS classification with a fixed depth-of-edge distance of 100 m.

The following metrics have been selected:

- *Edge* (PERIM) (*per patch*). The sum of all patch perimeters within a landscape (landscape level) or the sum of perimeters of a particular class (class level), in map units.

Patch *perimeter* is another fundamental piece of information available about a landscape and is the basis for many class and landscape metrics. Specifically, the perimeter of a patch is treated as an edge, and the intensity and distribution of edges constitutes a major aspect of landscape pattern. In addition, the relationship between patch perimeter and patch area is the basis for most shape indices (McGarigal & Marks 1995).

It is directly affected by the landscape size. At the class level, high total edge implies that the class is made up of small or convoluted patches. At the landscape level, total amount of edge is directly related to the degree of spatial heterogeneity in that landscape (McGarigal & Marks 1995):

$$(6) PERIM = p_{ij}$$

Where

p_{ij} = perimeter (m) of patch *ij*.

The range is PERIM > 0, without limit.

<u>Core Area metrics</u>

Core areas have been defined on the basis of the GUIDOS classification results.

Core area is a simple measurement of area. Core area is defined as the total available habitat minus the edge effect (Betts 2000).

For our purposes according to the methodology applied in JRC project see above, a depth-of-edge of 100 m has been used.

Core areas indicate interior areas of a patch, which retain similar abiotic and biotic conditions to pre-fragmented conditions and do not experience strong influences from neighbouring patches (Rutledge 2003).

The following metrics have been calculated:

- *Core Area* (CORE) (*per patch*). *Core area* represents the area in the patch greater than the specified depth-of-edge distance from the perimeter.

CORE equals the area (m^2) within the patch that is further than the specified depth-of-edge distance (100 m) from the patch perimeter, divided by 10000 (to convert to hectares) (McGarigal & Marks 1995):

$$(7) CORE = a_{ij}^{c}\left(\frac{1}{10000}\right)$$

Where

a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m).

The range is CORE ≥ 0, without limit.

CORE = 0 when every location within the patch is within the specified depth-of-edge distance from the patch perimeter. CORE approaches AREA as the specified depth-of-edge distance(s) decreases and as patch shape is simplified.

- *Total Core Area* (TCA) (*per class/landscape*). TCA equals the sum of the core areas of each patch (m^2) of the corresponding patch type, divided by 10000 (to convert to hectares) (McGarigal & Marks 1995):

$$(8) TCA = \sum_{j=1}^{n} a_{ij}^{c}\left(\frac{1}{10000}\right)$$

Where

a_{ij}^{c}= core area (m^2) of patch *ij* based on specified edge depths (m).

The range is TCA ≥ 0, without limit.

TCA = 0 when every location within each patch of the corresponding patch type is within the specified depth-of-edge distance(s) from the patch perimeters. TCA approaches total class area (CA) as the specified depth-of-edge distance(s) decreases and as patch shapes are simplified (McGarigal & Marks 1995).

- *Core Area Percentage of Landscape* (CPLAND) (*per class*). Is defined the same as core area (CORE) at the patch level (see Core Area), but here core area is aggregated (summed) over all patches of the corresponding patch type and computed as a percentage of the total landscape area, which facilitates comparison among landscape of varying size.

CPLAND equals the sum of the core areas of each patch (m^2) of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, CPLAND equals the percentage the landscape comprised of core area of the corresponding patch type (McGarigal & Marks 1995):

$$(9)\, CPLAND = \frac{\sum_{j=1}^{n} a_{ij}^{c}}{A}(100)$$

Where

a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m).

A = total landscape area (m^2).

The CPLAND is expressed in percent and the range is $0 \leq CPLAND < 100$.

CPLAND approaches 0 when core area of the corresponding patch type (class) becomes increasingly rare in the landscape, because of increasing smaller patches and/or more convoluted patch shapes. CPLAND approaches 100 when the entire landscape consists of a single patch type (i.e., when the entire image is comprised of a single patch) and the specified depth-of-edge distance(s) approaches zero (McGarigal & Marks 1995).

Patch density, patch size and variability metrics

These metrics usually are best considered as representing landscape configuration, even though they are not spatially explicit measures (McGarigal & Marks 1995).

The following metrics have been selected:

- *Number of patches indexes* (NP) (*per class/landscape*). This index measures the number of patches of a particular class. It depends on patch definition and data resolution. NP equals the number of patches of the corresponding patch type (class).

Number of patches of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type. Although the number of patches in a class may be fundamentally important to a number of ecological processes, often it has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics (McGarigal & Marks 1995):

$$(10)\, NP = n_i$$

Where

n_i = number of patches in the landscape of patch type (class) *i*.

The range is NP ≥ 1, without limit.

NP = 1 when the landscape contains only 1 patch of the corresponding patch type (that is, when the class consists of a single patch) (McGarigal & Marks 1995).

- *Patch density index* (PD) (*per class/landscape*). The number of patches of a particular class per unit area. PD equals the number of patches of the corresponding patch type divided by total landscape area (m^2), multiplied by 10000 and 100 (to convert to 100 hectares). PD is express in Number per 100 hectares.

Patch density is a limited, but fundamental, aspect of landscape pattern. Patch density has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. Of course, if total landscape area is held constant, then patch density and number of patches convey the same information. Like number of patches, patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches (McGarigal & Marks 1995):

$$(11)\, PD = \frac{n_i}{A}(10000)(100)$$

Where

n_i= number of patches in the landscape of patch type (class) *i*.

A= total landscape area (m^2).

The range is PD > 0, constrained by cell size.

PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class (i.e., in a checker board manner; because adjacent cells of the same class would be in the same patch) (McGarigal & Marks 1995).

<u>Patch shape metrics</u>

Patch shape metrics attempt to quantify patch complexity, which can be important for different ecological processes (Forman 1998).

Numerous metrics exists for evaluating patch shapes but this landscape feature remains the most difficult to measure effectively. Measuring patch shape has proven to be problematic in that no single measurement or index of shape can unambiguously differentiate all shapes (Forman 1998).

The following metrics have been selected:

- *Shape index* (SHAPE) (per patch). SHAPE measures the complexity of patch shape compared to a standard shape.

In the raster version of FRAGSTATS, patch shape is evaluated with a square standard; shape index in minimum for square patches and increases as patches becomes increasingly no square.

SHAPE equals patch perimeter (m) divided by the square root of patch area (m^2), adjusted by a constant to adjust for a square standard (raster).

$$(12)\, SHAPE = \frac{0.25 p_{ij}}{\sqrt{a_{ij}}}$$

Where

p_{ij} = perimeter of patch *ij* in terms of number of cell surfaces

a_{ij}= the minimum perimeter for an aggregate of like-valued square pixels

SHAPE ≥ 1, without limit.

SHAPE = 1 when the patch is maximally compact (i.e., square or almost square) and increases without limit as patch shape becomes more irregular (McGarigal & Marks 1995).

- *Fractal dimension index* (FRAC) (*per patch*). Is appealing because it reflects shape complexity across a range of spatial scales (patch sizes). Thus, it overcomes one of the major limitations of the straight perimeter-area ratio as a measure of shape complexity (McGarigal & Marks 1995).

FRAC equals 2 times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m^2); the perimeter is adjusted to correct for the raster bias in perimeter (McGarigal & Marks 1995):

$$(13)\, FRAC = \frac{2 \ln(0.25 p_{ij})}{\ln a_{ij}}$$

Where

p_{ij} = perimeter (m) of patch *ij*.

a_{ij} = area (m^2) of patch *ij*.

The range is 1 ≤ FRAC ≤ 2.

A fractal dimension greater than 1 for a 2-dimensional patch indicates a departure from Euclidean geometry (i.e., an increase in shape complexity). FRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters (McGarigal & Marks 1995).

- *Mean Shape index* (SHAPE_MN) (*per class*). Mean shape index represent the same basic information as the corresponding patch indices (patch shape index), but instead of considering a single patch, it consider all patches of a particular type simultaneously.

Mean shape index measures the average patch shape (or the average perimeter-to-area ratio), for a particular patch type (class) or for all patches in the landscape.

Mean shape index equals the sum of the patch perimeter (m) divided by the square root of patch area (m^2) for each patch of the corresponding patch type, adjusted by a constant to adjust for square standard (raster), divided by the number of patches of the same type; in other words, SHAPE_MN equals the average shape index (SHAPE) of patches of the corresponding patch type.

$$(14)\, SHAPE\_MN = \frac{\sum_{j=1}^{n}\left(\frac{0.25 p_{ij}}{\sqrt{a_{ij}}}\right)}{n_i}$$

Where

n_i = number of patches of the same type.

The range is SHAPE_MN ≥ 1, without limit.

SHAPE_MN = 1 when all patches of the corresponding patch type are square (raster); SHAPE_MN increases without limit as the patch shapes become more irregular (McGarigal & Marks 1995).

- *Mean fractal dimension* (FRAC_MN) (*per class*). Mean fractal dimension equals the sum of 2 times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m2) for each patch of the corresponding patch type, divided by the number of patches of the same type; the raster formula is adjusted to correct for the bias in perimeter (McGarigal & Marks 1995).

$$(15)\, FRAC\_MN = \frac{\sum_{j=1}^{n}\left(\frac{2\ln(0.25 p_{ij})}{\ln a_{ij}}\right)}{n_i}$$

Where

a_{ij} = area (m2) of patch *ij*

n_i = number of patches of the same type.

The range is 1 ≤ FRAC_MN ≤ 2

A fractal dimension greater than 1 for a 2-dimensional landscape mosaic indicates a departure from a Euclidean geometry (that is, an increase in patch shape complexity). FRAC_MN approaches 1 for shapes with very simple perimeters, such squares (raster), and approaches 2 for shapes with highly convoluted, plane-filling perimeters.

Nearest neighbor metrics

Nearest neighbor distance is defined as the distance from a patch to the nearest neighboring patch of the same type, based on edge-to-edge distance. Nearest neighbor metrics quantify landscape configuration.

Nearest neighbor distance can influence a number of important ecological processes. For example, there has been a proliferation of mathematical models on population dynamics and species interactions in spatially subdivided populations, and results suggest that the dynamics of local plant and animal populations in a patch are influenced by their proximity to other subpopulations of the same or competing species (McGarigal & Marks 1995).

The follow metrics has been selected:

- *Euclidean Nearest Neighbor distance* (ENN) (*per patch*). Euclidean nearest-neighbor distance is perhaps the simplest measure of patch context and has been used extensively to quantify patch isolation. Here, nearest neighbor distance is defined using simple Euclidean geometry as the shortest straight-line distance between the focal patch and its nearest neighbor of the same class.

ENN equals the distance (m) to the nearest neighboring patch of the same type, based on shortest edge-to-edge distance (defined as 100 meters). The edge-to-edge distances are from cell center to cell center.

$$(16)\ ENN = h_{ij}$$

Where

h_{ij} = distance (m) from patch *ij* to nearest neighboring patch of the same type (class), based on patch edge-to-edge distance, computed from cell center to cell center.

The range is ENN > 0, without limit.

ENN approaches 0 as the distance to the nearest neighbor decreases. The minium ENN is constrained by the cell size, and is equal to twice the cell size when the 8-neighbor patch rule is used or the distance between diagonal neighbors when the 4-neighbor rule is used. The upper limit is constrained by the extent of the landscape. ENN is undefined and reported as inapplicable ("N/A" in the "basename" patch file) if the patch has no neighbors (i.e., no other patches of the same class) (McGarigal & Marks 1995).

Figure 18 reports metrics summarization.

Metric types	Scale	Acronym	Unit	Range	
Area metrics	Patch	AREA	Hectares	AREA > 0, without limit.	The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Area metrics	Class	CA	Hectares	CA > 0, without limit.	CA approaches 0 as the patch type becomes increasing rare in the landscape. CA = TA when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Area metrics	Class	AREA_MN	Hectares	AREA > 0, without limit.	
Area metrics	Class	PLAND	Percent	0 < PLAND ≤ 100	PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch
Area metrics	Class	LPI	Percent	0 < LPI ≤ 100	LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.
Edge metrics	Patch	PERIM	Meters	PERIM > 0, without limit.	
Core area metrics	Class	TCA	Hectares	TCA ≥ 0, without limit.	TCA = 0 when every location within each patch of the corresponding patch type is within the specified depth-of-edge distance(s) from the patch perimeters. TCA approaches total class area (CA) as the specified depth-of-edge distance(s) decreases and as patch shapes are simplified.
Core area metrics	Class	CPLAND	Percent	0 ≤ CPLAND < 100	CPLAND approaches 0 when core area of the corresponding patch type (class) becomes increasingly rare in the landscape, because of increasing smaller patches and/or more convoluted patch shapes. CPLAND approaches 100 when the entire landscape consists of a single patch type (i.e., when the entire image is comprised of a single patch) and the specified depth-of-edge distance(s) approaches zero.
Patch density, patch size and variability metric	Class	NP	None	NP ≥ 1, without limit.	NP = 1 when the landscape contains only 1 patch of the corresponding patch type; that is, when the class consists of a single patch.
Patch density, patch size and variability metric	Class	PD	Number per 100 hectares	PD > 0, constrained by cell size.	PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class (i.e., in a checker board manner; because adjacent cells of the same class would be in the same patch).
Shape metrics	Class	SHAPE_MN	None	SHAPE ≥ 1, without limit.	
Shape metrics	Class	FRAC_MN	None	1 ≤ FRAC ≤ 2	
Shape metrics	Patch	SHAPE	None	SHAPE ≥ 1, without limit.	SHAPE = 1 when the patch is maximally compact (i.e., square or almost square) and increases without limit as patch shape becomes more irregular.
Shape metrics	Patch	FRACT	None	1 ≤ FRAC ≤ 2	A fractal dimension greater than 1 for a 2-dimensional patch indicates a departure from Euclidean geometry (i.e., an increase in shape complexity). FRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters.
Nearest neighbor metrics	Patch	ENN	Meters	ENN > 0, without limit.	ENN approaches 0 as the distance to the nearest neighbor decreases. The minium ENN is constrained by the cell size, and is equal to twice the cell size when the 8-neighbor patch rule is used or the distance between diagonal neighbors when the 4-neighbor rule is used. The upper limit is constrained by the extent of the landscape. ENN is undefined and reported as "N/A" in the "basename".patch file if the patch has no neighbors (i.e., no other patches of the same class).

Figure 18: List of landscape metrics calculated for each test areas.

Each calculated metric has been mapped for both “large” and “small” areas of each test site.

Landscape ecology metrics calculated for each test area have been reported in Figure 19.

Maps of all calculated metrics for each test area will be provided in raster format (ArcGis GeoTIFF file) in DVD support and attached at the present report.

Metric type	Metric	Acronym	Scale	Resolution	Target	Classification types
Area metrics	Patch area	AREA	Patch	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Area metrics	Class area	CA	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
				High	Forest types map	Outputs GUIDOS
				Low	CLC1990 wnw	Outputs GUIDOS
				Low	CLC2000 wnw	Outputs GUIDOS
				Low	CLC2006 wnw	Outputs GUIDOS
Area metrics	Mean patch size	AREA_MN	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Area metrics	Percentage of landscape	PLAND	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
				High	Forest types map	Outputs GUIDOS
				Low	CLC1990 wnw	Outputs GUIDOS
				Low	CLC2000 wnw	Outputs GUIDOS
				Low	CLC2006 wnw	Outputs GUIDOS
Area metrics	Largest patch index	LPI	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Edge metrics	Edge	PERIM	Patch	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Core area metrics	Total Core Area	TCA	Class	High	Forest types map	core/no core
				Low	CLC1990 wnw	core/no core
				Low	CLC2000 wnw	core/no core
				Low	CLC2006 wnw	core/no core

Metric type	Metric	Acronym	Scale	Resolution	Target	Classification types
Core area metrics	Core Area Percentage of Landscape	CPLAND	Class	High	Forest types map	core/no core
				Low	CLC1990 wnw	core/no core
				Low	CLC2000 wnw	core/no core
				Low	CLC2006 wnw	core/no core
Patch density, patch size and variability metric	Number of patches	NP	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Patch density, patch size and variability metric	Patch density	PD	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Shape metrics	Shape index	SHAPE	Patch	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Shape metrics	Fractal dimension index	FRAC	Patch	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Shape metrics	Mean Shape index	SHAPE_MN	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Shape metrics	Mean fractal dimension	FRAC_MN	Class	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..
Nearest neighbor metrics	Euclidean Nearest Neighbor distance	ENN	Patch	High	Forest types map	Forest types
				Low	CLC1990	CLC 3° lev.
				Low	CLC2000	CLC 3° lev.
				Low	CLC2006	CLC 3° lev..

Figure 19: List of landscape ecology metrics maps.

Diversity metrics

These metrics quantify landscape composition. Diversity measures have been used in order to evaluate the landscape diversity at landscape level within both "large" and "small" areas.

FRAGSTATS computes several statistics that quantify diversity at the landscape level. We selected the following two metrics:

- *Shannon's diversity index* (SHDI) *(landscape).* Is the most popular diversity index, which is based on information theory (Shannon and Weaver 1949). The value of this index represents the amount of "information" per patch. The absolute magnitude of Shannon's diversity index is not particularly meaningful; therefore, it is used as a relative index for comparing different landscapes or the same landscape at different times.

SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion.

$$(17)\ SHDI = -\sum_{i=1}^{m} \left(P_i \circ \ln P_i\right)$$

Where

P_i is the proportional abundance which is based on total landscape area (excluding any internal background present).

The range is: SHDI ≥ 0, without limit. SHDI = 0 when the landscape contains only 1 patch (no diversity). SHDI increases as the number of different patch types (patch richness, PR) increases or the proportional distribution of area among patch types becomes more equitable, or both.

- *Simpson's diversity index* (SIDI)(*landscape).* Simpson's index is less sensitive to the presence of rare types and has an interpretation that is much more intuitive than Shannon's index (Simpson 1949). The value of Simpson's index represents the probability that any two patches selected at random will be different types; the higher the value, the greater the diversity. Because Simpson's index is a probability, it can be interpreted in both absolute and relative terms.

SIDI equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared.

$$(19)\, SIDI = 1 - \sum_{i=1}^{m} P_i^2$$

Where

P_i is the proportional abundance which is based on total landscape area (excluding any internal background present).

SIDI range is: $0 \leq SIDI < 1$. SIDI = 0 when the landscape contains only 1 patch (no diversity). SIDI approaches 1 as the number of different patch types (patch richness, PR) increases and the proportional distribution of area among patch types becomes more equitable.

Diversity indexes have been calculated at landscape level on CLC data within "large" area and on forest cover (EFT) data within "small" areas.

2.1.6. Forest spatial pattern analysis

The forest spatial pattern of each test areas has been mapped by applying the mathematical morphology based freeware GUIDOS (Graphical User Interface for the Detection of Objects and Shapes) software (developed by the JRC-IES and available at URL: http://forest.jrc.ec.europa.eu/download/software/guidos), on all binary forest (forest type)/non forest maps.

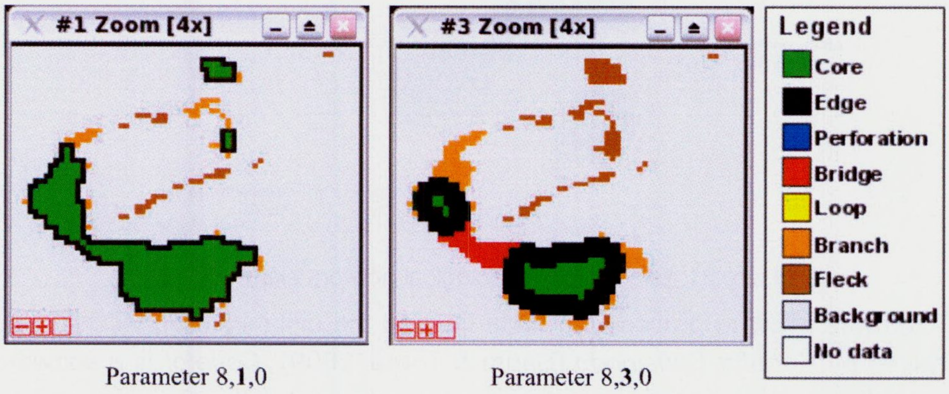
The GUIDOS classification has been developed for each test areas and for both "small" areas (where maps of forest cover/types have been considered) and "large" areas (where third level CLC maps has been taken into consideration).

The GUIDOS application provides a forest spatial pattern classification composed by seven main classes:

- core (interior forest area minus a fixed edge size);
- edge (external perimeter of core patch);
- perforation (perimeter of perforation in core patch);
- bridge and loop (when same core) connectors between cores;
- branches (pixels that do not belong to any of the previously defined categories. They emanate from boundaries as edge or perforation);
- islet/fleck (isolated non-core forest patches).

For more details on the use of Mathematical Morphology Spatial Pattern Analysis (MSPA) and GUIDOS application please see the specific bibliography (Vogt et al. 2006a; Vogt et al. 2006b; Estreguil et al. 2007; Vogt & Soille 2009; Vogt et al. 2009).

The choice of the depth-of-edge clearly influences the classification results. An example of the GUIDOS classification is showed in Figure 20.



Parameter 8,**1**,0 Parameter 8,**3**,0

Figure 20: Example of the GUIDOS classification with two different input parameters (or Structuring Element). In the 8,1,0 setting the software classification will be based on 1 pixel edge. In the 8,3,0 setting it will be based on 3 pixels edge.

Within the "Forest Spatial pattern" project, after a huge bibliographic review on the topic, has been fixed a depth-of-edge of 100 m in order to reduce the influence of the "edge effect" for the forest fauna interior species.

The GUIDOS classification has an obvious interest in the context of ecological networks planning. In fact, an ecological network, aims to ensure a full functionality to species within an ecological-mosaic where land transformations processes, fragmentation and isolation of natural habitats, as well as the decrease in size and environmental quality of it, may threats their survival (Barbati & Chirici 2009).

Resulting forest landscape spatial pattern classified by GUIDOS allow to identify the main elements of a potential ecological network (on the basis of a defined fixed edge dimension) related for example to a defined species or group of species (Figure 21).

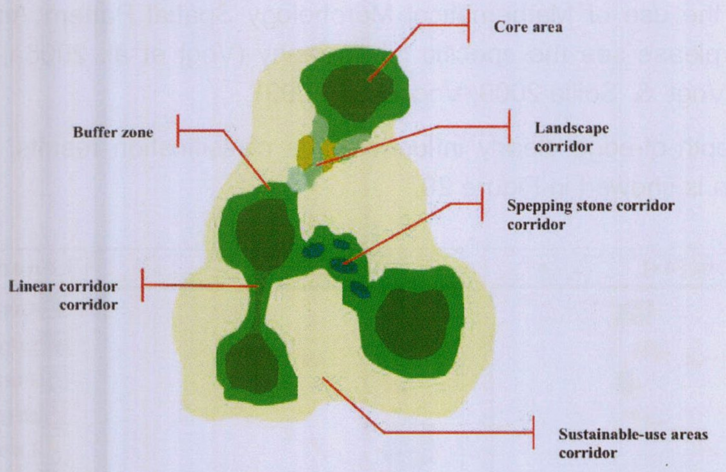


Figure 21: Example of a ecological network elements.

The GUIDOS software allow to process the node file and the distance (connection) file directly in the format required by *Conefor Sensinode* (Saura & Torné, 2009). *Conefor* is a software package that allows quantifying the importance of habitat areas and links for the maintenance or improvement of landscape connectivity. It is conceived as a tool for decision-making support in landscape planning and habitat conservation, through the identification and prioritization of critical sites for ecological connectivity.

In this first phase of the action activities no connectivity analysis has been evaluated. This kind of analysis generally attempts to reflect the degree to which patches are isolated or connected across landscapes and is strictly correlated to ecological aspects. For this reason, after the definition of zoological parameters related to habitat suitability, landscape connectivity indexes will be also calculated.

In the second phase of Action ECo, connectivity evaluations will be carried out within "small" areas forest landscape in pre-treatments condition and within simulated landscapes in post-treatments conditions.

2.2. Results from Sub-action 1 – Activities in Italy

In this section, results of developed landscape analysis for each test site will be presented and discussed.

In order to present and compare the quantitative data of geometric and spatial landscape characteristics of each test sites, among all calculated and mapped landscape ecology metrics, in this section will be taken into consideration in particular six metrics (calculated per class):

- *Number of Patches* (NP): Is the total number of patches of a particular class. It is a measure of the degree of subdivision of classes within the landscape.

Figure 22: meaning of the degree of subdivision of classed within the landscape (Font: Turner et al. 2001).

- *Mean Patch Size* (MPS): Is the mean size of the patches of particular class. This metric offer a fundamentally patch-based perspective of the landscape structure. It provides a measure of central tendency of the patch size across the entire landscape, but nevertheless describes the patch structure of the landscape as that of the average patch characteristic. Thus, each patch regardless of its size is considered equally (i.e., given equal weight) in describing the landscape structure.
- *Mean Core Area* (MCA): Is the mean size of core area. Core area is the area of the inner of a patch (considered stable and intact) surrounded by a buffer area. It provides a measure of central tendency of the core patch size across the entire landscape.

Figure 23: core area meaning (Font: Turner et al. 2001).

- *Euclidean nearest-neighbour distance* (ENN): Is the mean distance between patch of the same class, measured as the shortest distance which separates two patches belonging to the same class. The ENN index is the simpler and more immediate quantification of the *isolation factor.*

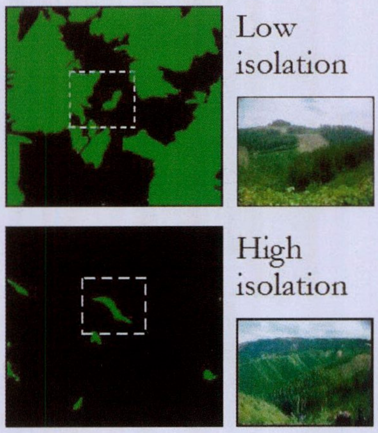


Figure 25: isolation meaning (Font: Turner et al. 2001).

- *Area Weighted Mean Shape Index* (AWMSI): Is a measure of the geometric complexity of the patch, weighted on the mean size. Values close to 1 means regular and simple shapes (square shape), while higher values correspond to more complex shapes. This metric quantify the amount of edge present in a class relative to what would be present in a class of the same size but with a square (for raster data) shape. In other terms, this metric provide a relative measurement of shape complexity. The particularity about AWMSI is that larger patches are weighted more heavily than smaller patches in calculating the average patch shape.
- *Total edge* (TE): is the sum of all the patches edges for single class. It is useful to evaluate the margin effect. For example, one of the most dramatic and well-studied consequences of habitat fragmentation is an increase in the proportional abundance of edge influenced habitat and its adverse impacts on interior sensitive species.

The analysis of landscape metrics allow to analyse and compare the shape, the composition and spatial configuration of the patch (land use or forest cover classes) within considered landscapes (large or small areas). For "large" areas comparison of metrics between the two considered dates (from year 1990 to year 2006) showed the shape, the composition and spatial configuration of land use changes.

The results have been presented per test site.

For each site, results of the six selected landscape metrics see above will be analysed in order to describe the landscape context of both "large" and "small" areas.

For "large" areas results of the six landscape metrics calculated for year 1990 and year 2006 will be compared. For "large" areas will be also presented results of cross tabulation analysis between land use data at the two dates (1990-2006).

Quantitative results of the forest spatial pattern classification and resulting GUIDOS outputs will be reported for both "large" and "small" areas.

Images of mapped metrics will be reported for each test site and for both "large" and "small" areas. For "large" areas, figures of landscape metrics maps will be referred to the year 2006.

2.2.1. Tarvisio – Site 6

- Evaluation of the landscape context and land uses changes: "large" area

Figure 27 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

The landscape of Tarvisio "large" area is mainly composed by natural and semi-natural land use classes. Mixed and coniferous forests are dominant (Table 4) (Figure 25) (for the year 2006, respectively 57.08 % and 15.81 % of total surface) at medium altitudes above 1000 m.a.s.l. (Table 5) and more accentuated slopes (class 6) (Table 6) and their presence have been relatively stable over considered time period. Broad-leaved forest class (311) covers 190 hectares (1.9 %).

Artificial surfaces (class 1 of first CLC level) within "large" area cover 329 hectares at the year 2006 (3.2 % of the total area).

CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
TARVISIO (large area 100 kmq)											
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	161	240	252	1.63	2.42	2.55	79.00	12.00	12.00	56.52
121	Industrial or commercial units	0	0	31	0.00	0.00	0.31	0.00	31.00	31.00	
122	Road and rail networks and associated land	58	58	58	0.59	0.59	0.59	0.00	0.00	0.00	0.00
133	Construction sites	0	40	0	0.00	0.40	0.00	40.00	-40.00	-40.00	
211	Non-irrigated arable land	46	40	39	0.46	0.40	0.39	-6.00	-1.00	-1.00	-15.22
242	Complex cultivation patterns	27	27	27	0.27	0.27	0.27	0.00	0.00	0.00	0.00
243	Land principally occupied by agriculture, with significant areas of natural vegetation	778	705	689	7.86	7.12	6.96	-73.00	-16.00	-16.00	-11.44
311	Broad-leaved forest	190	190	190	1.92	1.92	1.92	0.00	0.00	0.00	0.00
312	Coniferous forest	1587	1587	1565	16.03	16.03	15.81	0.00	-22.00	-22.00	-1.39
313	Mixed forest	5642	5602	5650	57.00	56.60	57.08	-40.00	48.00	48.00	0.14
321	Natural grasslands	0	0	34	0.00	0.00	0.34	0.00	34.00	34.00	
324	Transitional woodland-shrub	728	728	860	7.36	7.36	8.69	0.00	132.00	132.00	18.13
331	Beaches, dunes, sands	98	98	98	0.99	0.99	0.99	0.00	0.00	0.00	0.00
332	Bare rocks	199	199	134	2.01	2.01	1.35	0.00	-65.00	-65.00	-32.66
333	Sparsely vegetated areas	381	381	268	3.85	3.85	2.71	0.00	-113.00	-113.00	-29.66
512	Water bodies	3	3	3	0.03	0.03	0.03	0.00	0.00	0.00	0.00
	Total	9898	9898	9898	100	100	100				

Table 4: Area values per class and per year and relative changes between dates for Tarvisio "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

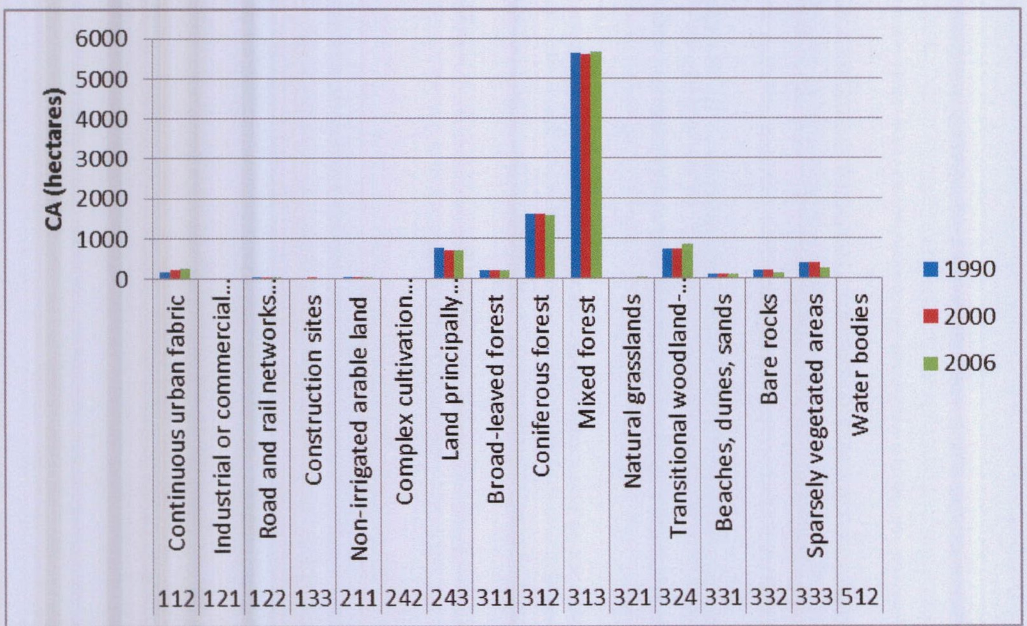


Figure 26: Tarvisio "large" (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

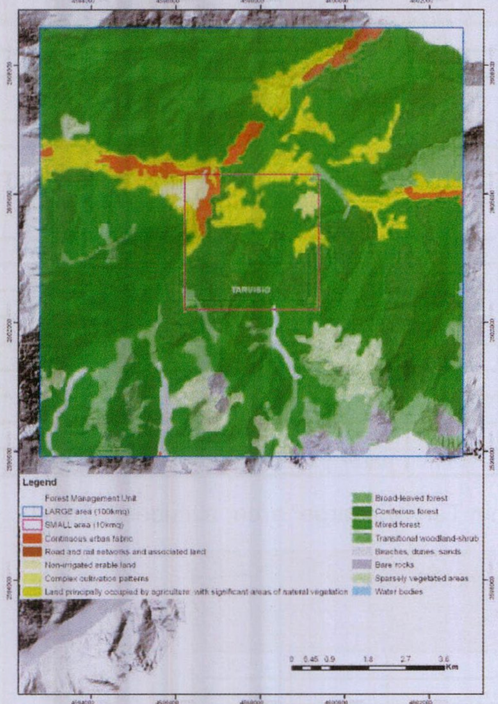
TARVISIO (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	6287	669	917	248	751.74	725	669	750
121	Industrial or commercial units	725	675	779	104	742.78	750	687	746
122	Road and rail networks and associated land	1421	619	750	131	664.21	650	620	657
211	Non-irrigated arable land	1038	724	850	126	777.78	775	724	775
242	Complex cultivation patterns	660	800	906	106	879.71	875	833	878
243	Land principally occupied by agriculture, with significant areas of natural vegetation	17299	622	1025	403	797.69	800	622	800
311	Broad-leaved forest	4687	765	1525	760	1047.27	1125	765	1012
312	Coniferous forest	39078	625	1925	1300	1087.77	1000	637	1050
313	Mixed forest	141230	647	1893	1246	1092.37	1025	667	1050
321	Natural grasslands	766	1416	1794	378	1528.69	1475	1416	1510
324	Transitional woodland-shrub	21584	723	2390	1667	1440.88	1600	723	1452
331	Beaches, dunes, sands	2454	873	1050	177	934.40	975	926	924
332	Bare rocks	3333	1381	2600	1219	1903.37	1850	1381	1883
333	Sparsely vegetated areas	6636	796	2100	1304	1548.70	1625	801	1638
512	Water bodies	70	928	933	5	929.57	930	932	930

Table 5: Topographic features for each class within Tarvisio "large" area: altitudes (m.a.s.l).

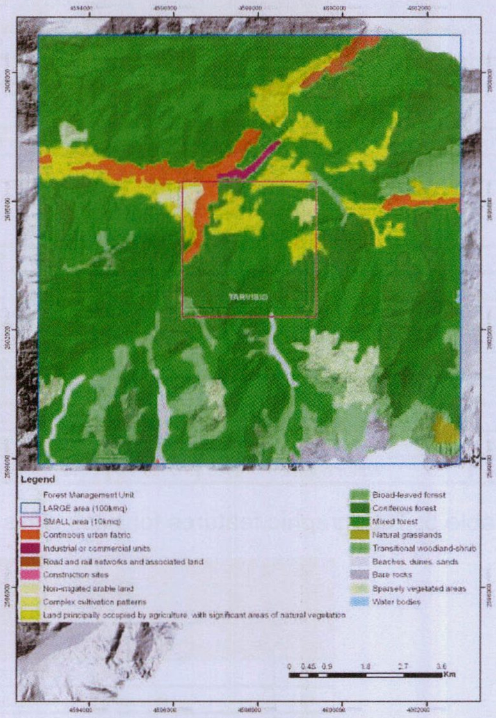
TARVISIO (large area 100 kmq)			
Code	Class	Class of majority presence	Slope values
112	Continuous urban fabric	3	10 - 20 %
121	Industrial or commercial units	3	10 - 20 %
122	Road and rail networks and associated land	5	30 - 50 %
211	Non-irrigated arable land	3	10 - 20 %
242	Complex cultivation patterns	3	10 - 20 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	3	10 - 20 %
311	Broad-leaved forest	6	> 50 %
312	Coniferous forest	6	> 50 %
313	Mixed forest	6	> 50 %
321	Natural grasslands	6	> 50 %
324	Transitional woodland-shrub	6	> 50 %
331	Beaches, dunes, sands	2	3 - 10 %
332	Bare rocks	6	> 50 %
333	Sparsely vegetated areas	6	> 50 %
512	Water bodies	1	< 3%

Table 6: Topographic features for each class within Tarvisio "large" area: class of slopes (percentage).

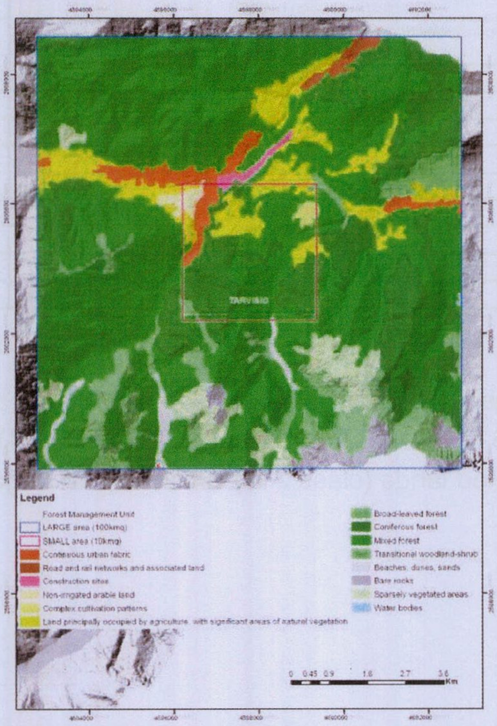
The land use class showing the largest rate of change is continuous and urban fabric (class 122), which shows a variation of 56 % between 1990 and 2006 (Table 4). The opposite process has been affected by the non-irrigated lands (class 211) which have a negative change rate of 11.44 % for the same period.



CLC 1990



CLC 2000



CLC 2006

Figure 27: CORINE Land Cover data of Tarvisio “large” area.

The cross tabulation analysis for the same period (Table 7 and Table 8) showed as urban areas have been mainly increased within agricultural areas (classes 211 and 243) of respectively 7 hectares (15.2 %) and 82 hectares (10.5 %). Cross tabulation showed also the relative stability of forest classes (Table x and Table xx) and a colonization process of areas sparsely vegetated (class 333) by the transitional woodlands-shrub formations (class 324) of 36 %.

TARVISIO (large area 100 kmq)																
Cross tabulation (hectares)																
	2006															
1990	112	121	122	211	242	243	311	312	313	321	324	331	332	333	512	Total
112	159	2	0	0	0	0	0	0	0	0	0	0	0	0	0	161
121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
122	0	0	58	0	0	0	0	0	0	0	0	0	0	0	0	58
211	7	0	0	39	0	0	0	0	0	0	0	0	0	0	0	46
242	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	27
243	82	0	0	0	0	666	0	0	30	0	0	0	0	0	0	778
311	0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	190
312	0	0	0	0	0	3	0	1536	46	0	2	0	0	0	0	1587
313	4	29	0	0	0	20	0	26	5558	0	3	0	0	2	0	5642
321	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324	0	0	0	0	0	0	0	3	6	0	718	0	1	0	0	728
331	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	98
332	0	0	0	0	0	0	0	0	0	34	0	0	133	32	0	199
333	0	0	0	0	0	0	0	0	10	0	137	0	0	234	0	381
512	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Total	252	31	58	39	27	689	190	1565	5650	34	860	98	134	268	3	9898

Table 7: contingency matrix of Tarvisio large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

TARVISIO (large area 100 kmq)																
Cross tabulation (%)																
	2006															
1990	112	121	122	211	242	243	311	312	313	321	324	331	332	333	512	Total
112	98.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
122	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
211	15.2	0.0	0.0	84.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
242	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
243	10.5	0.0	0.0	0.0	0.0	85.6	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	100.0
311	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
312	0.0	0.0	0.0	0.0	0.0	0.2	0.0	96.8	2.9	0.0	0.1	0.0	0.0	0.0	0.0	100.0
313	0.1	0.5	0.0	0.0	0.0	0.4	0.0	0.5	98.5	0.0	0.1	0.0	0.0	0.0	0.0	100.0
321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	0.0	98.6	0.0	0.1	0.0	0.0	100.0
331	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
332	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.1	0.0	0.0	66.8	16.1	0.0	100.0
333	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	36.0	0.0	0.0	61.4	0.0	100.0
512	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0

Table 8: contingency matrix of Tarvisio large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

The landscape ecology metric analysis showed as the landscape has been changed between the two dates (1990-2006).

Almost all the classes have experienced a decrease of number of patches (NP) (Figure 28), except the class 243 (which groups agricultural areas and natural vegetated lands and that is the most heterogeneous between CLC classes). The mean patch size (MPS) for this class decreased in year 2006, while has been identified a general increase in all other classes.

The core area metric (MCA) analysis showed as values for coniferous and mixed forest (class 312 and 313) have been increased, while for broadleaved forest core area (class 311) have been remained constant as the Euclidean Nearest-Neighbor distance (ENN) index, while there was a slight increasing of the ENN values for coniferous forest, which indicates the increase of patch isolation within this class. The same process seems was occurred at the class 333, and urban areas (class 112).

The *Area Weighted Mean Shape Index* (AWMSI) which is a measure of the shape complexity of patches, showed as the mixed forest (class 313) has the highest values but it decreased in the second period. For this metric, there was an increasing only for sparsely vegetated areas (class 333) between natural and semi-natural classes and for urban areas.

The decreasing of total edge (TE) for mixed forest (class 313) confirm the decrease of shape complexity for this class.

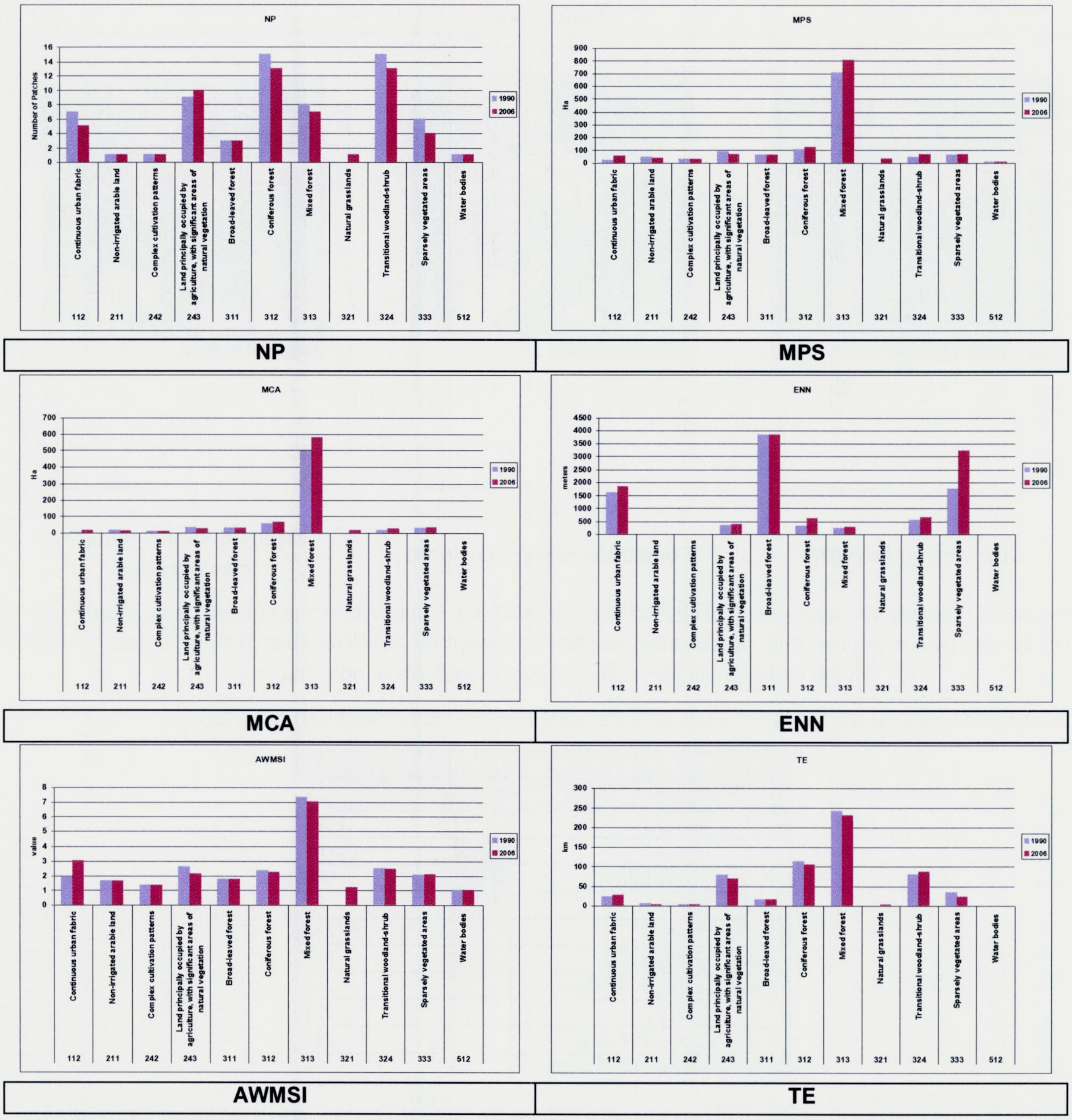
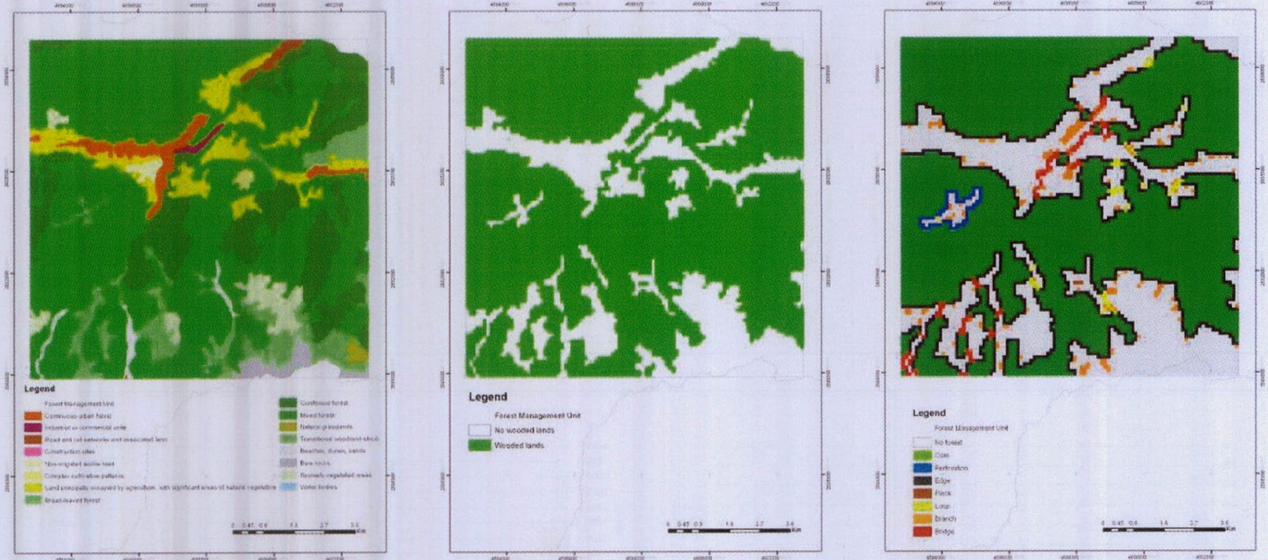


Figure 28: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Tarvisio "large" area.

- **Forest spatial pattern classification results: "large" area**

Figure 29 shows the input and output of GUIDOS forest spatial pattern classification for Tarvsio "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006)	Forest/non forest map input	GUIDOS spatial pattern classification

Figure 29: Inputs and outputs maps of GUIDOS classification for Tarvisio forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 9, area (in hectares) of each forest spatial pattern class has been reported.

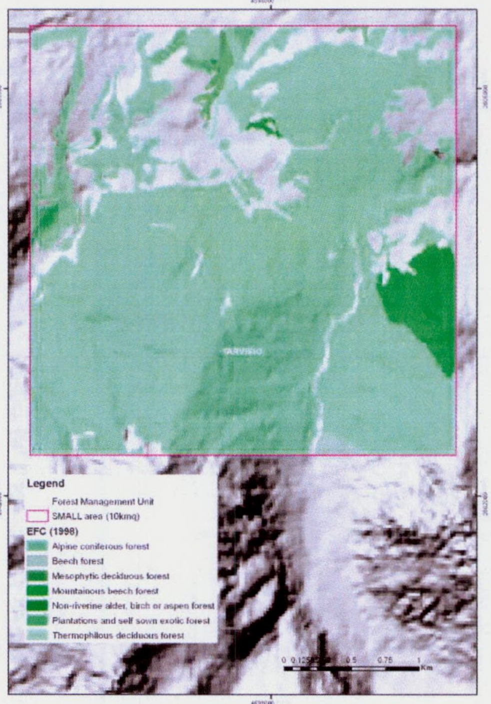
Tarvisio (large area 100 kmq)			
Code	***Description***		***AREA (ha)***
1	Branch		199
3	Edge		1176
5	Perforation		68
9	Islet		3
17	Core		5771
33	Bridge		71
35	Bridge in Edge		56
65	Loop		32
67	Loop in Edge		27
69	Loop in Perforation		2

Table 9: Area (hectares) of GUIDOS forest spatial pattern classes for Tarvisio forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 30 show forest cover data of Tarvisio "small" area.

On the basis of map of forest types of year 1998, within Tarvisio "small" area, forest covers about 789 hectares of the area. The alpine coniferous forest (class 3) is the EFC dominant (723 hectares) (Table 10 and Figure 31) and in particular EFT "subalpine and mountainous spruce and mountainous mixed spruce silver fir forest" (class 32) (334 hectares). This forest extends at mean altitudes up to 1000 m.a.s.l. (Table 11) and on steeps slopes (Table 12). The second class most represented is "mountainous beech forest" (34.5 hectares) which extends at altitudes between 900 and 1200 m.a.s.l. (Table 11) and on very steep slopes (30-50 %) (Table 12).

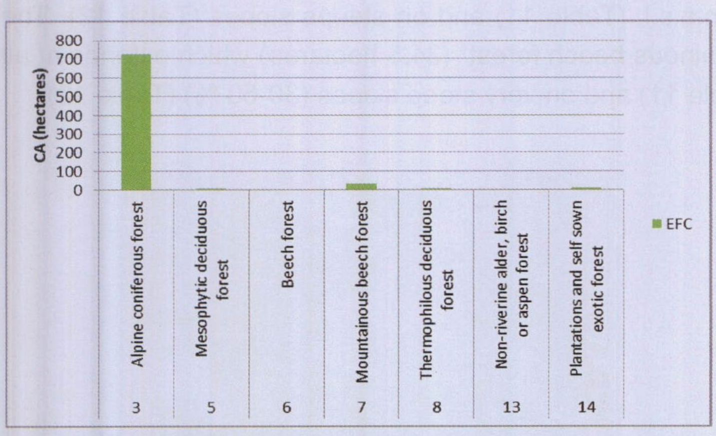


European Forest Categories (1998)

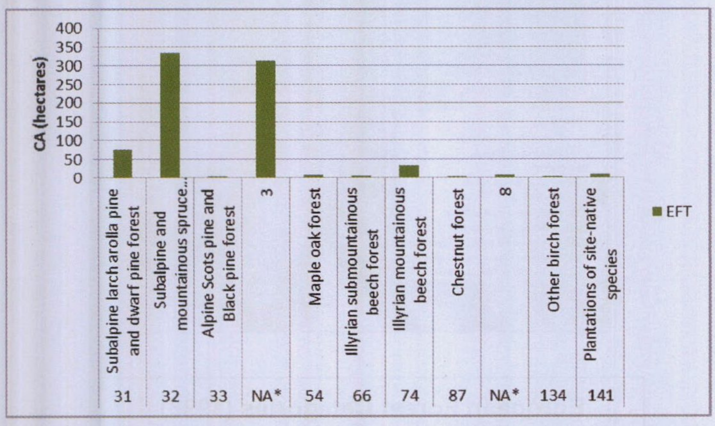
Figure 30: European Forest Categories map (1998) for Tarvisio "small" area.

TARVISIO (small area 10 kmq)				
EFC Code	*Class description*	*EFT Code*	*Class description*	*AREA (hectares)*
3	Alpine coniferous forest	31	Subalpine larch arolla pine and dwarf pine forest	76.50
		32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	334.19
		33	Alpine Scots pine and Black pine forest	0.81
		NA*		312.40
			sub total	**723.91**
5	Mesophytic deciduous forest	54	Maple oak forest	7.45
			sub total	**7.45**
6	Beech forest	66	Illyrian submountainous beech forest	4.33
			sub total	**4.33**
7	Mountainous beech forest	74	Illyrian mountainous beech forest	34.51
			sub total	**34.51**
8	Thermophilous deciduous forest	87	Chestnut forest	0.56
		NA*		6.92
			sub total	**7.48**
13	Non-riverine alder, birch or aspen forest	134	Other birch forest	2.00
			sub total	**2.00**
14	Plantations and self sown exotic forest	141	Plantations of site-native species	10.11
			sub total	**10.11**
			TOTAL	**789.78**
(*) NA: not applicable.				

Table 10: Tarvisio "small" area. Area (hectares) for EFC and EFT classes. Forest Types date: 1998. NA: not applicable means the impossibility of reclassification for that level.



EFC level classification



EFT level classification

Figure 31: Tarvisio “small” (10 kmq) area. Graphs of Class Area (CA) metric for both EFC and EFT level classification.

TARVISIO (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFT	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
3	3 (Alpine coniferous forest)	64	750	845	95	782.64	750	753	768
8	8 (Thermophilous deciduous forest)	13	875	886	11	879.39	875	876	879
31	Subalpine larch arolla pine and dwarf pine forest	7805	711	1537	826	926.62	850	711	885
32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	8307	725	1450	725	1031.87	1125	729	1025
33	Alpine Scots pine and Black pine forest	1908	800	934	134	893.12	875	800	896
54	Maple oak forest	186	750	830	80	793.68	799	760	796
66	Illyrian submountainous beech forest	107	899	1050	151	950.67	925	899	945
74	Illyrian mountainous beech forest	860	880	1245	365	1024.87	925	880	991
87	Chestnut forest	178	793	870	77	815.99			
134	Other birch forest	53	825	856	31	841.17	850	826	842
141	Plantations of site-native species	251	725	850	125	784.48	800	726	785

Table 11: Topographic features for each class within Tarvisio "small" area: altitudes (m.a.s.l).

TARVISIO (small area 10 kmq)			
Code	EFT	Class of majority presence	Slope values
3	3 (Alpine coniferous forest)	5	30 - 50 %
8	8 (Thermophilous deciduous forest)	3	10 - 20 %
31	Subalpine larch arolla pine and dwarf pine forest	6	> 50 %
32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	6	> 50 %
33	Alpine Scots pine and Black pine forest	3	10 - 20 %
54	Maple oak forest	2	3 - 10 %
66	Illyrian submountainous beech forest	4	3 - 10 %
74	Illyrian mountainous beech forest	5	30 - 50 %
87	Chestnut forest	2	3 - 10 %
134	Other birch forest	3	10 - 20 %
141	Plantations of site-native species	3	10 - 20 %

Table 12: Topographic features for each class within Tarvisio "small" area: class of slopes (percentage).

The metrics analysis showed as the "sub alpine and mountainous spruce and mountainous mixed spruce silver fir forest" (class 32) type has the largest mean patch size (MPS) while patches are less numerous than "sub alpine larch arolla pine and dwarf pine forest" (class 31) as showed by the number of patches (NP) metric (Figure 32).

The analysis of mean core area (MCA) showed as spruce and mixed spruce silver fir forests (class 32) contain the most of forest core areas. The Euclidean Nearest-Neighbor distance (ENN) metrics showed as larch arolla pine and dwarf pine forests (class 31) have a high isolation level respect to the spruce and mixed spruce silver fir forests (class 32). Low ENN values indicates as this typology has a more concentrated patches pattern within the landscape.

The *Area Weighted Mean Shape Index* (AWMSI) showed also as larch arolla pine and dwarf pine forests (class 31) patches have a high geometric complexity. The comparison between the total edge (TE) metric and the MPS for this forest type confirm the detected shape complexity (high length of edge and lower MPS).

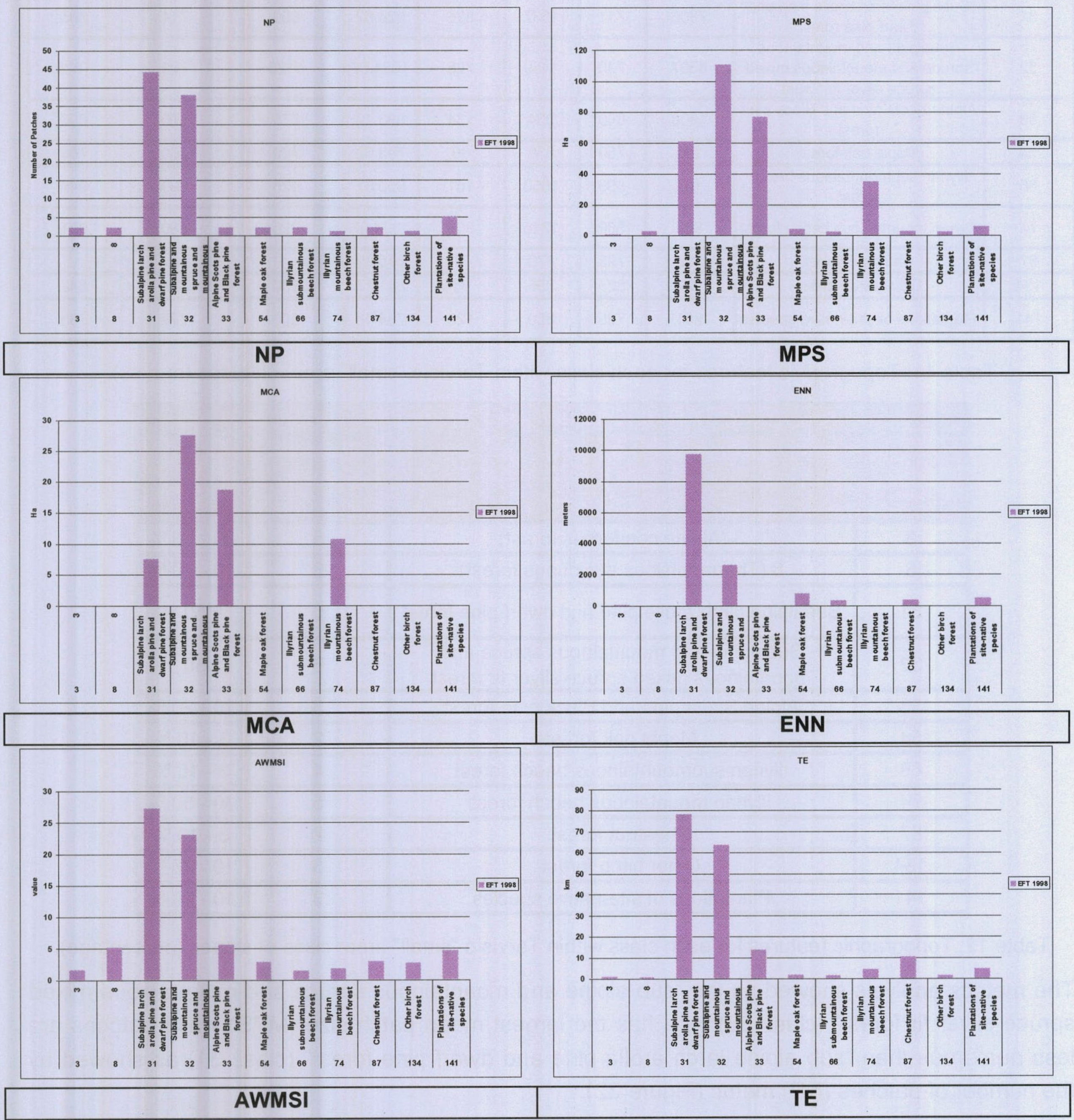
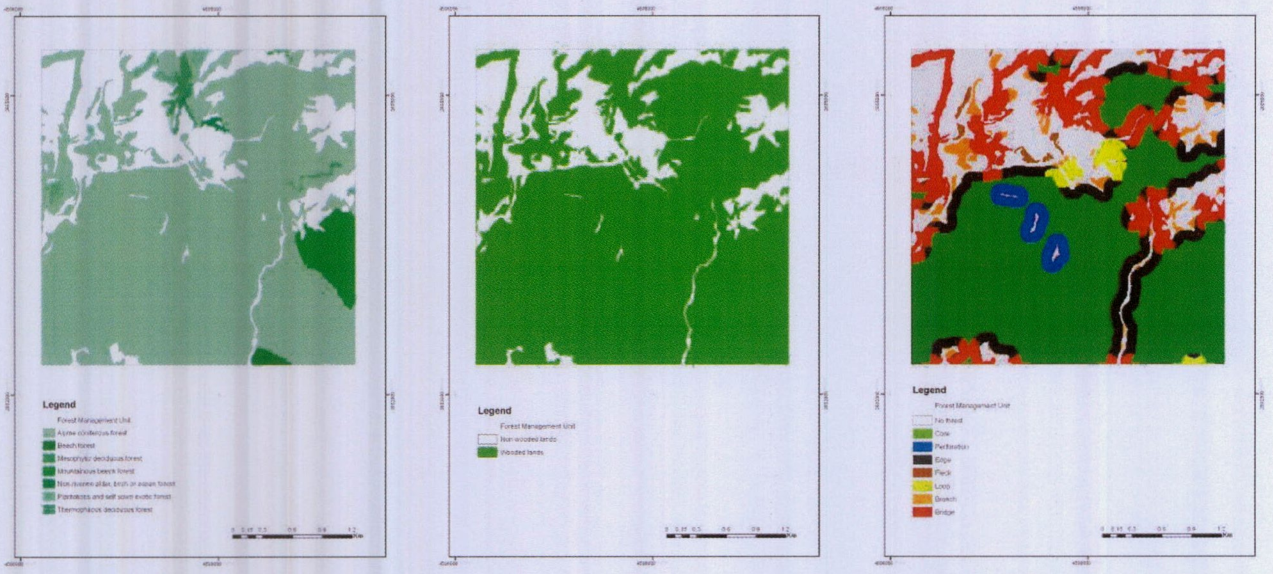


Figure 32: Results of landscape ecology metrics for forest cover (year 1998) within "small" area of Tarvisio site.

- **Forest spatial pattern classification results: "small" area**

Figure 33 shows the input and output of GUIDOS forest spatial pattern classification for Tarvsio "small" area based on the forest cover (at EFT level) data of year 1998.

Small area



Forest cover map | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 33: Inputs and outputs maps of GUIDOS classification for Tarvisio forest/non forest "small" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 13, area (in hectares) of each forest spatial pattern class has been reported.

Tarvisio (small area 10 kmq)			
Code	Description		AREA (ha)
1	Branch		28.7
3	Edge		101.07
5	Perforation		23.73
9	Islet		5.53
17	Core		456.27
33	Bridge		84.49
35	Bridge in Edge		73.76
65	Loop		6.54
67	Loop in Edge		9.44

Table 13: Area (hectares) of GUIDOS forest spatial pattern classes for Tarvisio forest/non forest "small" area.

- ## Maps of landscape ecology metrics

Patch area (ha) (*per patch*) (AREA)

Large area	Small area

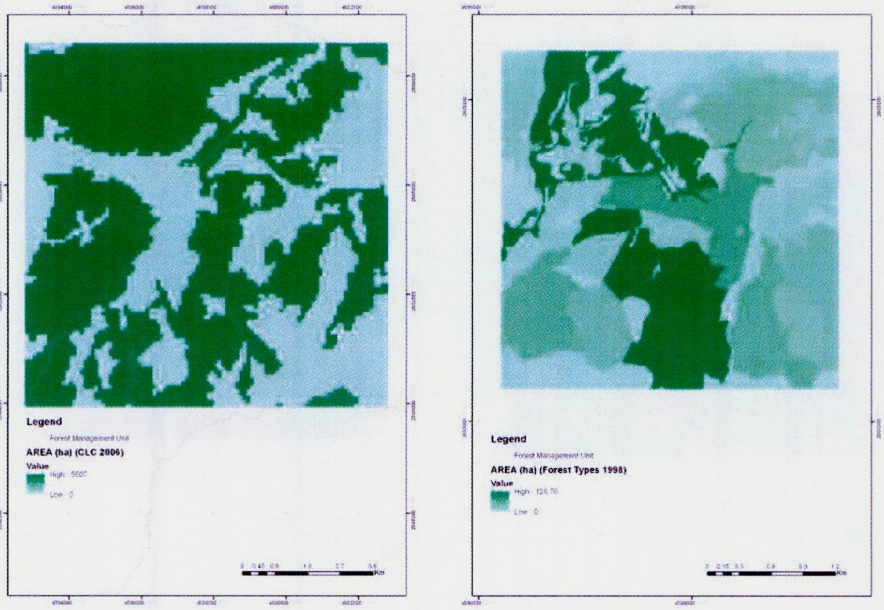


Figure 34: Patch area metrics resulting maps for “Tarvisio forest” site.

Class area (ha) (per class) (CA)

Large area	Small area

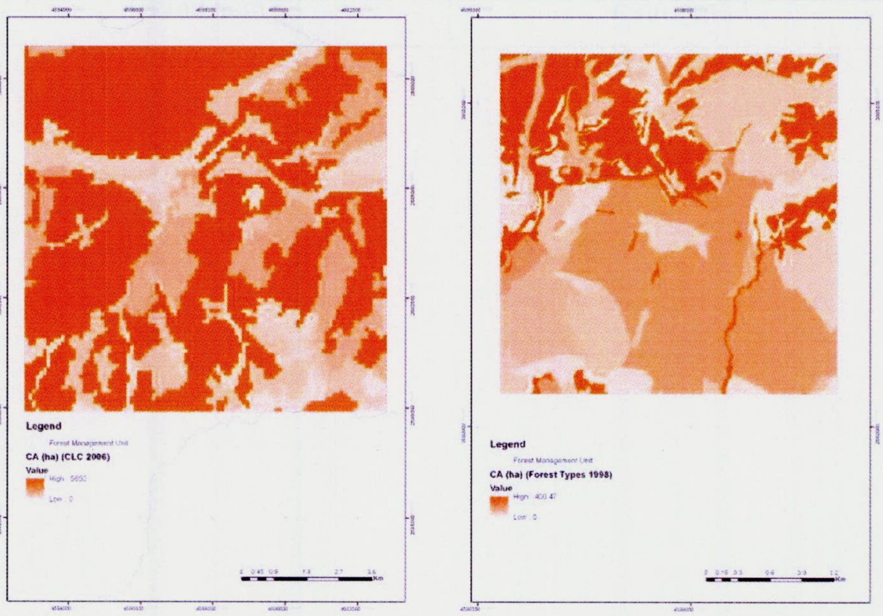
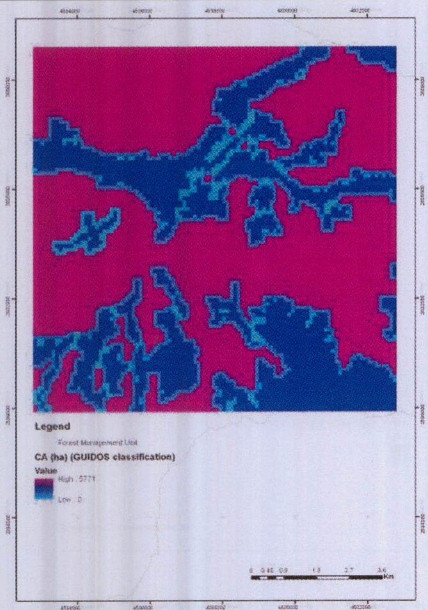


Figure 35: Class area metrics resulting maps for “Tarvisio forest” site.

Class area (ha) (*per class*) (CA)

Large area	Small area



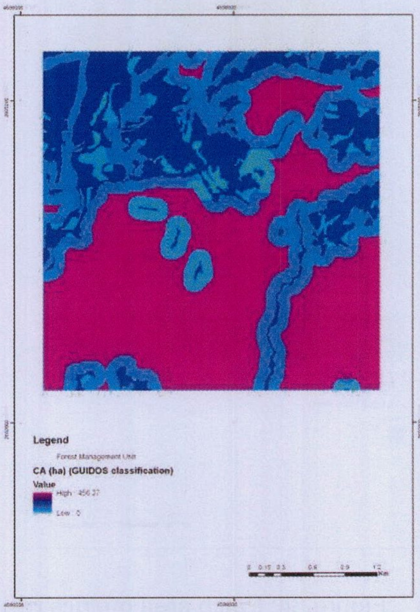


Figure 36: Class area size metrics resulting maps for “Tarvisio forest” site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

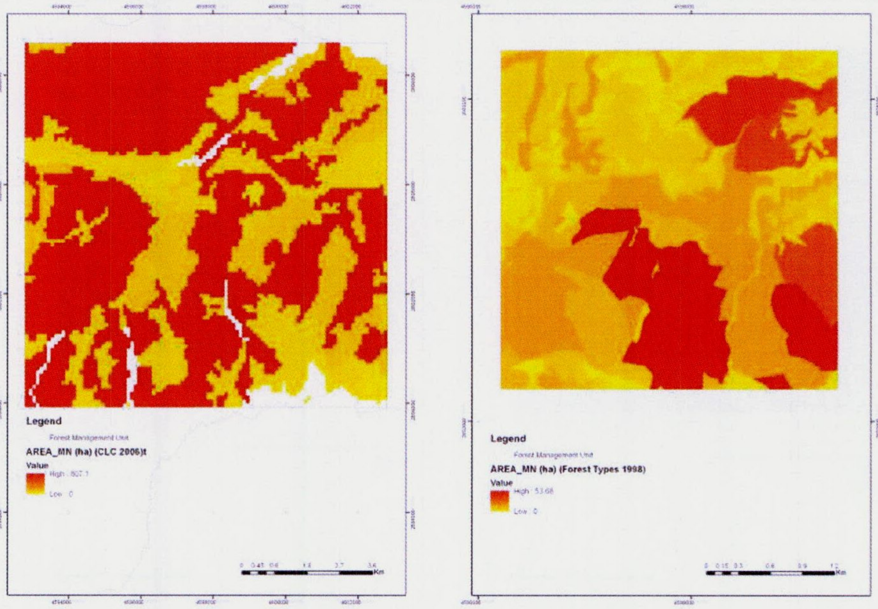


Figure 37: Mean patch size metrics resulting maps for “Tarvisio forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

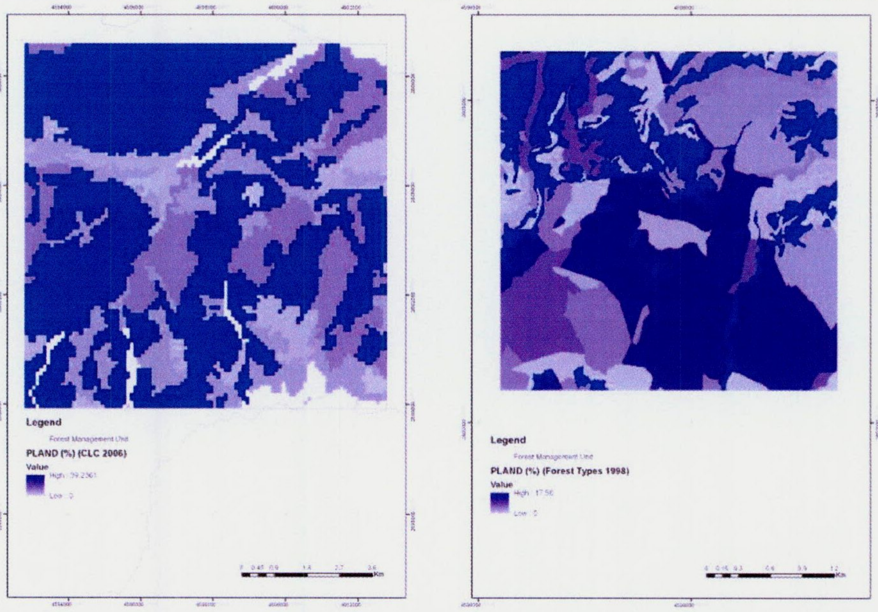


Figure 38: Percentage of landscape metrics resulting maps for “Tarvisio forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

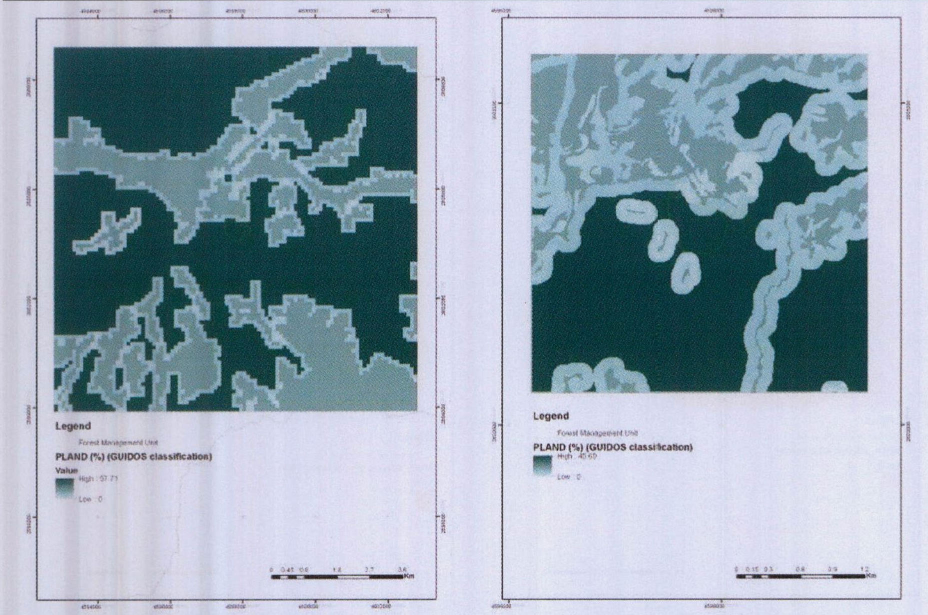


Figure 39: Percentage of landscape metrics resulting maps for “Tarvisio forest” site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

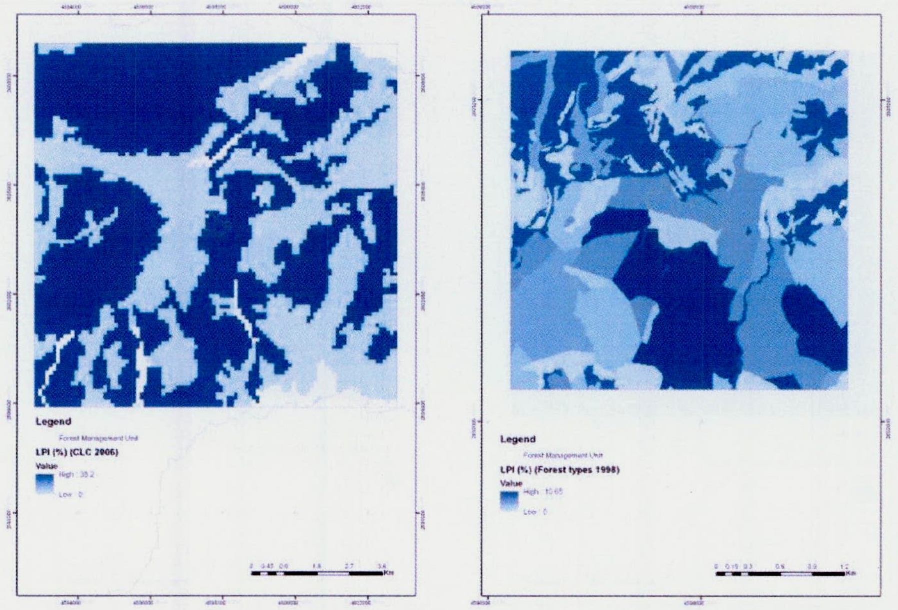


Figure 40: Largest patch index metrics resulting maps for “Tarvisio forest” site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

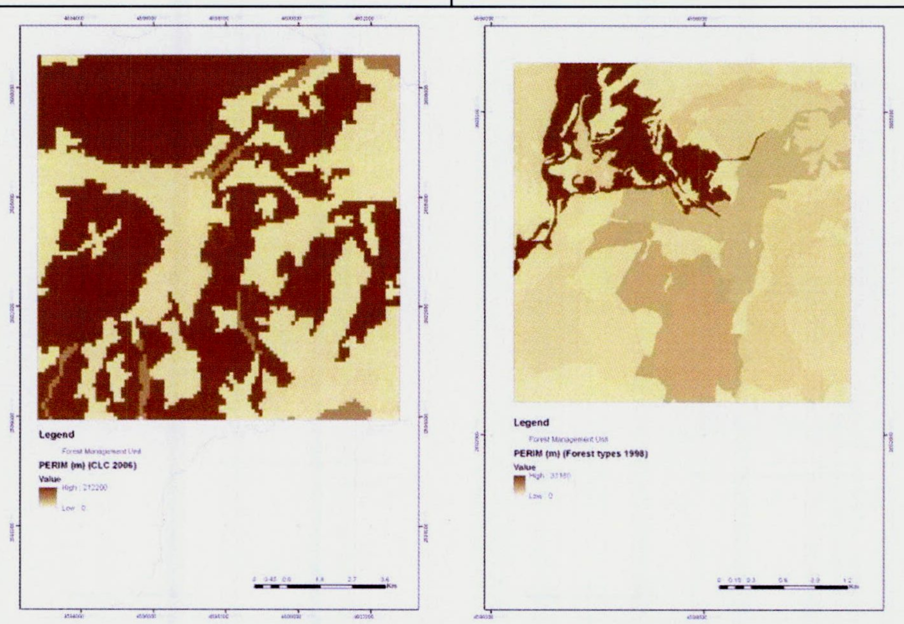


Figure 41: Edge metrics resulting maps for “Tarvisio forest” site.

Total core area (ha) (per class) (TCA)

Large area	Small area

Figure 42: Total core area metrics resulting maps for "Tarvisio forest" site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

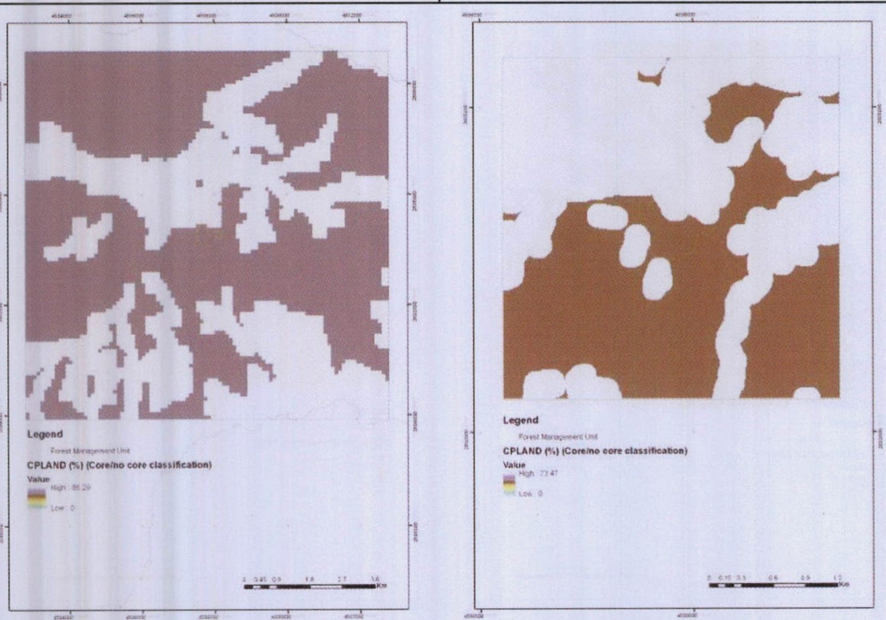


Figure 43: Core Area Percentage of Landscape metrics resulting maps for "Tarvisio forest" site.

Number of patches (per patch) (NP)

Large area	Small area

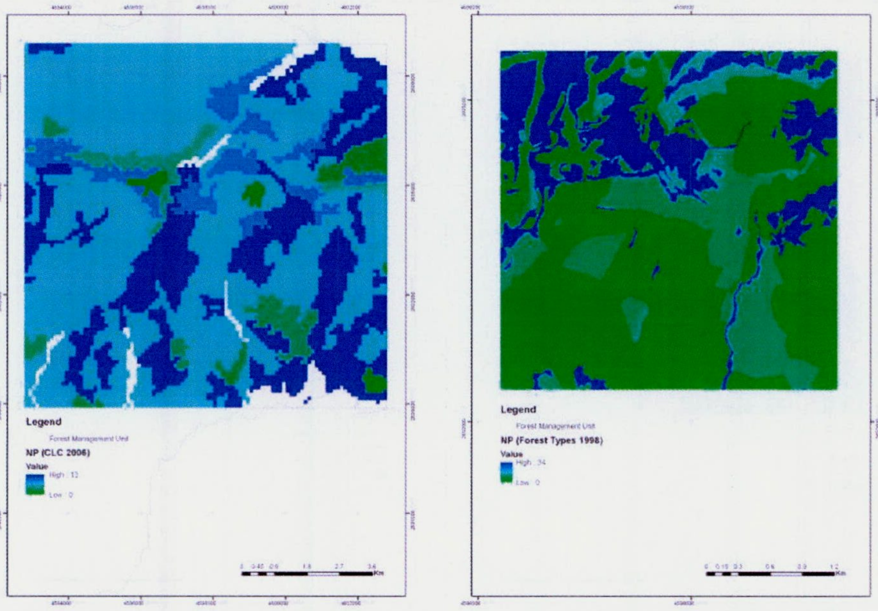


Figure 44: Number of patches in the landscape resulting maps for “Tarvisio forest” site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

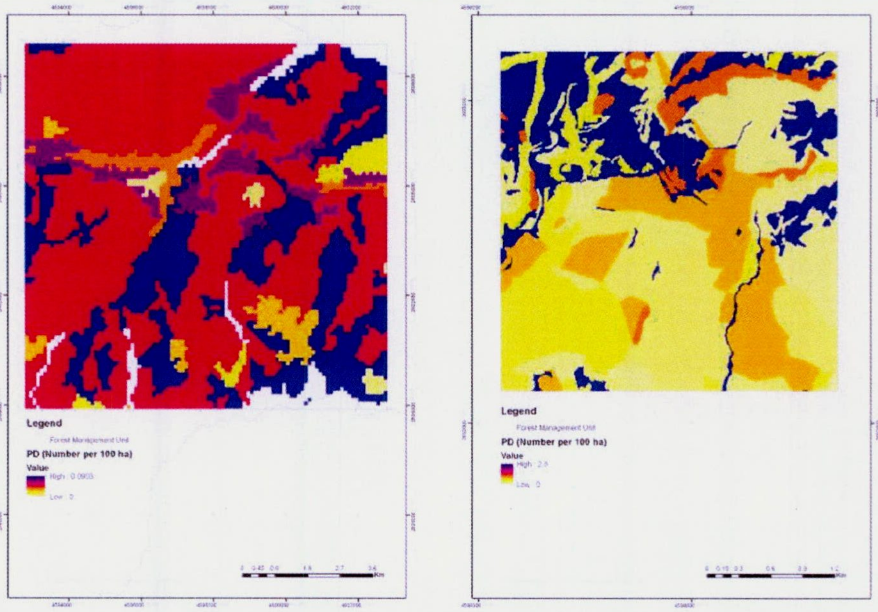


Figure 45: Patch density metrics resulting maps for “Tarvisio forest” site.

Shape (per patch) (SHAPE)

Large area	Small area

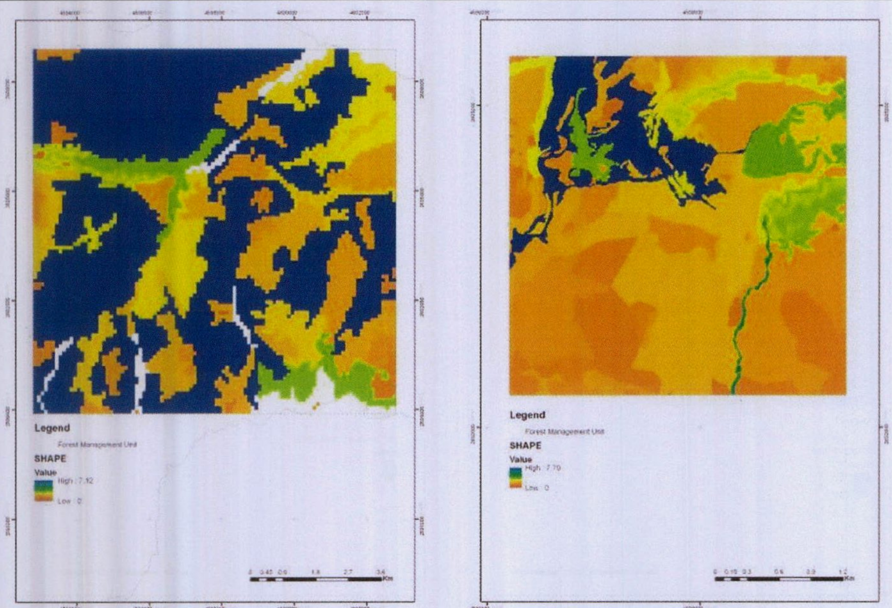


Figure 46: Shape metrics resulting maps for “Tarvisio forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

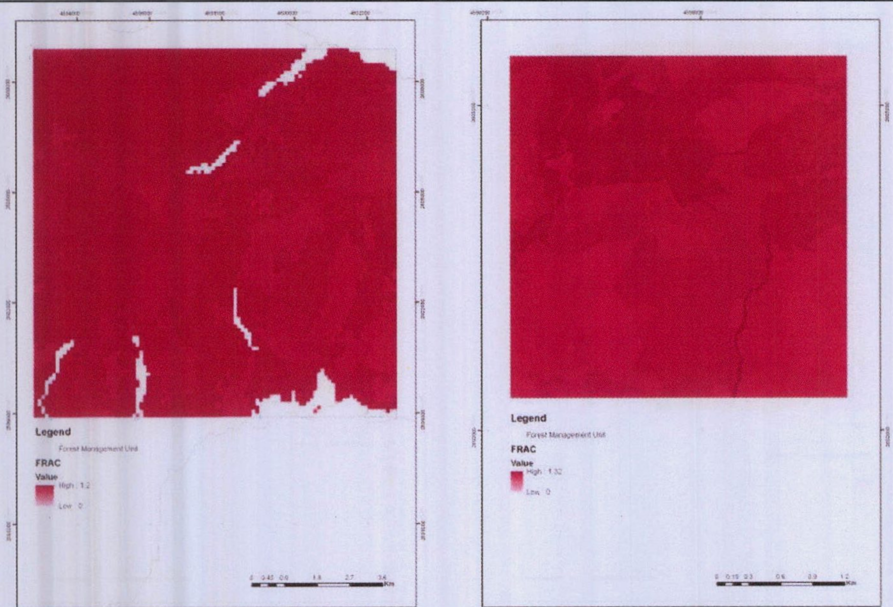


Figure 47: Fractal dimension metrics resulting maps for “Tarvisio forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

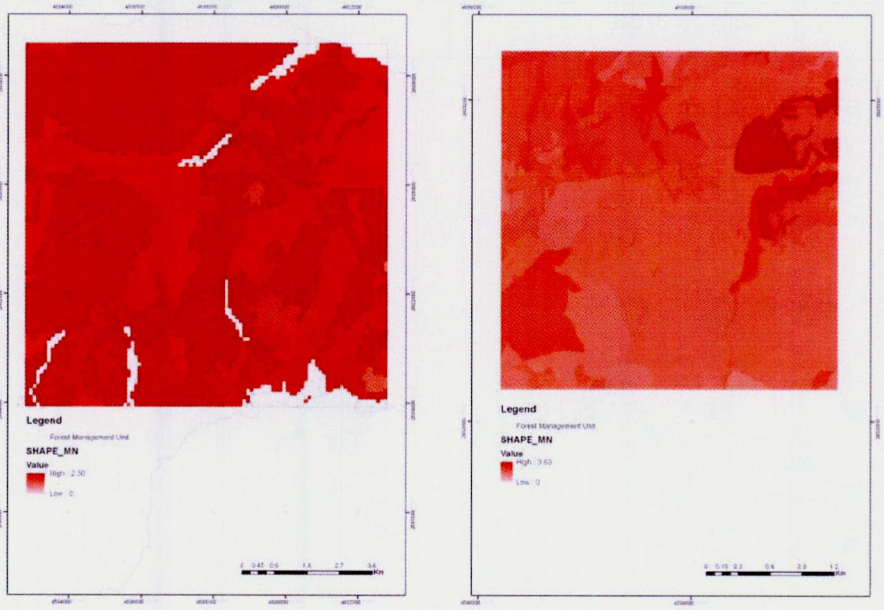


Figure 48: Mean shape indexes resulting maps for "Tarvisio forest" site.

Mean fractal dimension per class) (FRAC_MN)

Large area	Small area

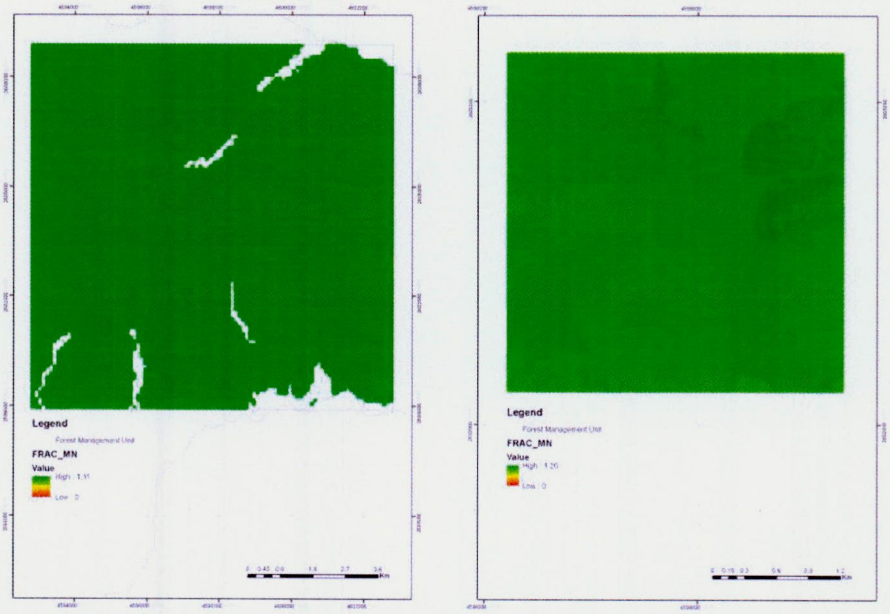


Figure 49: Mean fractal dimensions resulting maps for "Tarvisio forest" site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

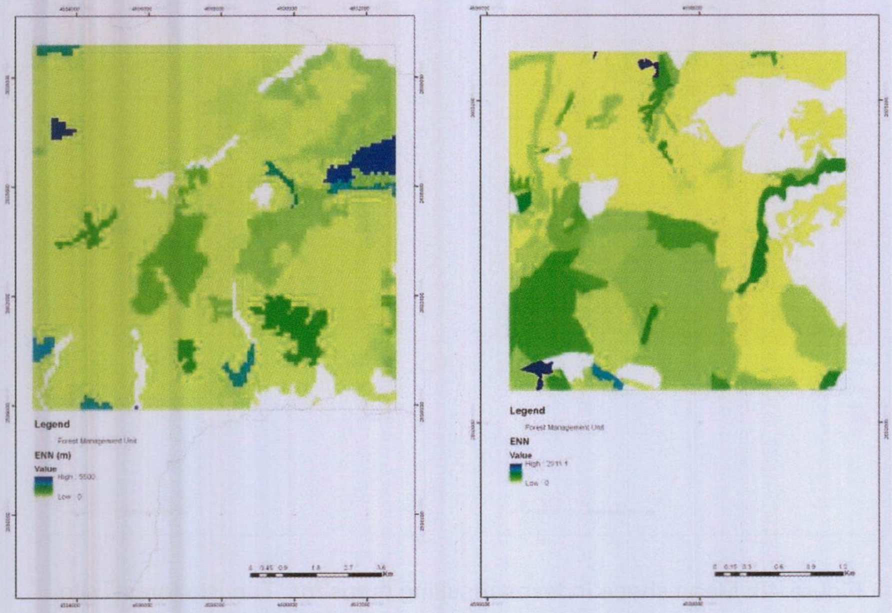


Figure 50: Euclidean nearest neighbor distances maps for “Tarvisio forest” site.

2.2.2. Cansiglio – Site 1

- **Evaluation of the landscape context and land uses changes: "large" area**

Figure 52 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

Within the landscape of Cansiglio "large" area broad-leaved forest (class 311) is the land use class most represented (5338 hectares for year 2006) (53 % of the total area) (Table 14 and Figure 51) which extend on mean altitudes of 930 m.a.s.l. (Table 15) and on steep slope (Table 16). Coniferous forests (class 312) and mixed forests (class 313) cover respectively the 8 % and the 15 % of total area.

Artificial land uses (class 1 of first CLC level) cover 243 hectares corresponding at only 2 % of total area.

The land use changes have occurred for the period from year 1990 to 2006 while they remained stables between the year 1990 to 2000 (Table 14). Transitional woodland-shrub (class 324) showed the higher change rate (227 %). Among forest land use classes a negative change rate has been detected for coniferous forest (class 312) (25.6 %) and a slightly positive change rate for class 311 (4.8 %) and class 313 (2.38 %).

CANSIGLIO (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	122	115	115	1	1	1	-7.00	0.00	-7.00	-5.74
122	Road and rail networks and associated land	0	17	17	0	0	0	17.00	0.00	17.00	
131	Mineral extraction sites	28	28	28	0	0	0	0.00	0.00	0.00	0.00
133	Construction sites	99	82	82	1	1	1	-17.00	0.00	-17.00	-17.17
231	Pastures	476	476	476	5	5	5	0.00	0.00	0.00	0.00
242	Complex cultivation patterns	203	211	211	2	2	2	8.00	0.00	8.00	3.94
243	Land principally occupied by agriculture, with significant areas of natural vegetation	483	482	482	5	5	5	-1.00	0.00	-1.00	-0.21
311	Broad-leaved forest	5093	5338	5338	51	53	53	245.00	0.00	245.00	4.81
312	Coniferous forest	1091	811	811	11	8	8	-280.00	0.00	-280.00	-25.66
313	Mixed forest	1471	1506	1506	15	15	15	35.00	0.00	35.00	2.38
321	Natural grasslands	839	789	789	8	8	8	-50.00	0.00	-50.00	-5.96
324	Transitional woodland-shrub	22	72	72	0	1	1	50.00	0.00	50.00	227.27
512	Water bodies	73	73	73	1	1	1	0.00	0.00	0.00	0.00
	Total	10000	10000	10000	100	100	100				

Table 14: Area values per class and per year and relative changes between dates for Cansiglio "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

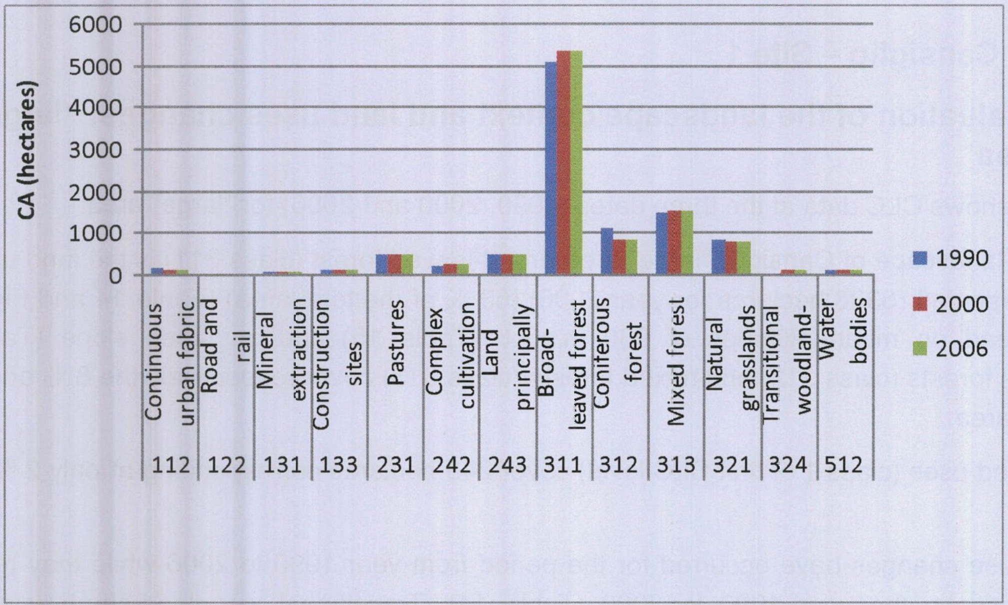


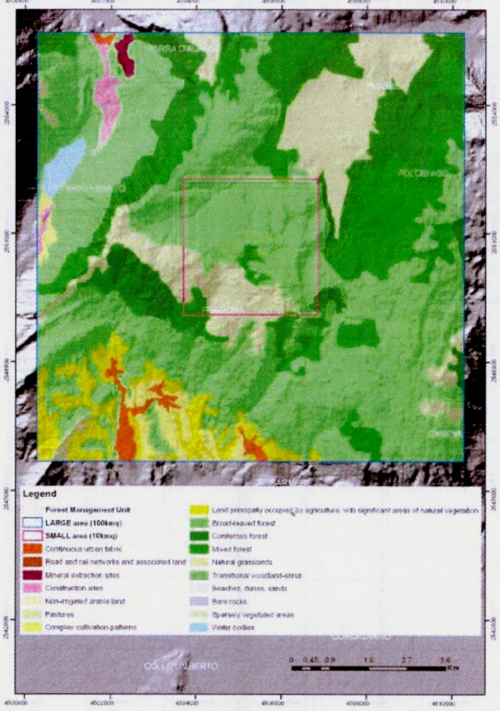
Figure 51: Cansiglio “large” (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

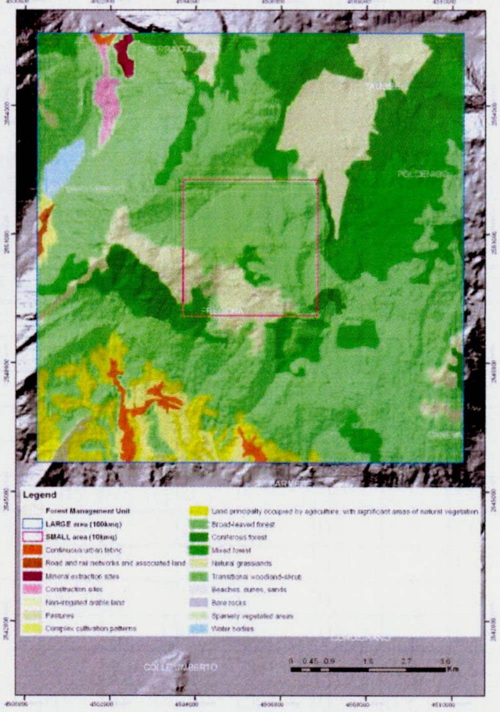
CANSIGLIO (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	2770	231	475	244	330.114	325	299	325
122	Road and rail networks and associated land	437	294	343	49	317.799	325	294	318
131	Mineral extraction sites	720	443	536	93	477.853	475	443	475
133	Construction sites	2041	297	505	208	410.133	375	297	408
231	Pastures	12112	268	1106	838	988.555	1005	268	1015
242	Complex cultivation patterns	5575	164	475	311	287.055	250	164	280
243	Land principally occupied by agriculture, with significant areas of natural vegetation	12129	164	688	524	360.278	400	164	363
311	Broad-leaved forest	133477	192	1579	1387	930.146	1325	192	950
312	Coniferous forest	19905	625	1540	915	1073.41	1025	642	1025
313	Mixed forest	37449	450	1513	1063	1135.62	1150	465	1149
321	Natural grasslands	19944	525	1565	1040	1182.99	1250	535	1220
324	Transitional woodland-shrub	1651	1000	1406	406	1208.88	1325	1008	1183
512	Water bodies	1790	274	295	21	274.539	274	275	274

Table 15 Topographic features for each class within Cansiglio “large” area: altitudes (m.a.s.l).

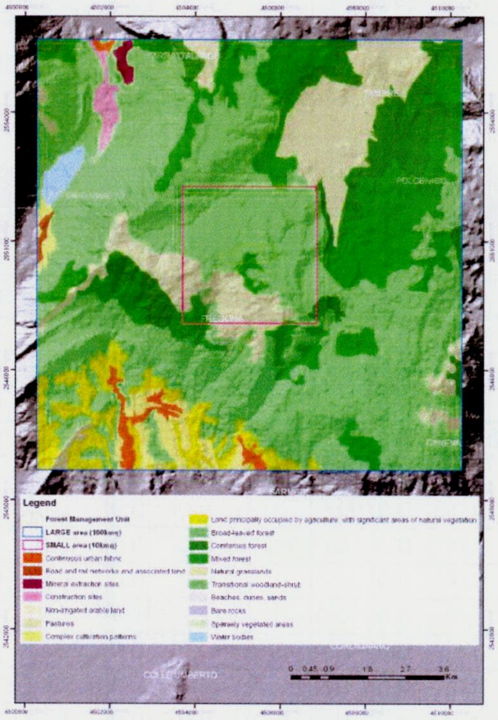
CANSIGLIO (large area 100 kmq)			
Code	Class	Class of majority presence	Slope values
112	Continuous urban fabric	3	10 - 20 %
122	Road and rail networks and associated land	3	10 - 20 %
131	Mineral extraction sites	3	10 - 20 %
133	Construction sites	3	10 - 20 %
231	Pastures	2	3 - 10 %
242	Complex cultivation patterns	3	10 - 20 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	5	30 - 50 %
311	Broad-leaved forest	6	> 50 %
312	Coniferous forest	6	> 50 %
313	Mixed forest	6	> 50 %
321	Natural grasslands	3	10 - 20 %
324	Transitional woodland-shrub	5	30 - 50 %
512	Water bodies	1	< 3%

Table 16: Topographic features for each class within Cansiglio “large” area: class of slopes (percentage).





CLC 1990	CLC 2000



CLC 2006

Figure 52: CORINE Land Cover data of Cansiglio “large” area.

The contingency table (Table 17 and 18) shows as natural grass land (class 321) increased in year 2006 within transitional woodland-shrub (class 324). Transitions between forest classes (from 312 to 311) and transitions from artificial land uses an agricultural land uses (from 112 to 242) should be considered carefully since they could be "false" changes, caused by differences between CORINE Land Cover Italian projects.

CANSIGLIO (large area 100 kmq)

Cross tabulation (hectares)

	2006													
1990	112	122	131	133	231	242	243	311	312	313	321	324	512	Total
112	112	0	0	0	0	10	0	0	0	0	0	0	0	122
122	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	28	0	0	0	0	0	0	0	0	0	0	28
133	0	17	0	82	0	0	0	0	0	0	0	0	0	99
231	0	0	0	0	476	0	0	0	0	0	0	0	0	476
242	2	0	0	0	0	201	0	0	0	0	0	0	0	203
243	1	0	0	0	0	0	482	0	0	0	0	0	0	483
311	0	0	0	0	0	0	0	5093	0	0	0	0	0	5093
312	0	0	0	0	0	0	0	245	811	35	0	0	0	1091
313	0	0	0	0	0	0	0	0	0	1471	0	0	0	1471
321	0	0	0	0	0	0	0	0	0	0	789	50	0	839
324	0	0	0	0	0	0	0	0	0	0	0	22	0	22
512	0	0	0	0	0	0	0	0	0	0	0	0	73	73
Total	115	17	28	82	476	211	482	5338	811	1506	789	72	73	10000

Table 17: contingency matrix of Cansiglio large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

CANSIGLIO (large area 100 kmq)

Cross tabulation (%)

	2006													
1990	112	122	131	133	231	242	243	311	312	313	321	324	512	Total
112	91.8	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
122	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
131	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
133	0.0	17.2	0.0	82.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
231	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
242	1.0	0.0	0.0	0.0	0.0	99.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
243	0.2	0.0	0.0	0.0	0.0	0.0	99.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0
311	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0
312	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	74.3	3.2	0.0	0.0	0.0	100.0
313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.0	6.0	0.0	100.0
324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0
512	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0

Table 18: contingency matrix of Cansiglio large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

The analysis of landscape ecology metrics showed as the landscape has been changed between the two dates (1990-2006) (Figure 53).

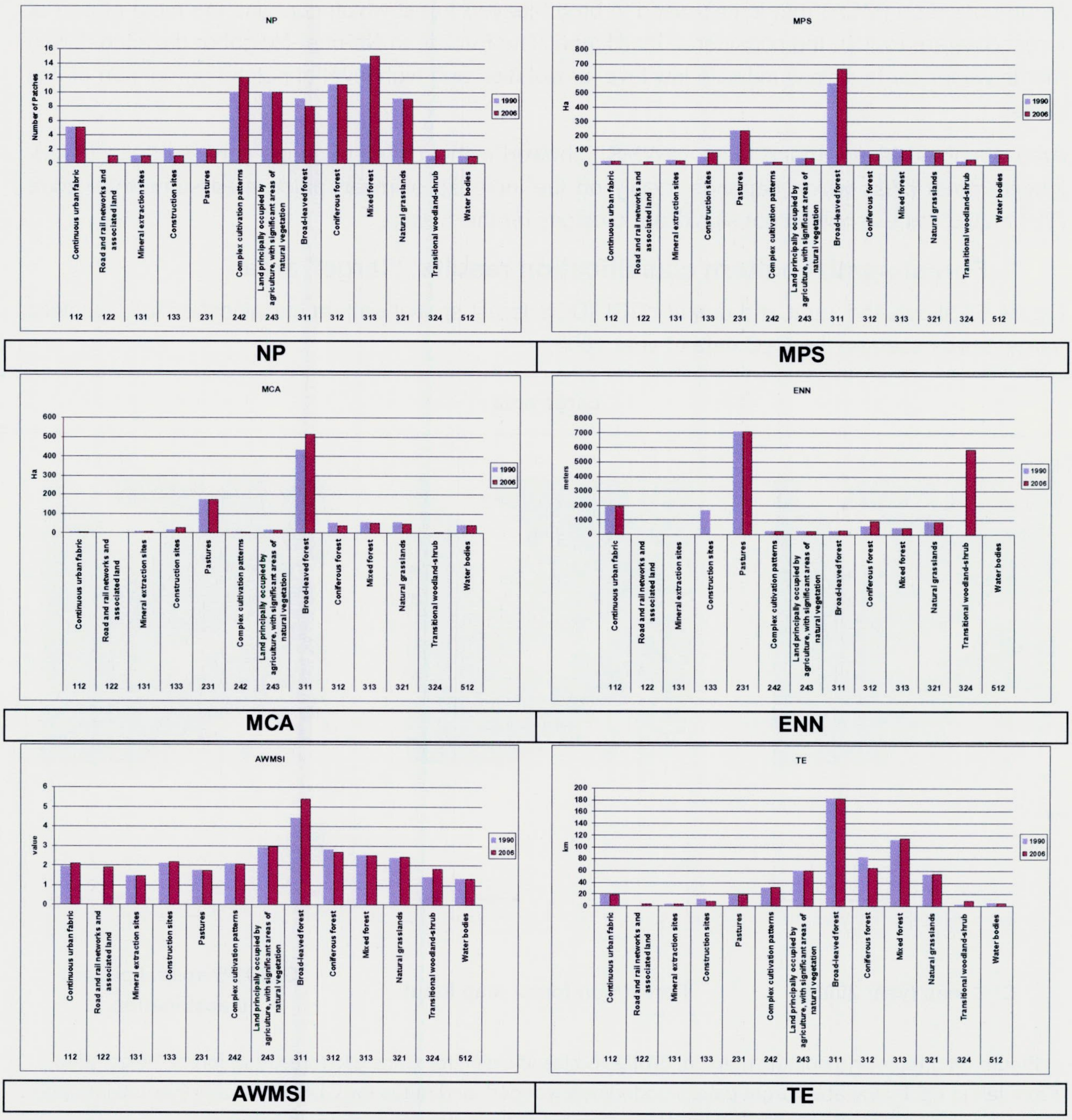


Figure 53: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Cansiglio "large" area.

Changes in number of patches (NP) have been detected for: complex cultivation patterns (class 324); mixed forest (class 313) and transitional woodland-shrub (class 324) which showed an increasing of NP, while broad-leaved forest (class 311) showed a decreasing of patch number. The mean patch size metric (MPS) showed as the loss of patch abundance for broad-leaved forest correspond at an increasing of mean size and indicates a reduction of forest fragmentation for this class.

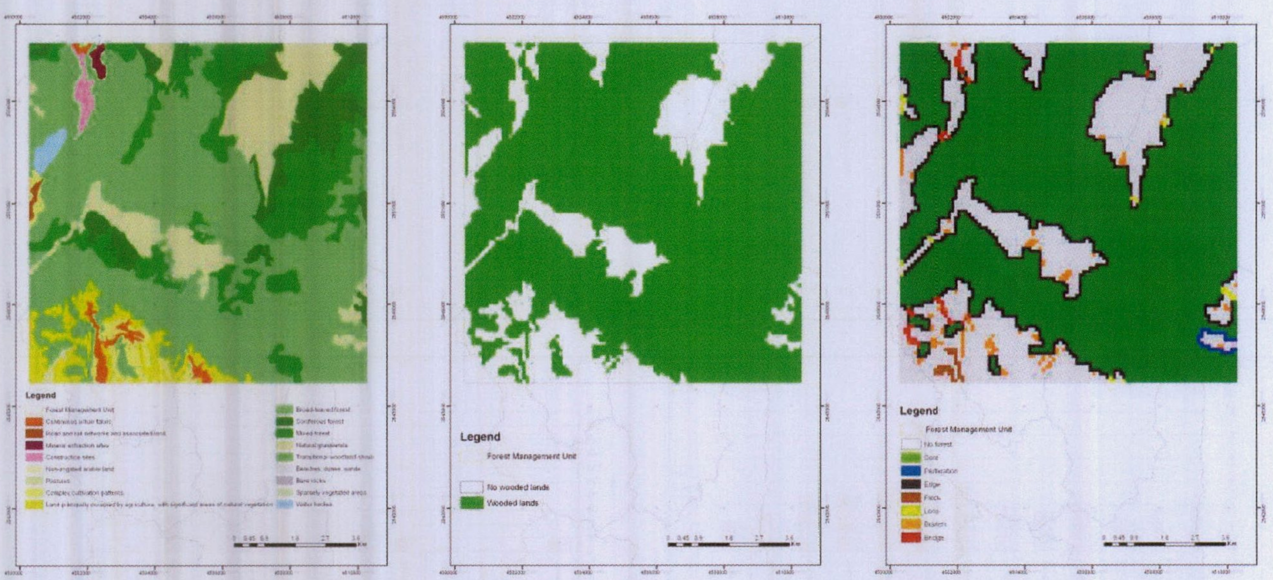
Mean core area (MCA) metric increased in broad-leaved forest which contains the most of part of forest core area within the considered landscape. The Euclidean Nearest-Neighbor distance (ENN) metric values for this class indicate low level of isolation and high level of patch aggregation of this class.

Area Weighted Mean Shape Index (AWMSI) showed highest level of shape complexity for broad-leaved forest class which depends mainly on the increase of mean patch area since total edge (TE) metric values showed not significant changes for this class.

- ## Forest spatial pattern classification results: "large" area

Figure 54 shows the input and output of GUIDOS forest spatial pattern classification for Cansiglio "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006) | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 54: Inputs and outputs maps of GUIDOS classification for Cansiglio forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

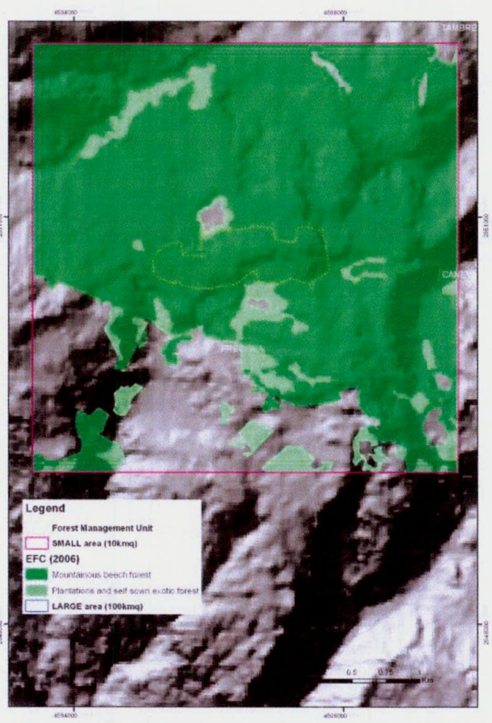
In Table 19, area (in hectares) of each forest spatial pattern class has been reported.

Cansiglio (large area 100 kmq)			
Code	**Description**		**AREA (ha)**
1	Branch		125
3	Edge		855
5	Perforation		34
9	Islet		35
17	Core		6589
33	Bridge		34
35	Bridge in Edge		22
65	Loop		14
67	Loop in Edge		19

Table 19: Area (hectares) of GUIDOS forest spatial pattern classes for Cansiglio forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 55 show forest cover data of Cansiglio "small" area.



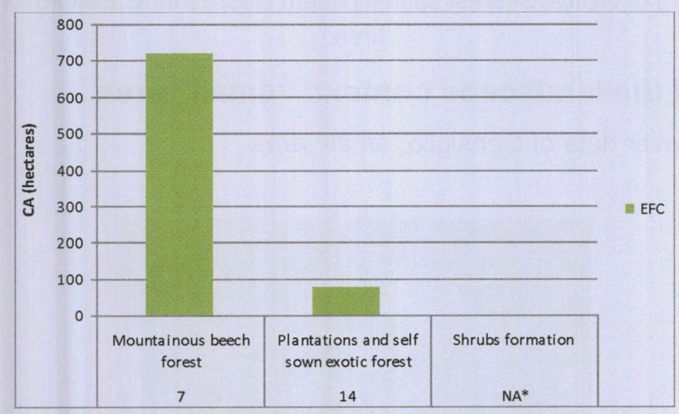
European Forest Categories (2006)

Figure 55: European Forest Categories map (2006) for Cansiglio "small" area.

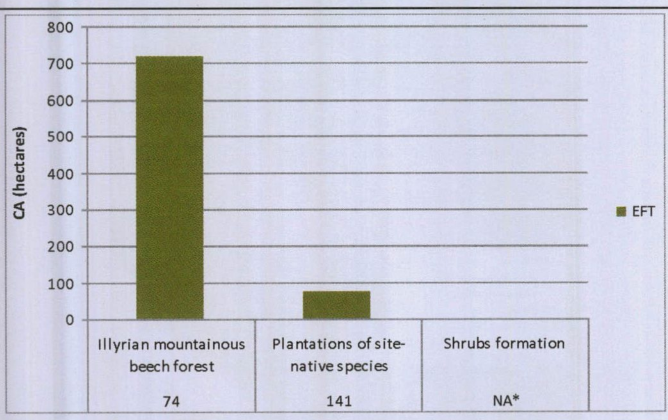
On the basis of map of forest type of year 2006, within Cansiglio "small" area, forest cover about 794 hectares of the entire area. The "mountainous beech forest" (class 7) category is dominant (718 hectares) (Table 20 and Figure 56). This forests extend up to 1200 m.a.s.l. altitudes (Table 21) and on moderate slopes (10-20 %) (Table 22). Plantations (class 14) are the second forest category most represented (74.5 hectares) which extend on the same altitudes range and slopes of beech forest.

CANSIGLIO (small area 10 kmq)				
EFC Code	Class description	EFT Code	Class description	Class Area (CA) (hectares)
7	Mountainous beech forest	74	Illyrian mountainous beech forest	718.45
			sub total	**718.45**
14	Plantations and self sown exotic forest	141	Plantations of site-native species	74.48
			sub total	**74.48**
NA*	"Shrubs formation"	NA*		1.38
			sub total	**1.38**
			TOTAL	**794.3**
(*) NA: not applicable.				

Table 20: Cansiglio "small" area. Area values (hectares) for EFC and EFT classes. Forest Types date: 2006. NA: not applicable, means the impossibility of reclassification for that level.



EFC level classification



EFT level classification

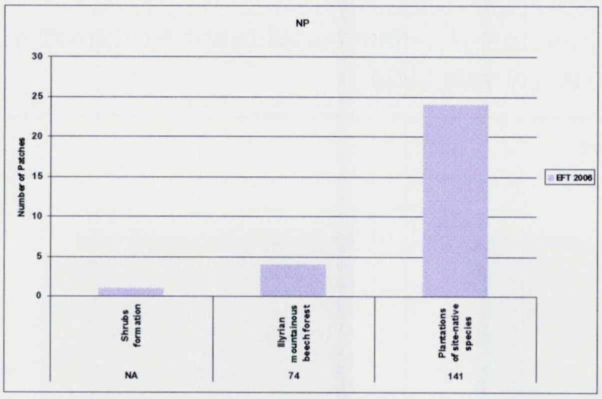
Figure 56: Cansiglio "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

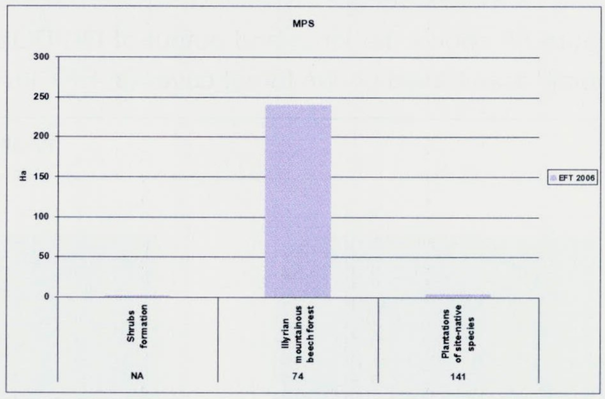
CANSIGLIO (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFT	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
NA*	Shrubs formation	33	1124	1149	25	1137.03	1124	1129	1138
74	Illyrian mountainous beech forest	17966	1040	1450	410	1249.24	1300	1040	1263
141	Plantations of site-native species	1860	1065	1378	313	1239.99	1225	1065	1245

Table 21: Topographic features for each class within Cansiglio "small" area: altitudes (m.a.s.l).

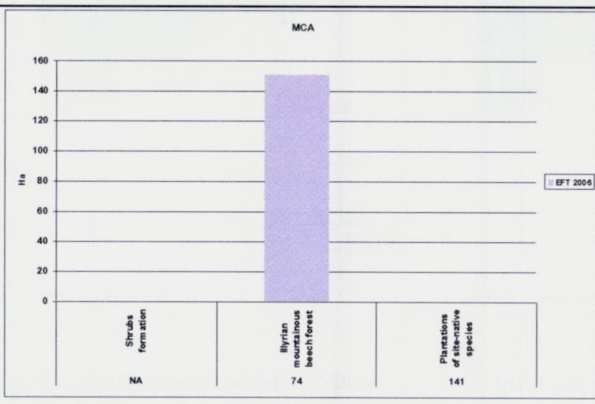
CANSIGLIO (small area 10 kmq)			
Code	***EFT***	***Class of majority presence***	***Slope values***
NA*	Shrubs formation	2	3 - 10 %
74	Illyrian mountainous beech forest	3	10 - 20 %
141	Plantations of site-native species	3	10 - 20 %

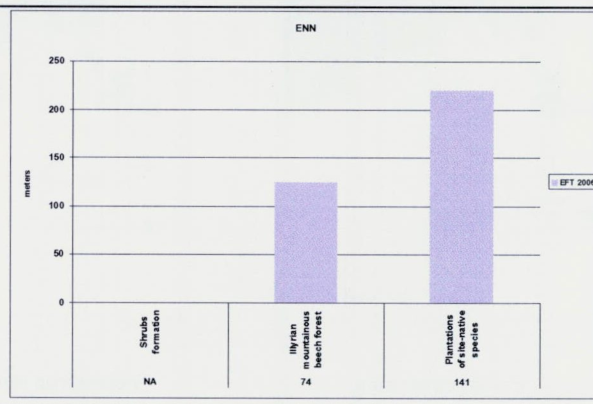
Table 22: Topographic features for each class within Cansiglio "small" area: class of slopes (percentage).



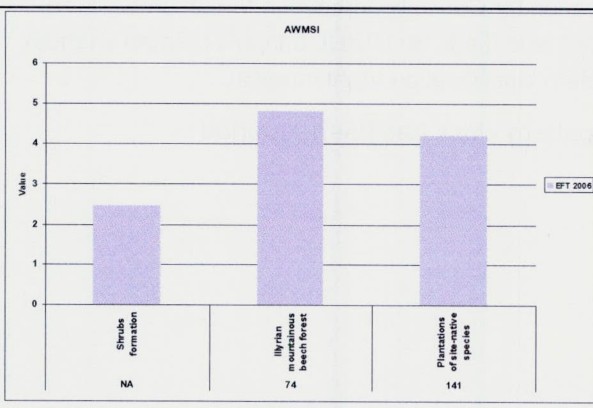


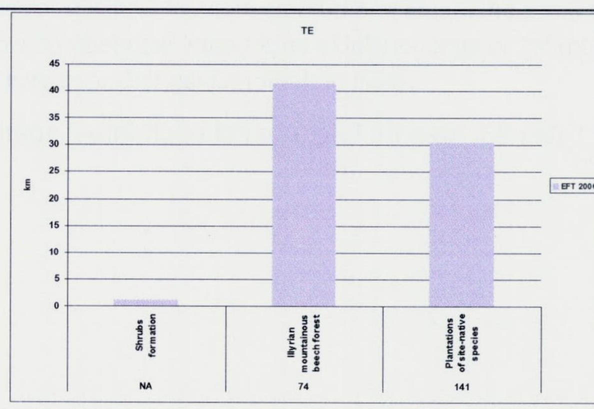
NP	MPS





MCA	ENN





AWMSI	TE

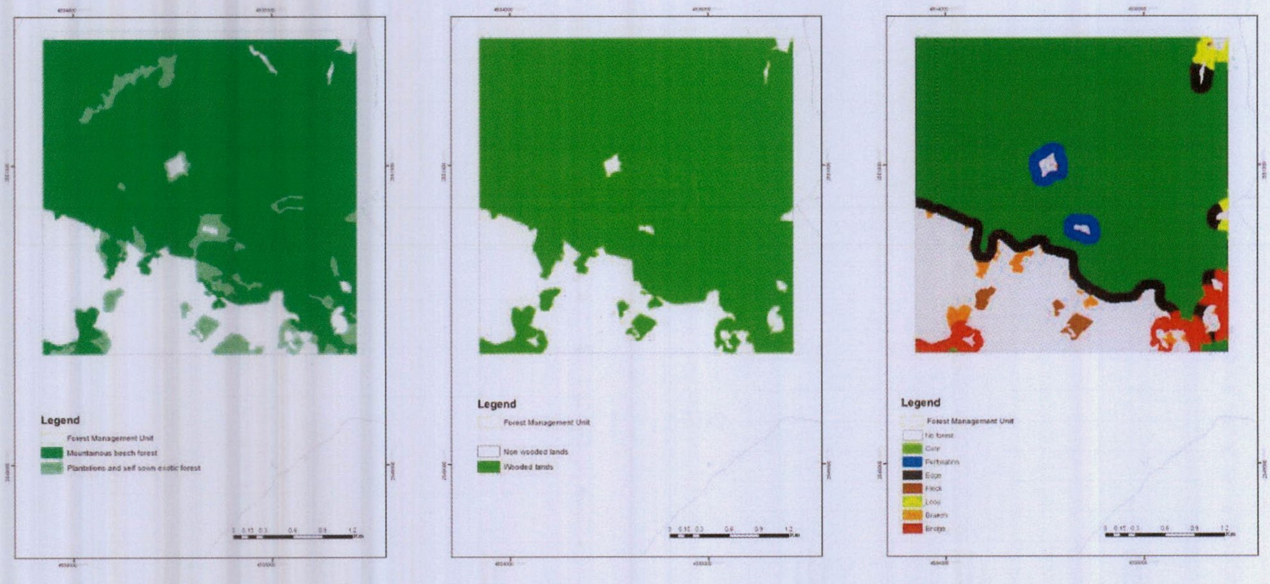
Figure 57: Results of landscape ecology metrics for forest cover (year 2006) within "small" area of Tarvisio site.

Analysis of landscape metrics showed as "plantations" are the most fragmented category within the considered landscape as showed by the largest number of patches (NP) (Figure 57). Beech forest (class 74) has the highest mean patch size (MPS) and contains the most part of core area (MCA metric). The Euclidean Nearest-Neighbor distance (ENN) metric showed as plantations have high level of isolation. The beech forest showed the highest shape complexity (AWMSI) and length of total edge (TE).

- Forest spatial pattern classification results: "small" area

Figure 58 shows the input and output of GUIDOS forest spatial pattern classification for Cansiglio "small" area based on the forest cover (at EFT level) data of year 2006.

Small area



Forest cover map | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 58: Inputs and outputs maps of GUIDOS classification for Cansiglio forest/non forest "small" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 23, area (in hectares) of each forest spatial pattern class has been reported.

Cansiglio (small area 10 kmq)			
Code	Description		AREA (ha)
1	Branch		11.82
3	Edge		56.05
5	Perforation		18.89
9	Islet		7.84
17	Core		649.74
33	Bridge		13.68
35	Bridge in Edge		20.01
65	Loop		0.78
67	Loop in Edge		7.94

Table 23: Area (hectares) of GUIDOS forest spatial pattern classes for Cansiglio forest/non forest "small" area

- **Maps of landscape ecology metrics**

Patch area (ha) (*per patch*) (AREA)

Large area	Small area

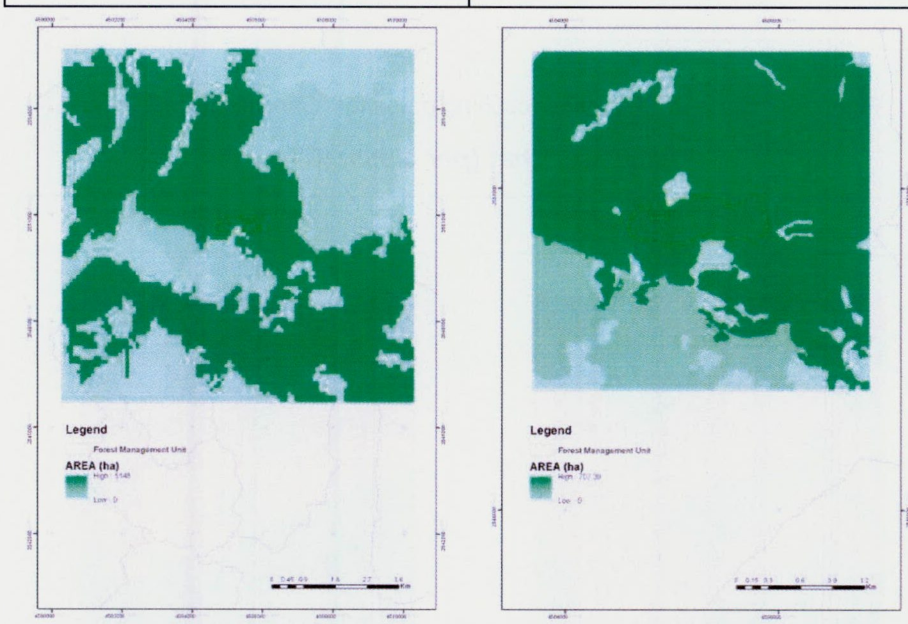


Figure 59: Patch area metrics resulting maps for "Cansiglio forest" site.

Class area (ha) (per class) (CA)

Large area	Small area

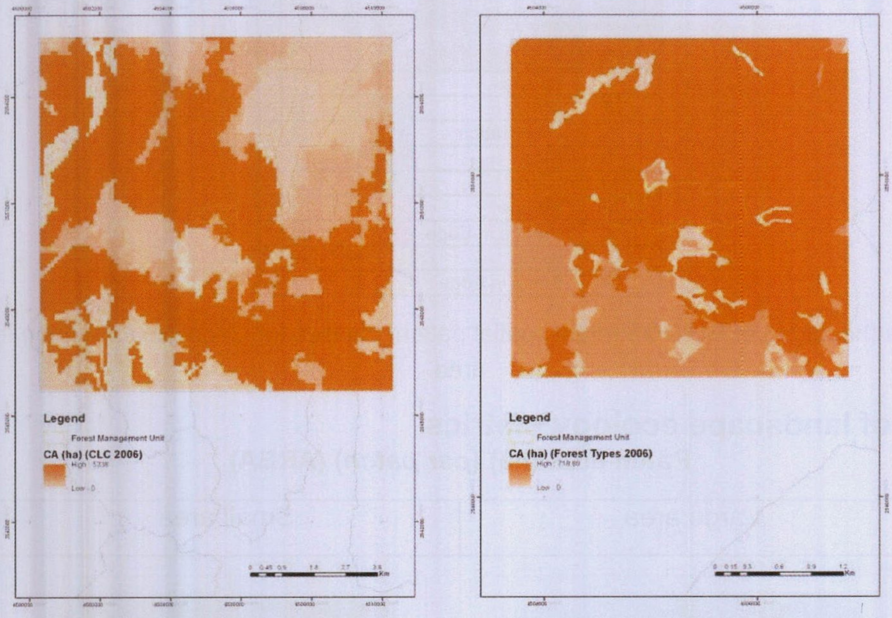


Figure 60: Class area metrics resulting maps for "Cansiglio forest" site.

Class area (ha) (*per class*) (CA)

Large area	Small area

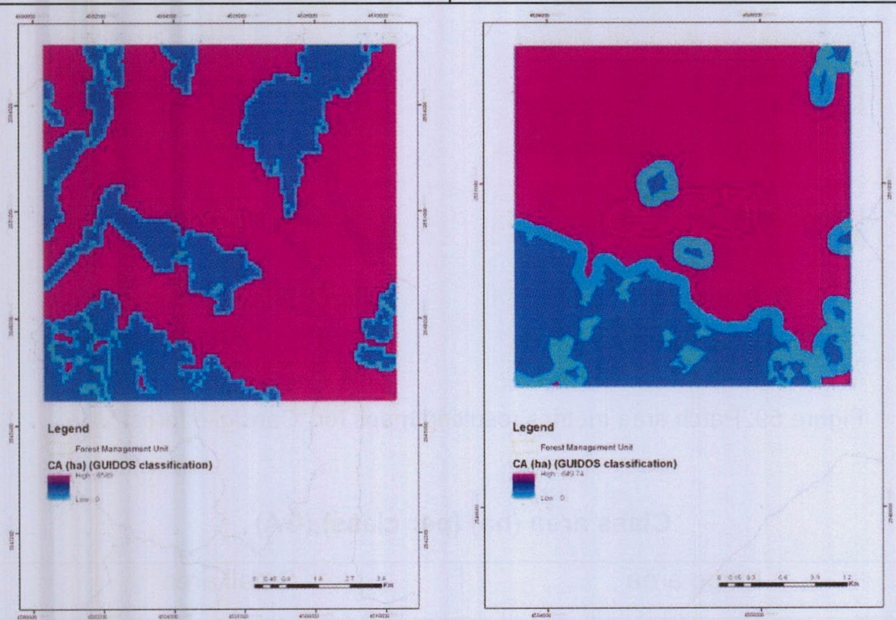


Figure 61: Class area size metrics resulting maps for "Cansiglio forest" site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

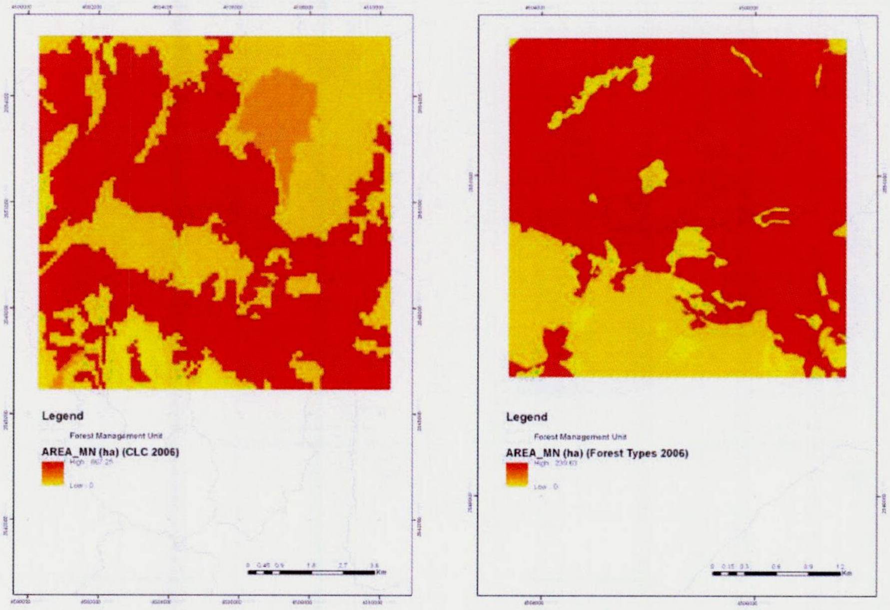


Figure 62: Mean patch size metrics resulting maps for “Cansiglio forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

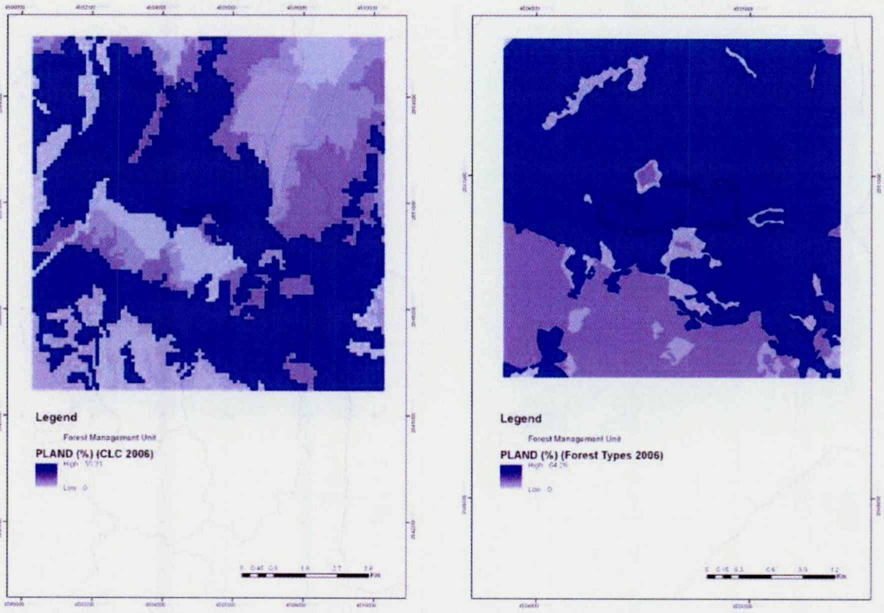


Figure 63: Percentage of landscape metrics resulting maps for “Cansiglio forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

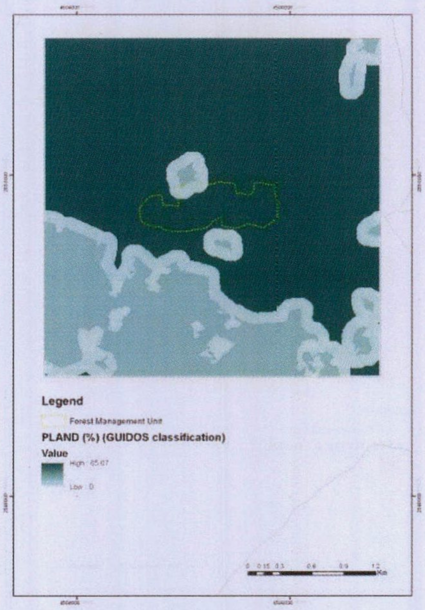


Figure 64: Percentage of landscape metrics resulting maps for "Cansiglio forest" site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

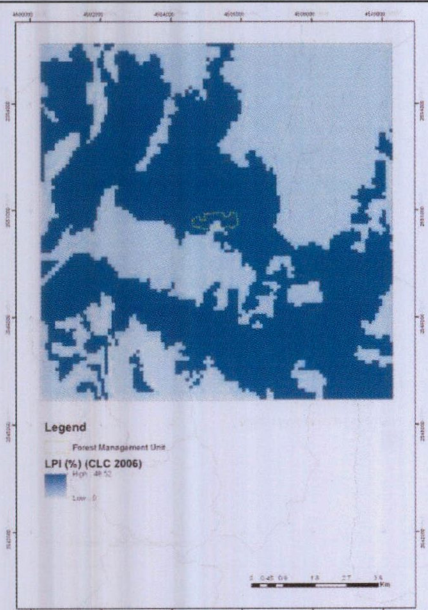


Figure 65: Largest patch index metrics resulting maps for "Cansiglio forest" site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

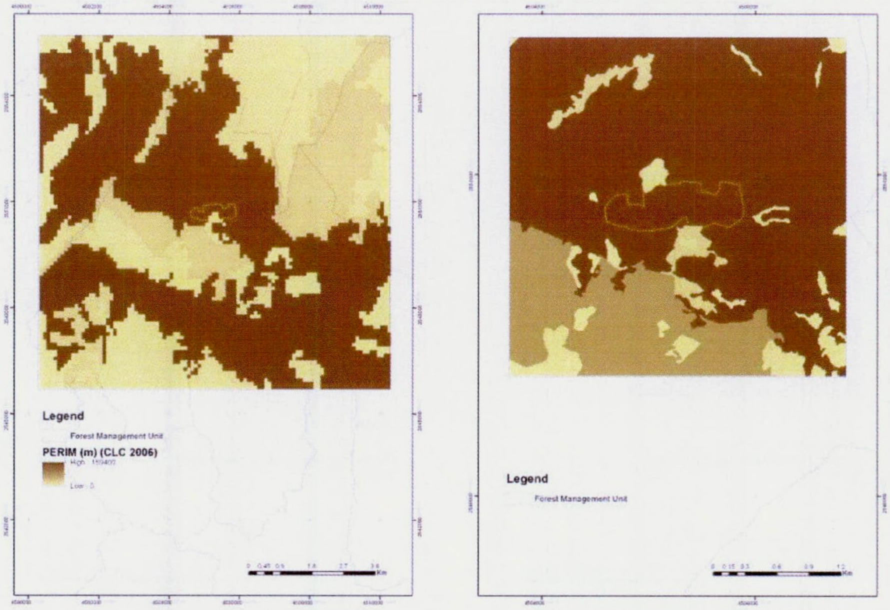


Figure 66: Edge metrics resulting maps for “Canisglio forest” site.

Total core area (ha) (per class) (TCA)

Large area	Small area

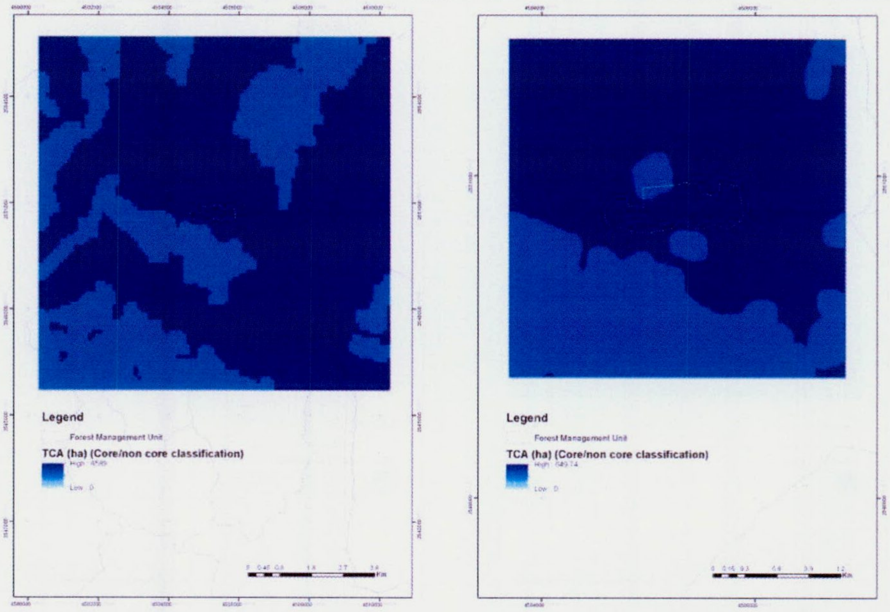


Figure 67: Total core area metrics resulting maps for “Cansiglio forest” site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

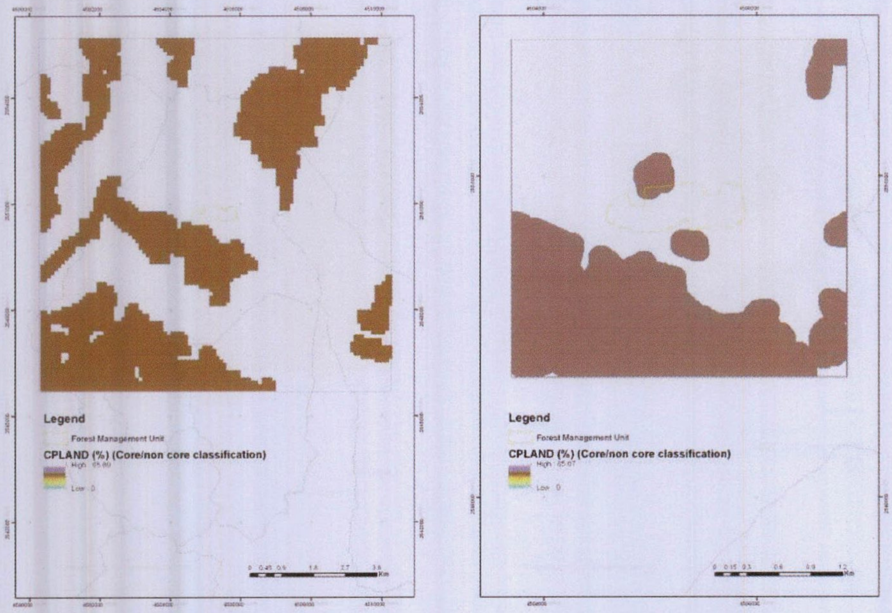


Figure 68: Core Area Percentage of Landscape metrics resulting maps for “Cansiglio forest” site.

Number of patches (per patch) (NP)

Large area	Small area

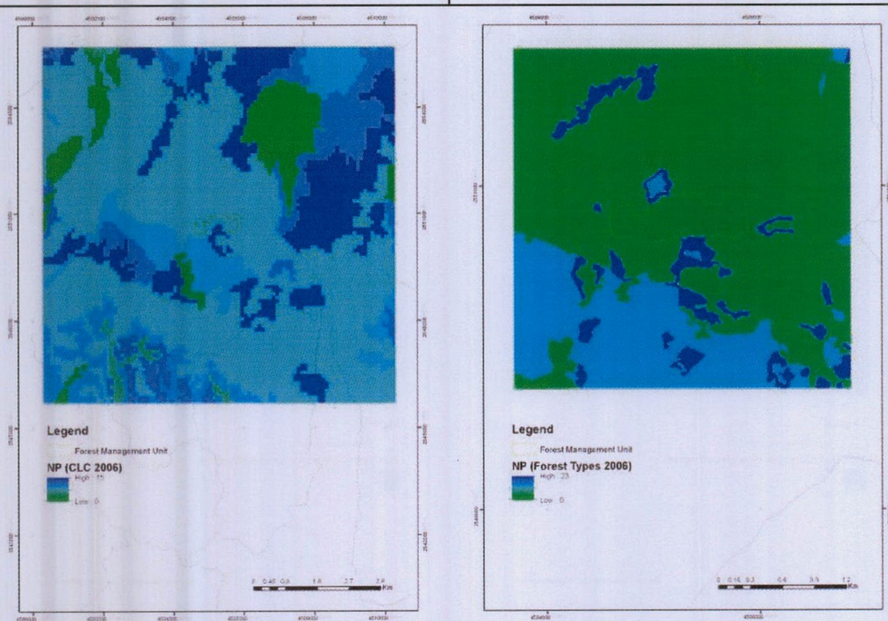


Figure 69: Number of patches in the landscape resulting maps for “Cansiglio forest” site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

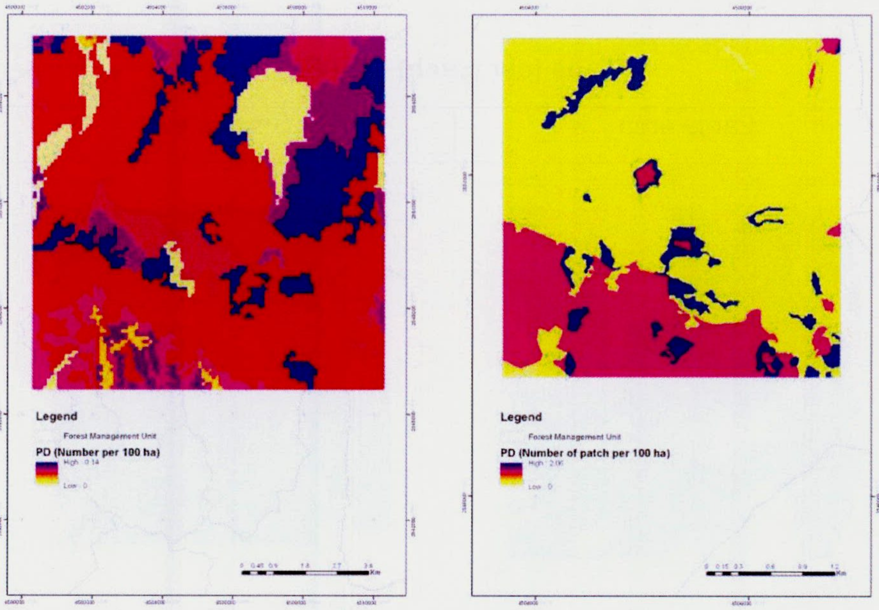


Figure 70: Patch density metrics resulting maps for “Cansiglio forest” site.

Shape (per patch) (SHAPE)

Large area	Small area

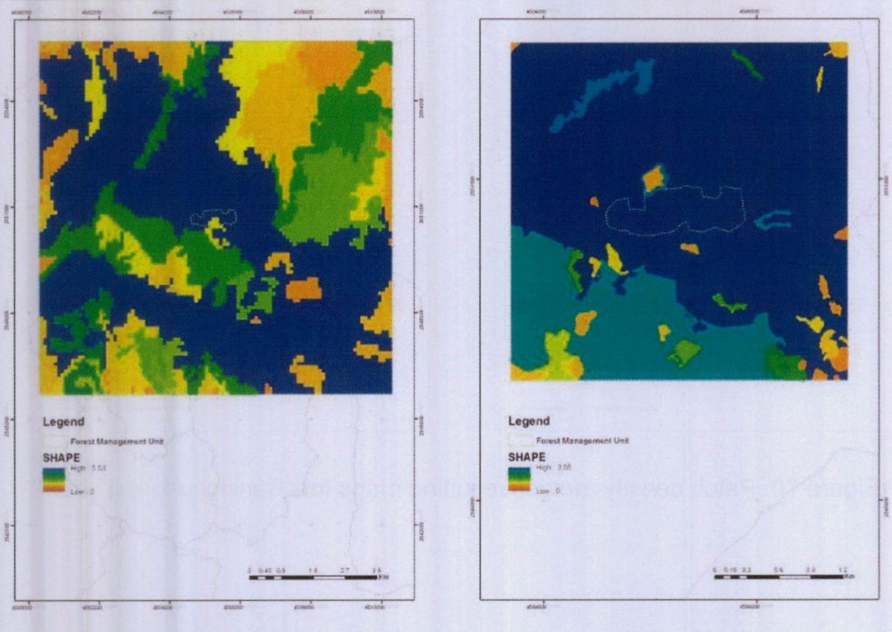


Figure 71: Shape metrics resulting maps for "Cansiglio forest" site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

Figure 72: Fractal dimension metrics resulting maps for "Cansiglio forest" site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

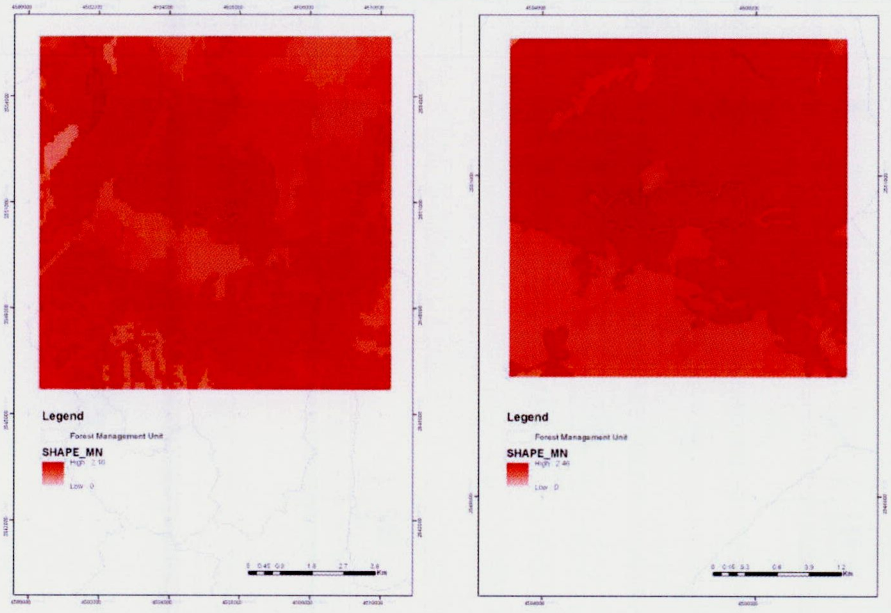


Figure 73: Mean shape indexes resulting maps for “Cansiglio forest” site.

Mean fractal dimension per class) (FRAC_MN)

Large area	Small area

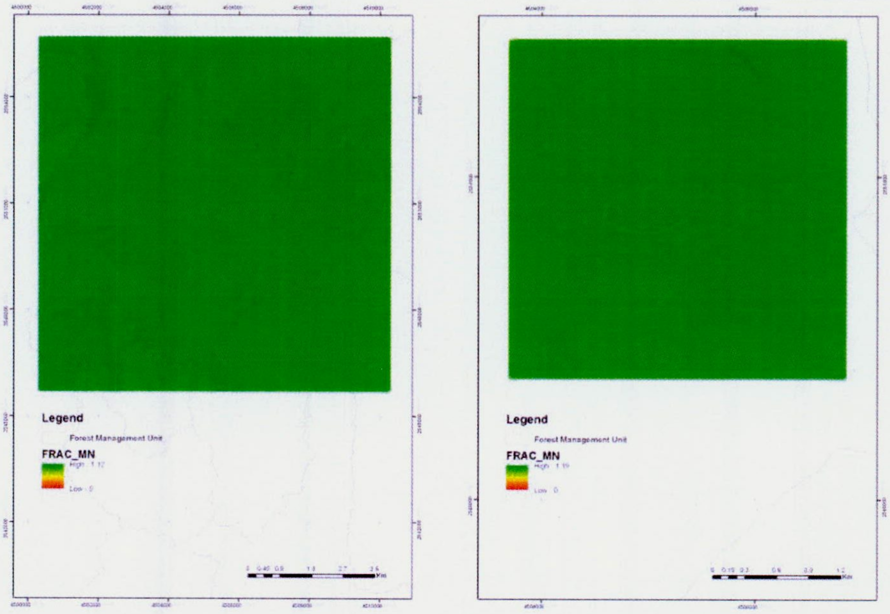


Figure 74: Mean fractal dimensions resulting maps for “Cansiglio forest” site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

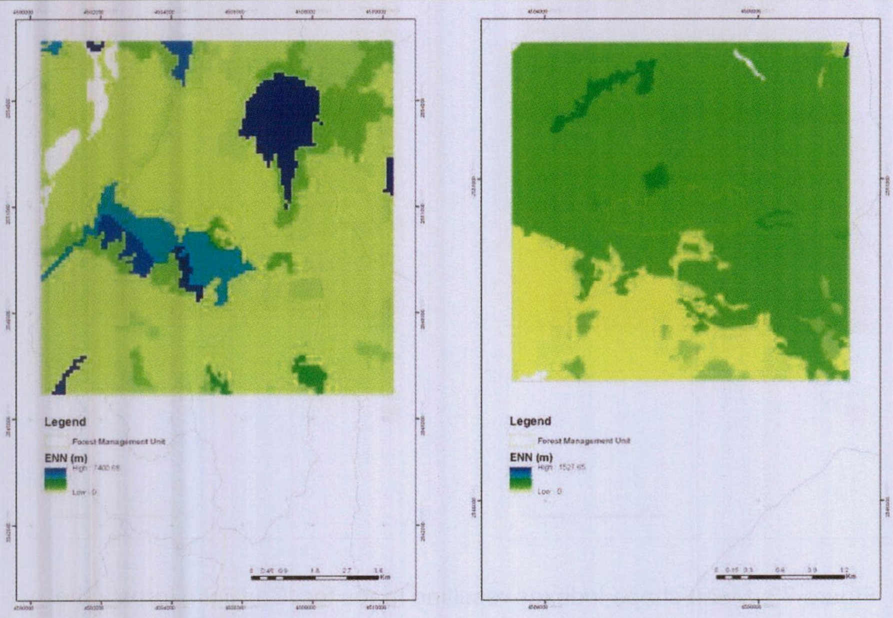


Figure 75: Euclidean nearest neighbor distances maps for “Cansiglio forest” site.

2.2.3. Lorenzago di Cadore – Site 3

- Evaluation of the landscape context and land uses changes: "large" area

Figure 77 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

Landscape within "large" area is mainly dominated by coniferous forest (class 312) (6418 hectares; 68.6 % of total area) at the year 2006 (Table 23 and Figure 76). These forests extend up to 1220 m.a.s.l. mean altitudes (Table 24) and on steep slopes (Table 25).

Broad-leaved forest (class 311) and mixed forest (class 313) cover the 0.1 % and the 4 % of total area respectively.

Artificial areas (class 1 of first CLC level) cover 2.7 % of total area.

LORENZAGO DI CADORE (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	231	208	208	2.47	2.22	2.22	-23	0	-23	-9.96
121	Industrial or commercial units	34	47	47	0.36	0.50	0.50	13	0	13	38.24
231	Pastures	224	224	224	2.40	2.40	2.40	0	0	0	0.00
243	Land principally occupied by agriculture, with significant areas of natural vegetation	521	558	558	5.57	5.97	5.97	37	0	37	7.10
311	Broad-leaved forest	12	12	12	0.13	0.13	0.13	0	0	0	0.00
312	Coniferous forest	6665	6418	6418	71.28	68.64	68.64	-247	0	-247	-3.71
313	Mixed forest	374	374	374	4.00	4.00	4.00	0	0	0	0.00
321	Natural grasslands	143	143	143	1.53	1.53	1.53	0	0	0	0.00
322	Moors and heathland	222	442	442	2.37	4.73	4.73	220	0	220	99.10
324	Transitional woodland-shrub	28	28	28	0.30	0.30	0.30	0	0	0	0.00
332	Bare rocks	617	617	617	6.60	6.60	6.60	0	0	0	0.00
333	Sparsely vegetated areas	212	212	212	2.27	2.27	2.27	0	0	0	0.00
512	Water bodies	67	67	67	0.72	0.72	0.72	0	0	0	0.00
		9350	9350	9350	100	100	100				

Table 23: Area values per class and per year and relative changes between dates for Lorenzago di Cadore "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

Land use changes analysis between year 1990 and year 2006 showed the increasing area for moors and heathland (from 222 to 442 hectares), with a change rate of 99 % (Table 23).

Cross tabulation analysis for the same period (Table 26 and Table 27) showed as this change was occurred mainly within class 312 and can be interpreted as the results of reforestation process (probably after forest cutting).

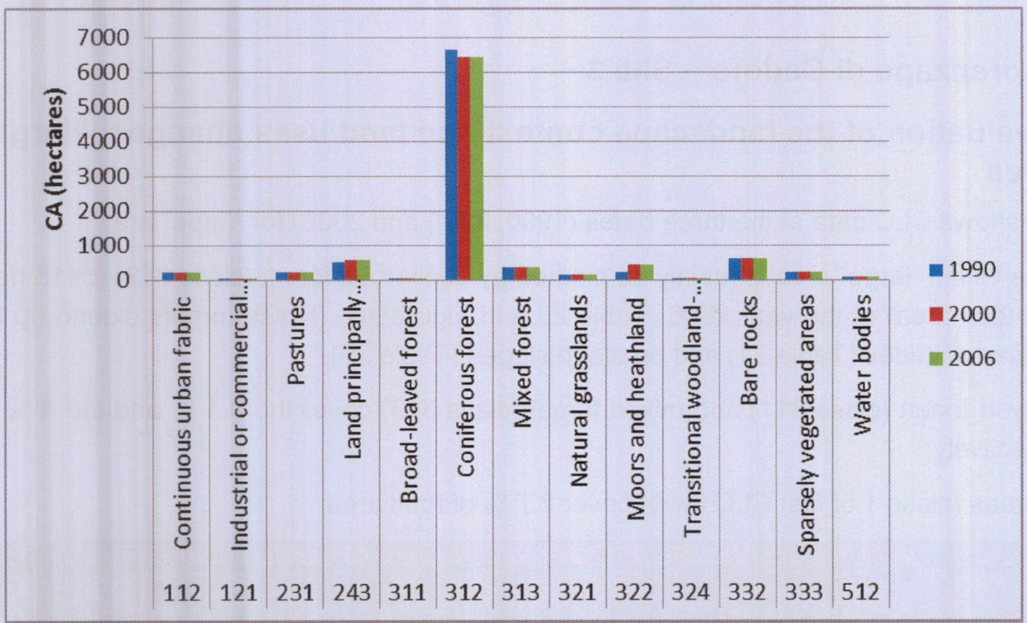


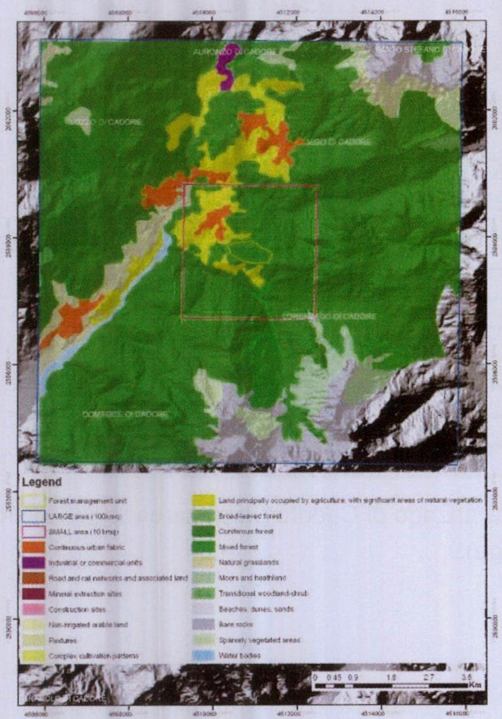
Figure 76: Lorenzago di Cadore "large" (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

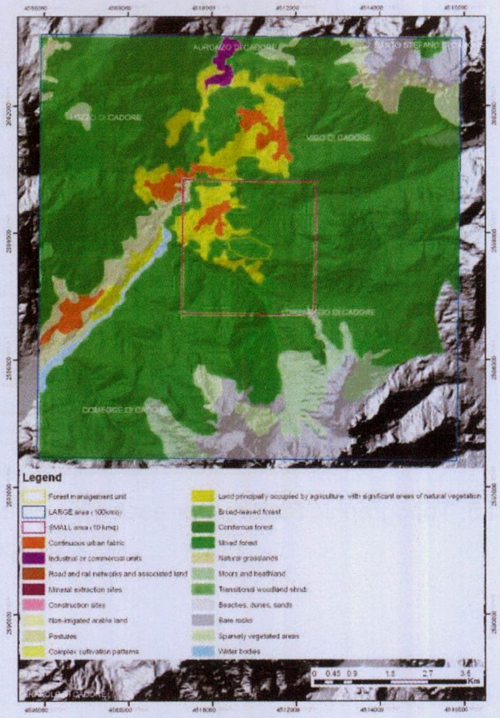
LORENZAGO DI CADORE (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	5181	682	1025	343	838.88	750	682	796
121	Industrial or commercial units	1125	718	820	102	763.492	725	718	767
231	Pastures	5715	693	938	245	765.496	700	726	763
243	Land principally occupied by agriculture, with significant areas of natural vegetation	13875	691	1400	709	866.125	825	709	854
311	Broad-leaved forest	327	1013	1425	412	1204.75	1200	1060	1200
312	Coniferous forest	161143	675	2300	1625	1224.6	1300	686	1200
313	Mixed forest	9308	743	2038	1295	1339.95	1275	743	1325
321	Natural grasslands	3576	1518	2300	782	1905.58	1800	1518	1863
322	Moors and heathland	10745	1083	2200	1117	1565.82	1600	1083	1575
324	Transitional woodland-shrub	705	1275	1775	500	1495.68	1450	1282	1487
332	Bare rocks	15416	1244	2501	1257	2085.88	2200	1262	2100
333	Sparsely vegetated areas	5421	825	2401	1576	1770.36	2000	844	1812
512	Water bodies	1678	685	763	78	700.485	700	685	699

Table 24: Topographic features for each class within Lorenzago di Cadore "large" area: altitudes (m.a.s.l).

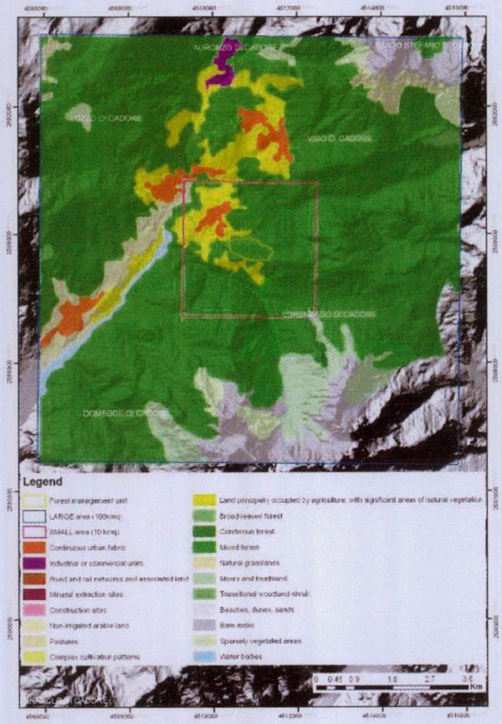
LORENZAGO DI CADORE (large area 100 kmq)			
Code	Class	Class of majority presence	Slope values
112	Continuous urban fabric	3	10 - 20 %
121	Industrial or commercial units	2	3 - 10 %
231	Pastures	3	10 - 20 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	3	10 - 20 %
311	Broad-leaved forest	6	> 50 %
312	Coniferous forest	6	> 50 %
313	Mixed forest	6	> 50 %
321	Natural grasslands	6	> 50 %
322	Moors and heathland	6	> 50 %
324	Transitional woodland-shrub	6	> 50 %
332	Bare rocks	6	> 50 %
333	Sparsely vegetated areas	6	> 50 %
512	Water bodies	1	< 3%

Table 25: Topographic features for each class within Lorenzago di Cadore “large” area: class of slopes (percentage).





CLC 1990	CLC 2000



CLC 2006

Figure 77: CORINE Land Cover data of Lorenzago di Cadore “large” area.

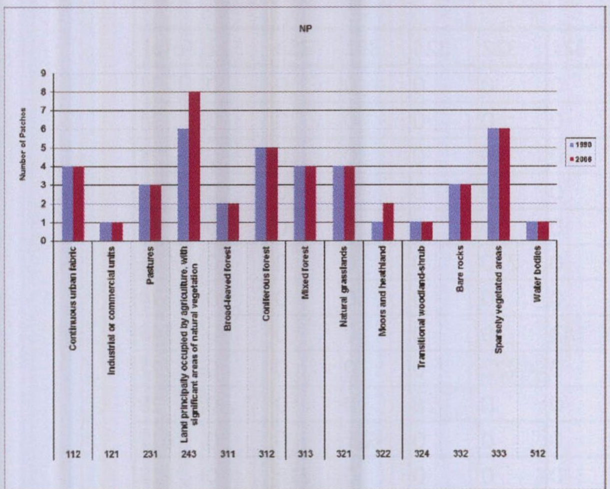
LORENZAGO DI CADORE (large area 100 kmq)														
Cross tabulation (hectares)														
	2006													
1990	**112**	**121**	**231**	**243**	**311**	**312**	**313**	**321**	**322**	**324**	**332**	**333**	**512**	**Total**
112	208	0	0	14	0	9	0	0	0	0	0	0	0	231
121	0	34	0	0	0	0	0	0	0	0	0	0	0	34
231	0	0	224	0	0	0	0	0	0	0	0	0	0	224
243	0	10	0	511	0	0	0	0	0	0	0	0	0	521
311	0	0	0	0	12	0	0	0	0	0	0	0	0	12
312	0	3	0	33	0	6409	0	0	220	0	0	0	0	6665
313	0	0	0	0	0	0	374	0	0	0	0	0	0	374
321	0	0	0	0	0	0	0	143	0	0	0	0	0	143
322	0	0	0	0	0	0	0	0	222	0	0	0	0	222
324	0	0	0	0	0	0	0	0	0	28	0	0	0	28
332	0	0	0	0	0	0	0	0	0	0	617	0	0	617
333	0	0	0	0	0	0	0	0	0	0	0	212	0	212
512	0	0	0	0	0	0	0	0	0	0	0	0	67	67
Total	**208**	**47**	**224**	**558**	**12**	**6418**	**374**	**143**	**442**	**28**	**617**	**212**	**67**	**9350**

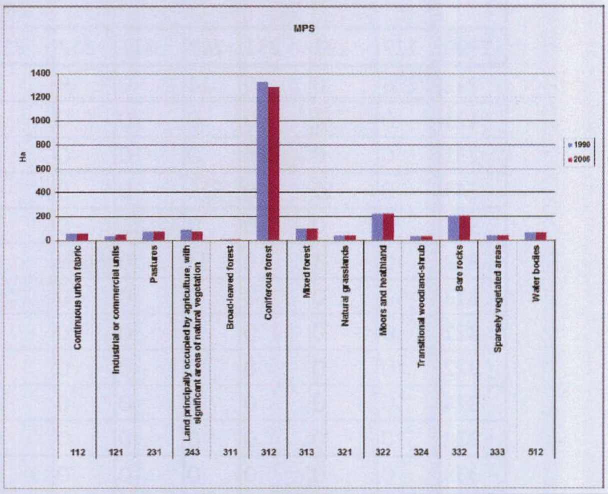
Tabella 26: contingency matrix of Lorenzago di Cadore large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

LORENZAGO DI CADORE (large area 100 kmq)														
Cross tabulation (percentage)														
	2006													
1990	**112**	**121**	**231**	**243**	**311**	**312**	**313**	**321**	**322**	**324**	**332**	**333**	**512**	**Total**
112	90.0	0.0	0.0	6.1	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
121	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
231	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
243	0.0	1.9	0.0	98.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
311	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
312	0.0	0.0	0.0	0.5	0.0	96.2	0.0	0.0	3.3	0.0	0.0	0.0	0.0	100.0
313	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0
322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
332	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0
333	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0
512	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0

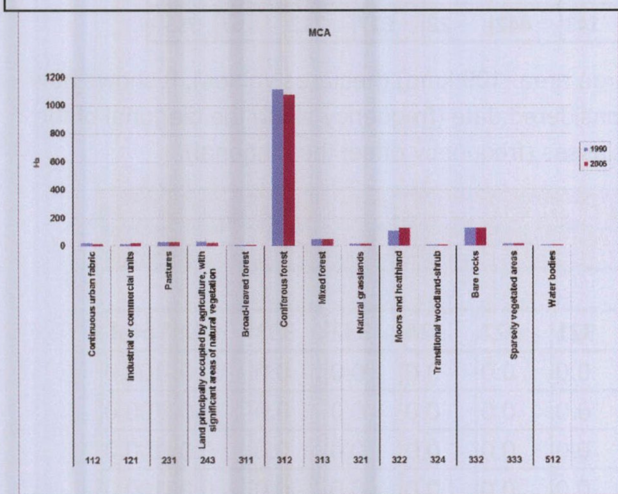
Tabella 27: contingency matrix of Lorenzago di Cadore (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

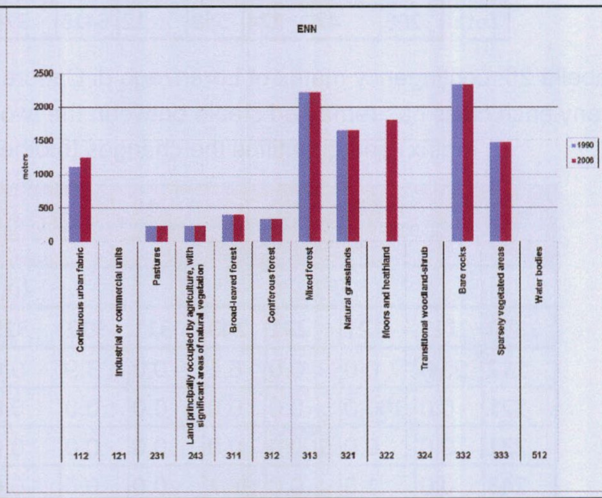
The analysis of landscape ecology metrics (Figure 78) showed as land principally occupied by agriculture, with significant areas of natural vegetation class (243) has the higher number of patches (NP) and then the most fragmented land use class within the landscape.



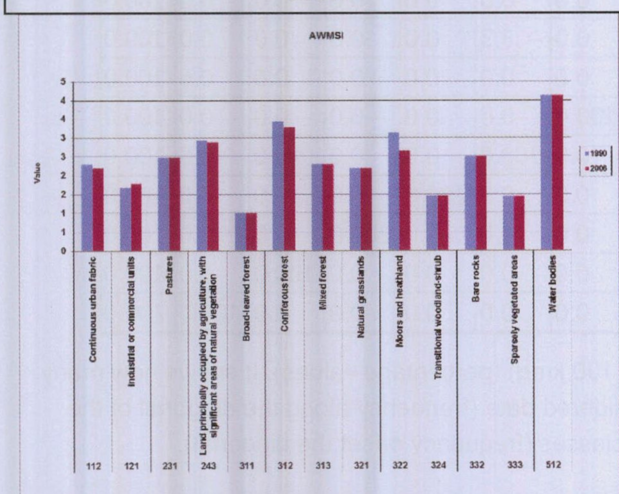


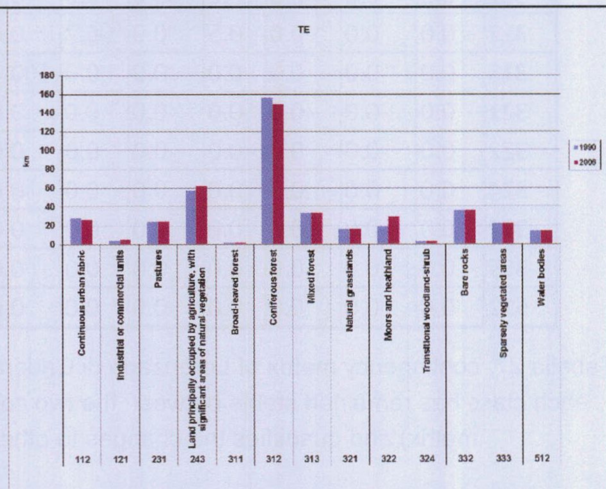
NP	MPS





MCA	ENN





AWMSI	TE

Figure 78: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Lorenzago di Cadore "large" area.

Coniferous forest (class 312) showed the greatest mean patch size (MPS) and this forest contains the most part of core areas (MCA).

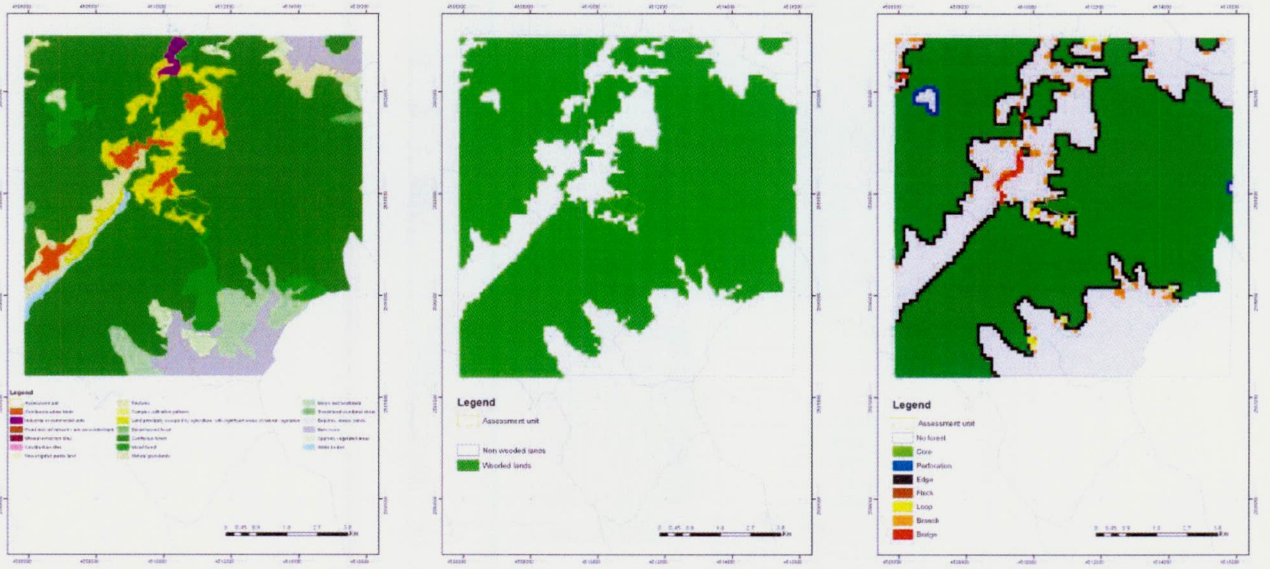
The Euclidean Nearest-Neighbor distance (ENN) for this forest did not show changes then patches isolation remained stable through the considered time. Mixed forest (class 313) are the most isolated within the landscape.

Patches of coniferous forest (class 312) showed a high shape complexity level (AWMSI) and this was caused by both patch size and perimeter (TE). Shape complexity decreased in year 2006.

- Forest spatial pattern classification results: "large" area

Figure 79 shows the input and output of GUIDOS forest spatial pattern classification for Lorenzago di Cadore "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006) | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 79: Inputs and outputs maps of GUIDOS classification for Lorenzago di Cadore forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

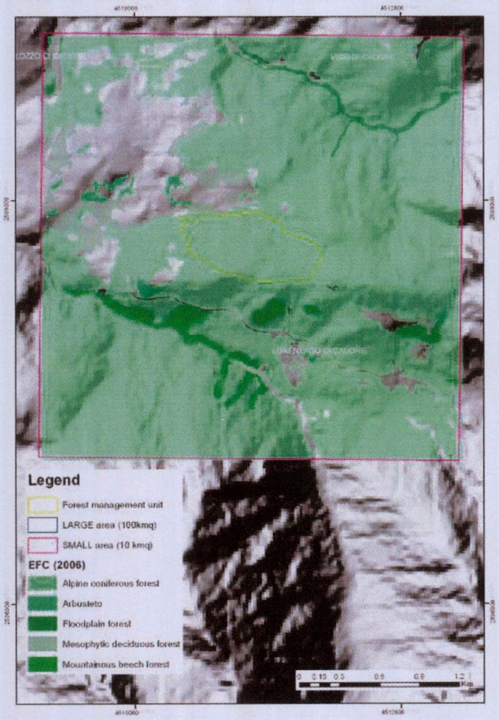
In Table 28, area (in hectares) of each forest spatial pattern class has been reported.

Code	Description		AREA (ha)
1	Branch		144
3	Edge		805
5	Perforation		36
17	Core		5749
33	Bridge		32
35	Bridge in Edge		10
65	Loop		12
67	Loop in Edge		16

Table 28: Area (hectares) of GUIDOS forest spatial pattern classes for Lorenzago di Cadore forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 80 show forest cover data of Lorenzago di Cadore "small" area.



European Forest Categories (2006)

Figure 80: European Forest Categories map (2006) for Lorenzago di Cadore small" area.

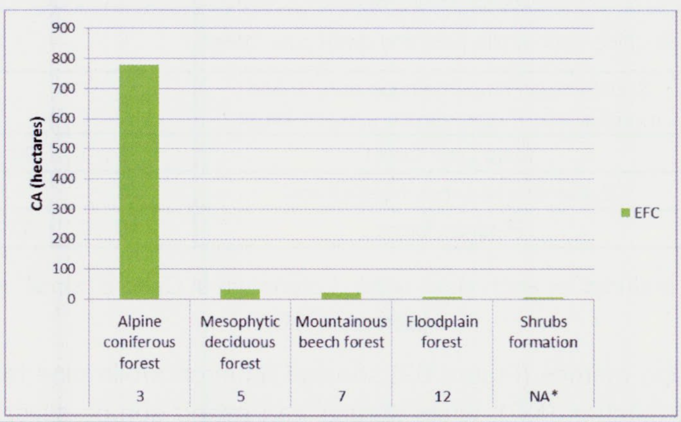
On the basis of map of forest type of year 2006, within Lorenzago di Cadore "small" area, forest covers about 856 hectares of the area (Table 29 and Figure 81).

Alpine coniferous forest (class 3) is the main category within the considered landscape (780 hectares) and in particular," subalpine larch arolla pine and dwarf pine forest" (class 31) type and "subalpine and mountainous spruce and mountainous mixed spruce silver fir forest" cover respectively 125 and 655 hectares.

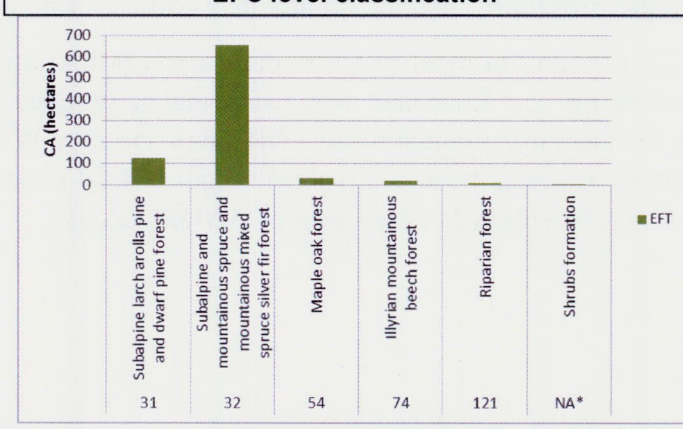
These two forest types grow at mean altitudes up to 1000 m.a.s.l. (Table 30) and on steep slopes (Table 31)

LORENZAGO DI CADORE (small area 10 kmq)				
EFC Code	**Class description**	**EFT Code**	**Class description**	**Class Area (CA) (hectares)**
3	Alpine coniferous forest	31	Subalpine larch arolla pine and dwarf pine forest	125.64
		32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	655.35
			sub total	**780.99**
5	Mesophytic deciduous forest	54	Maple oak forest	33.85
			sub total	**33.85**
7	Mountainous beech forest	74	Illyrian mountainous beech forest	22.73
			sub total	**22.73**
12	Floodplain forest	121	Riparian forest	10.12
			sub total	**10.12**
NA*	Shrubs formation	NA*	Shrubs formation	8.01
			sub total	**8.01**
			TOTAL	**855.7**
(*) NA: not applicable.				

Table 29: Lorenzago di Cadore "small" area. Area values (hectares) for EFC and EFT classes. Forest Types date: 2006. NA: not applicable, means the impossibility to reclassification for that level.



EFC level classification



EFT level classification

Figure 81: Lorenzago di Cadore "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

LORENZAGO DI CADORE (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFT	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
NA*	Shrubs formation	217	700	1258	558	899.346	850	713	858
31	Subalpine larch arolla pine and dwarf pine forest	3300	697	1371	674	1015.94	1000	697	1013
32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	16362	700	1425	725	1024.39	975	724	1017
54	Maple oak forest	863	694	1250	556	893.015	825	694	840
74	Illyrian mountainous beech forest	566	737	1219	482	952.86	875	737	900
121	Riparian forest	252	697	950	253	818.667	875	710	824

Table 30: Topographic features for each class within Lorenzago di Cadore “small” area: altidudes (m.a.s.l).

LORENZAGO DI CADORE (small area 10 kmq)			
Code	EFT	Class of majority presence	Slope values
NA*	Shrubs formation	5	30 - 50 %
31	Subalpine larch arolla pine and dwarf pine forest	6	> 50 %
32	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest	6	> 50 %
54	Maple oak forest	4	20 - 30 %
74	Illyrian mountainous beech forest	6	> 50 %
121	Riparian forest	5	30 - 50 %

Table31: Topographic features for each class within Lorenzago di Cadore “small” area: class of slopes (percentage).

The analysis of landscape metrics (Figure 82) showed as larch arolla pine forests (class 31) have the greatest number of patches (NP), while spruce and mixed spruce silver fir forests (class 32) have the greatest mean patch size (MPS) and the greater total edge (TE) index value.

Silver fir forests (class 32) contain the most of forest core areas (MCA) and patches have low isolation level as showed by the low Euclidean Nearest-Neighbor distance (ENN) value. Larch arolla pine forests (class 31) have the greatest mean ENN index and Area Weighted Mean Shape Index (AWMSI) value. Silver fir forests have the highest length of total edge (TE) but the shape complexity of patches is lower then class 31 as showed by AWMSI values.

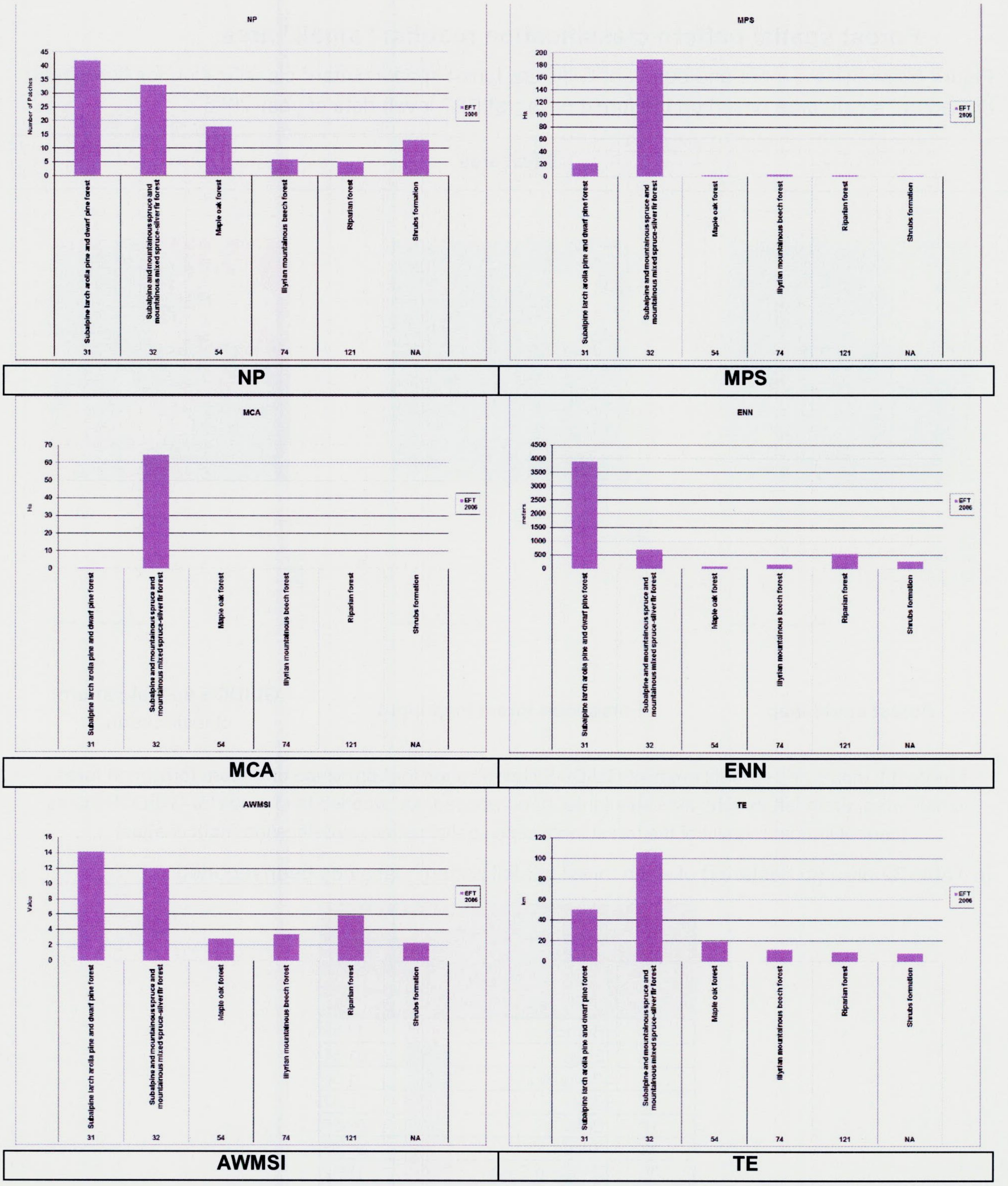
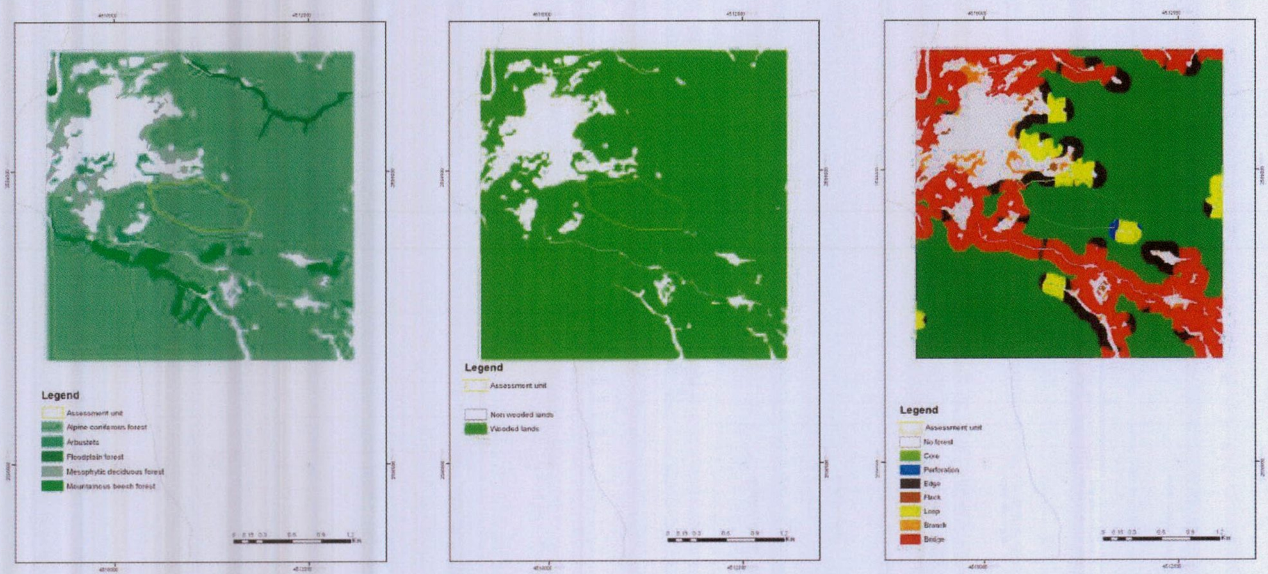


Figure 82: Results of landscape ecology metrics for forest cover (year 2006) within “small” area of Lorenzago di Cadore site.

- **Forest spatial pattern classification results: "small" area**

Figure 83 shows the input and output of GUIDOS forest spatial pattern classification for Lorenzago di Cadore "small" area based on the forest cover (at EFT level) data of year 2006.

Small area



Forest cover map	**Forest/non forest map input**	**GUIDOS spatial pattern classification**

Figure 83: Inputs and outputs maps of GUIDOS classification for Lorenzago di Cadore forest/non forest "small" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 32 area (in hectares) of each forest spatial pattern class has been reported.

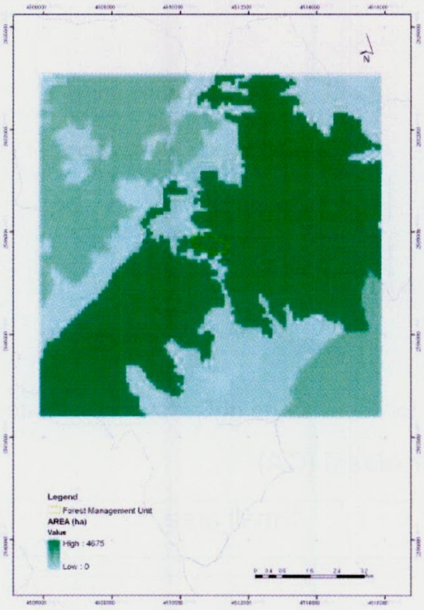
Lorenzago di Cadore (small area 10 kmq)			
Code	***Description***		***AREA (ha)***
1	Branch		13.89
3	Edge		61.54
5	Perforation		1.66
9	Islet		2.32
17	Core		502.56
33	Bridge		91.88
35	Bridge in Edge		139.2
65	Loop		5.11
67	Loop in Edge		31.44
69	Loop in Perforation		5.21

Table 32: Area (hectares) of GUIDOS forest spatial pattern classes for Lorenzago di Cadore forest/non forest “small” area.

- **Maps of landscape metrics:**

Patch area (ha) (*per patch*) (AREA)

Large area	Small area



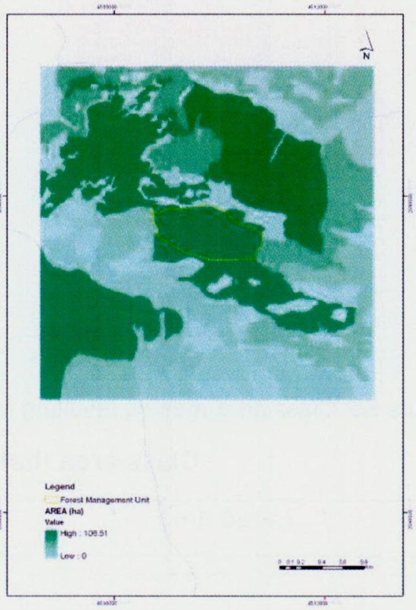


Figure 84: Patch area metrics resulting maps for “Lorenzago di Cadore forest” site.

Class area (ha) (per class) (CA)

Large area	Small area

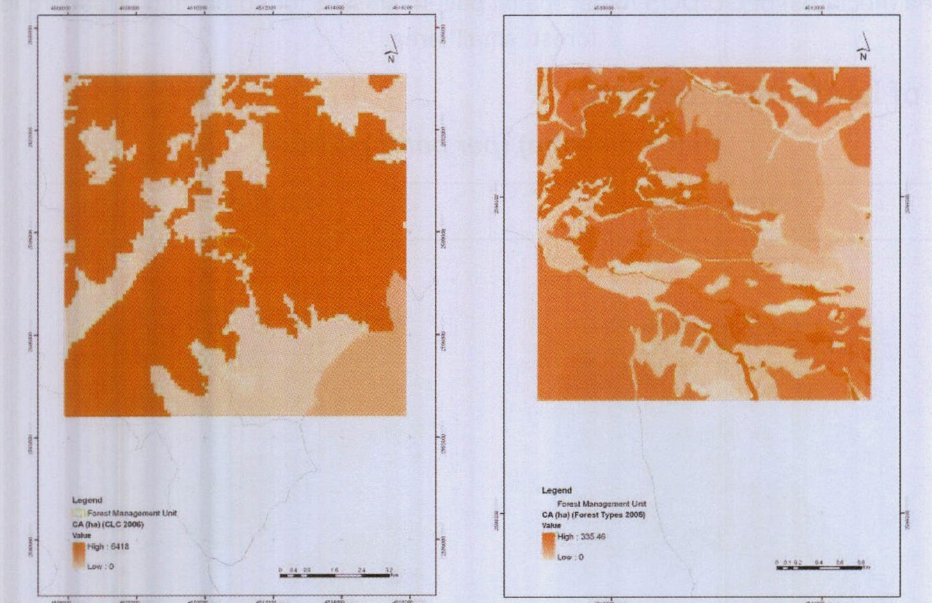


Figure 85: Class area metrics resulting maps for "Lorenzago di Cadore forest" site.

Class area (ha) (*per class*) (CA)

Large area	Small area

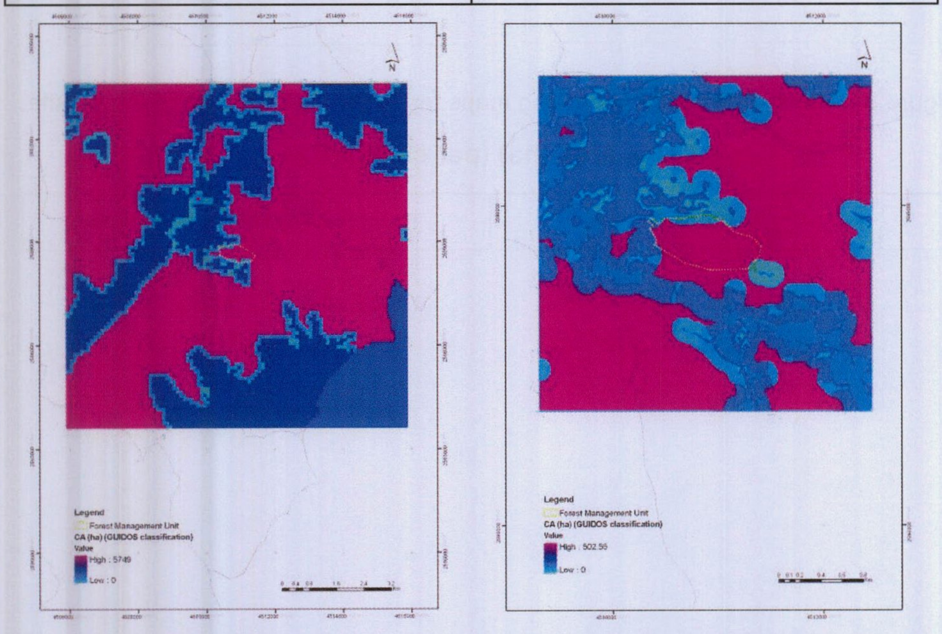


Figure 86: Class area size metrics resulting maps for "Lorenzago di Cadore forest" site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

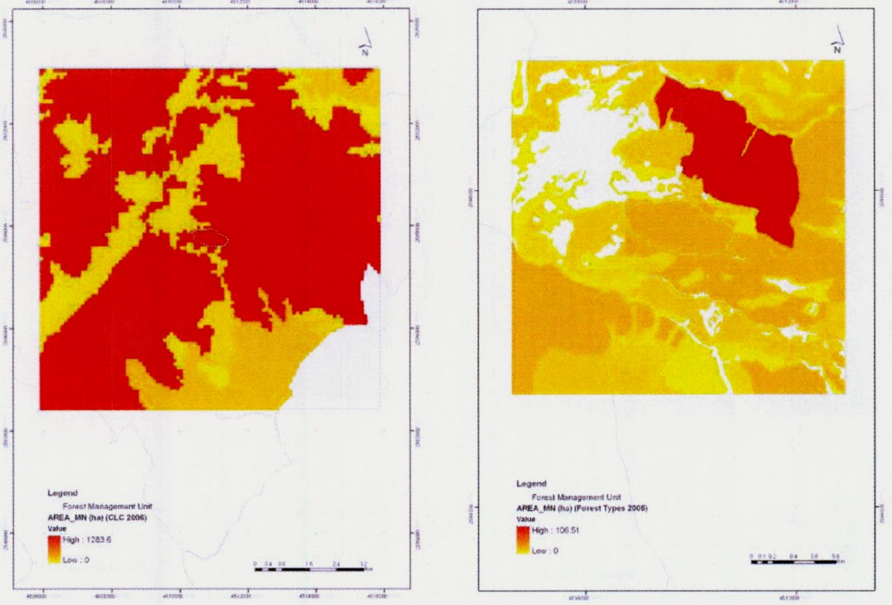


Figure 87: Mean patch size metrics resulting maps for "Lorenzago di Cadore forest" site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

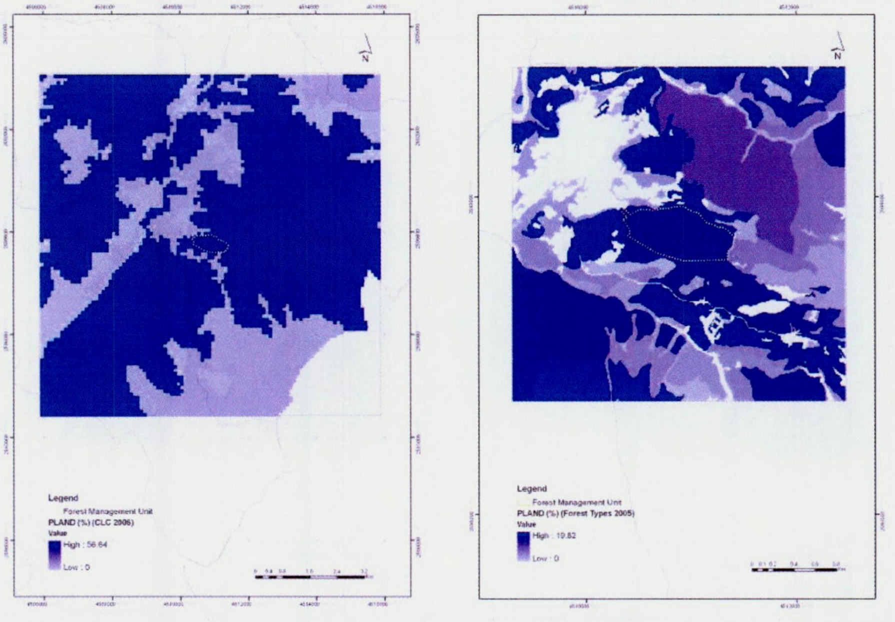


Figure 88: Percentage of landscape metrics resulting maps for "Lorenzago di Cadore forest" site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

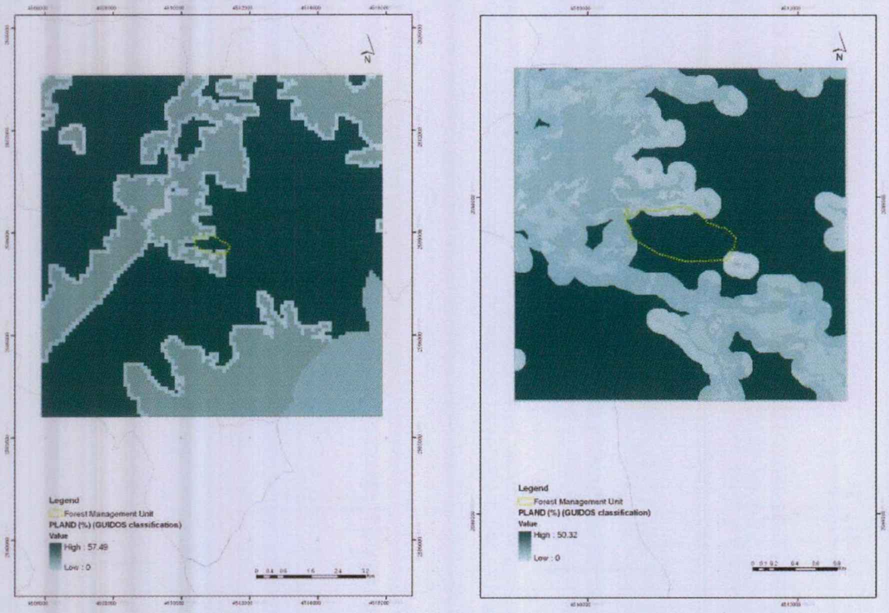


Figure 89: Percentage of landscape metrics resulting maps for "Lorenzago di Cadore forest" site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

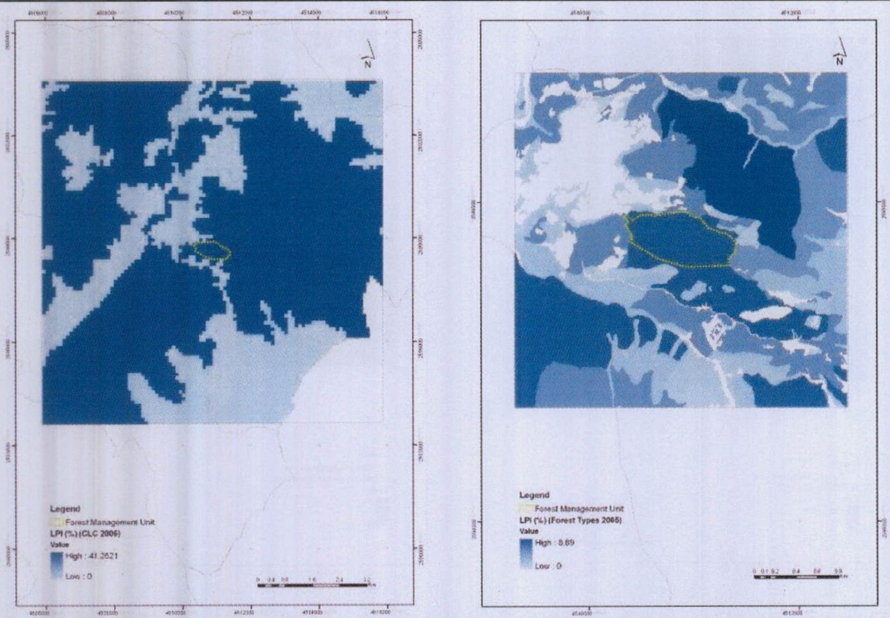


Figure 90: Largest patch index metrics resulting maps for "Lorenzago di Cadore forest" site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

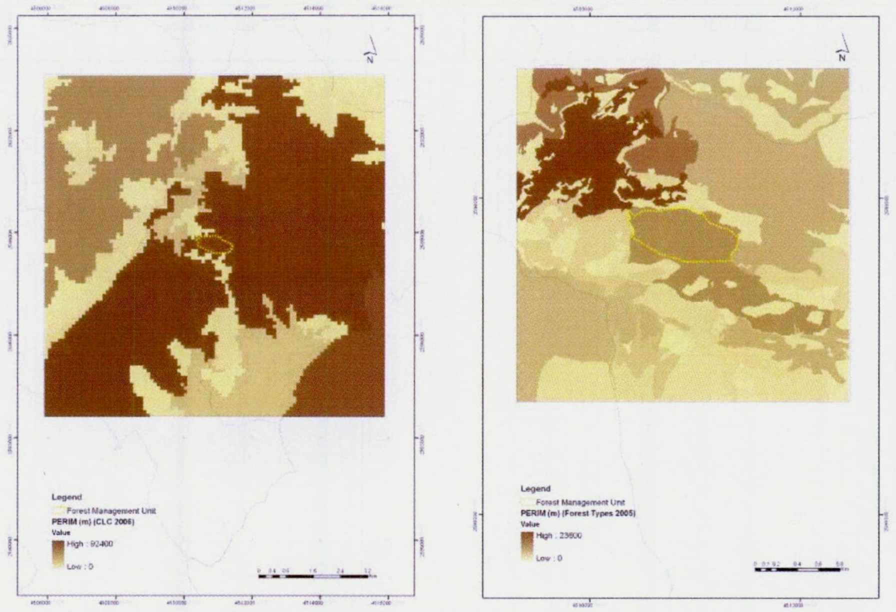


Figure 91: Edge metrics resulting maps for "Lorenzago di Cadore forest" site.

Total core area (ha) (per class) (TCA)

Large area	Small area

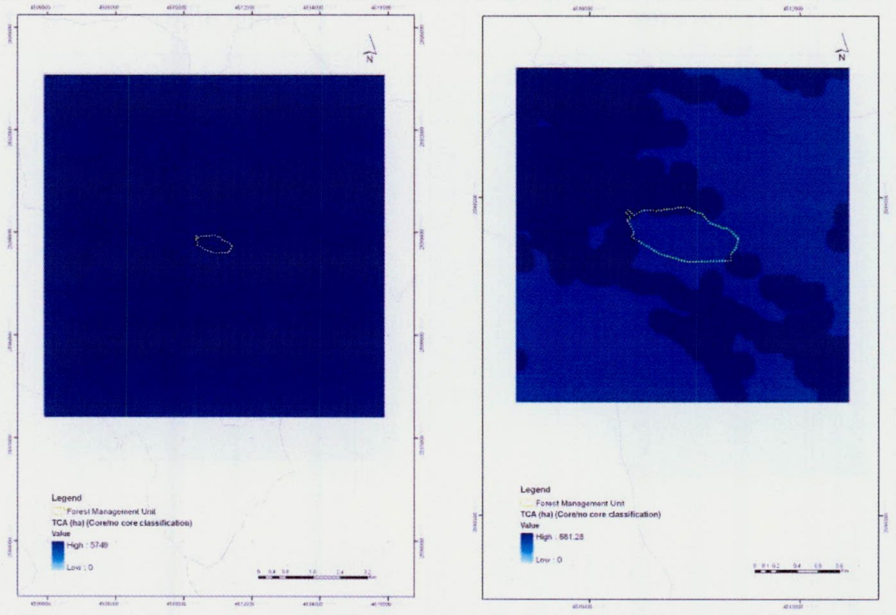


Figure 92: Total core area metrics resulting maps for "Lorenzago di Cadore forest" site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

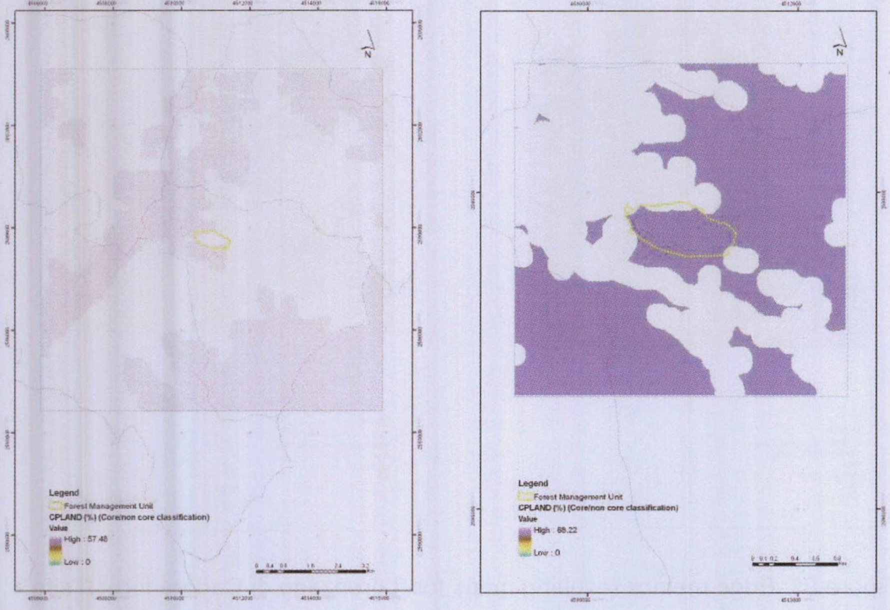


Figure 93: Core Area Percentage of Landscape metrics resulting maps for “Lorenzago di Cadore forest” site.

Number of patches (per patch) (NP)

Large area	Small area

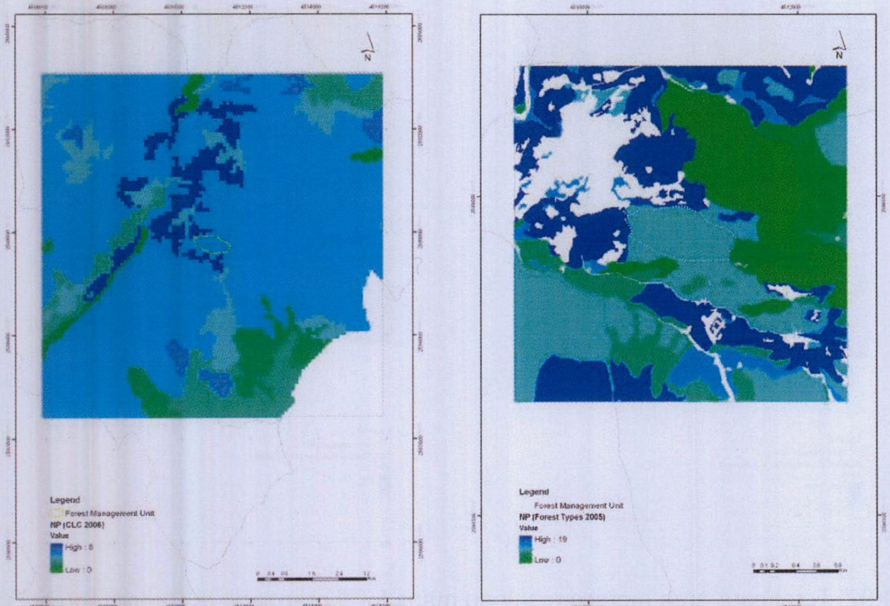


Figure 94: Number of patches in the landscape resulting maps for “Lorenzago di Cadore forest” site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

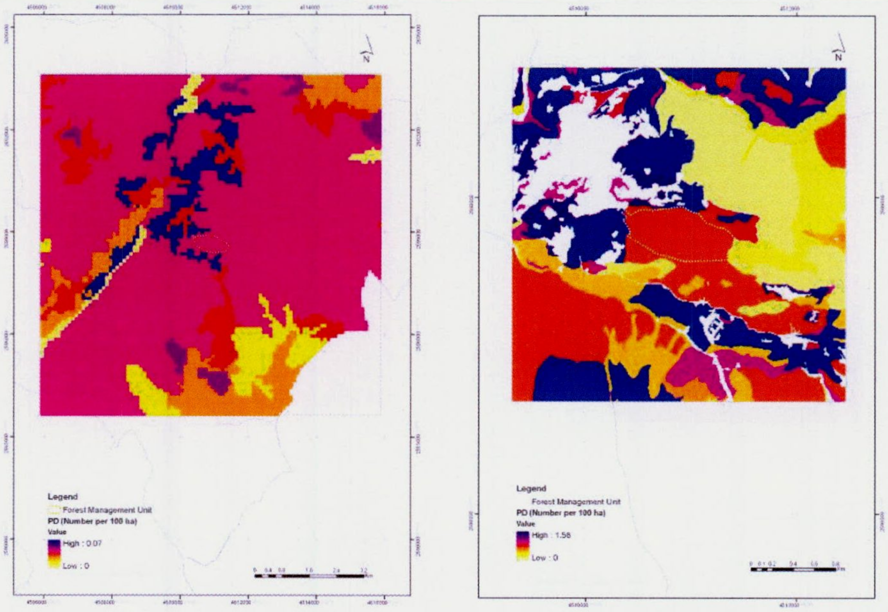


Figure 95: Patch density metrics resulting maps for “Lorenzago di Cadore forest” site.

Shape (per patch) (SHAPE)

Large area	Small area

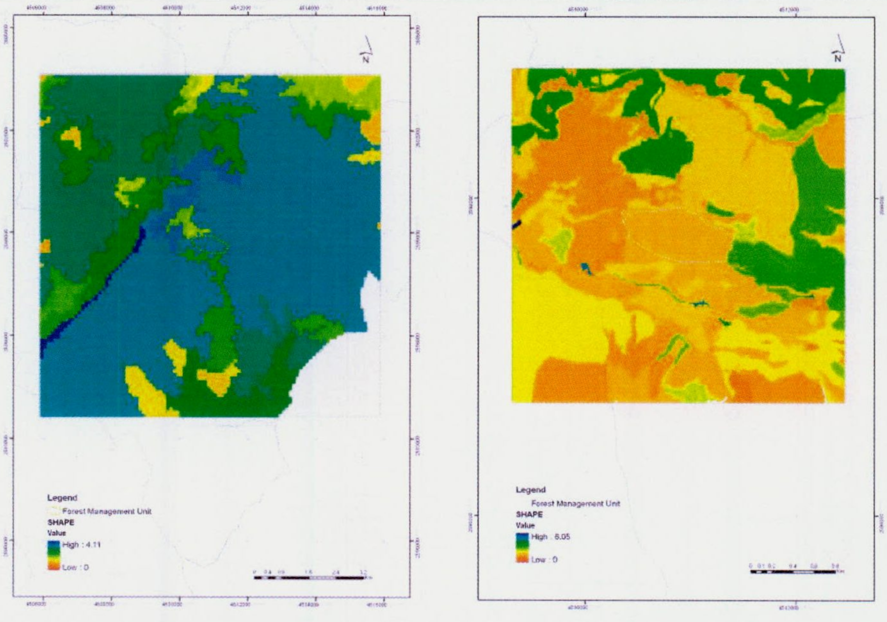


Figure 96: Shape metrics resulting maps for “Lorenzago di Cadore forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

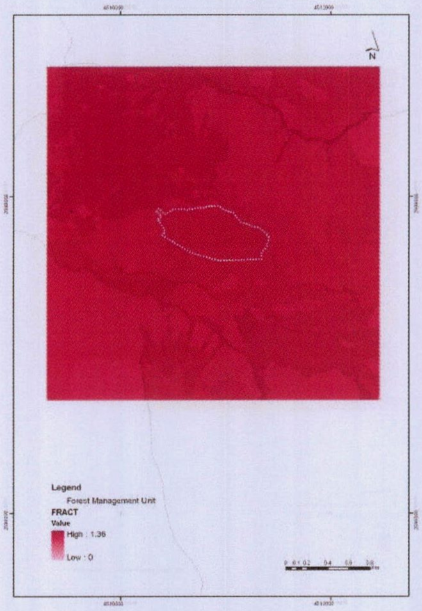
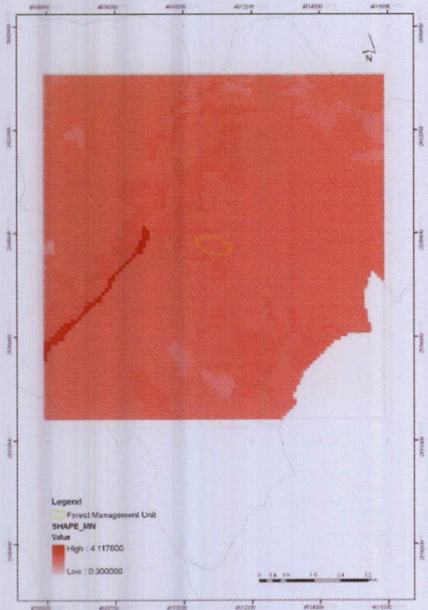


Figure 97: Fractal dimension metrics resulting maps for “Lorenzago di Cadore forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area



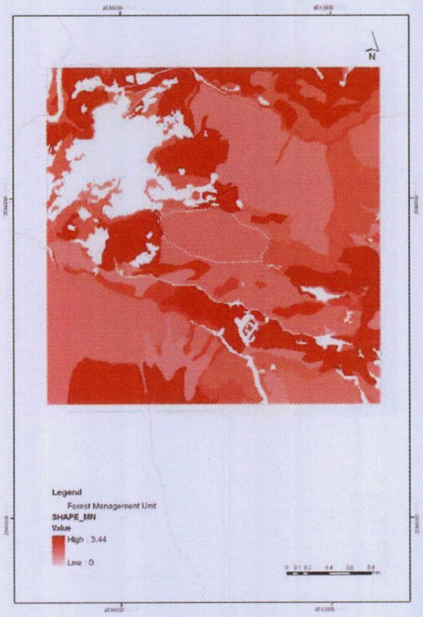


Figure 98: Mean shape indexes resulting maps for “Lorenzago di Cadore forest” site.

Mean fractal index (per class) (FRAC_MN)

Large area	Small area

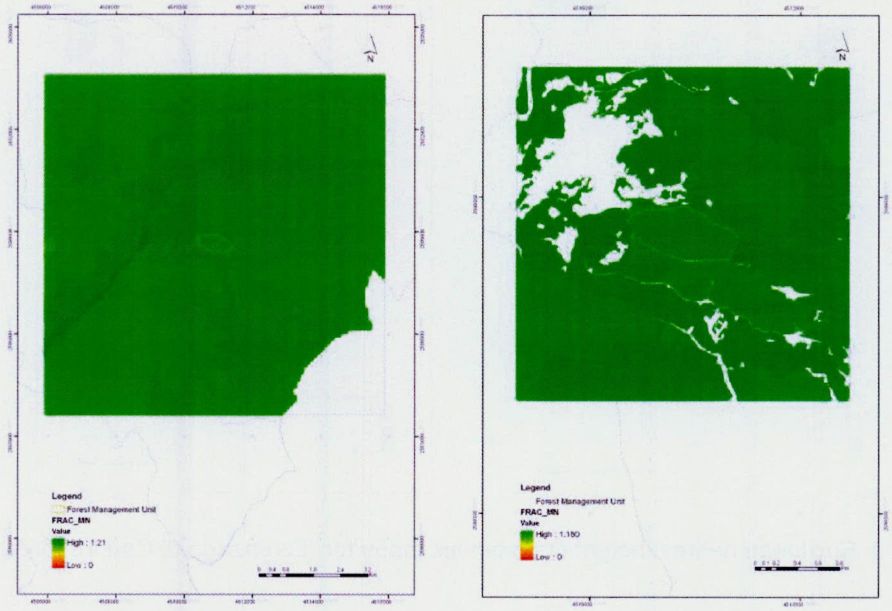


Figure 99: Mean fractal dimensions resulting maps for “Lorenzago di Cadore forest” site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

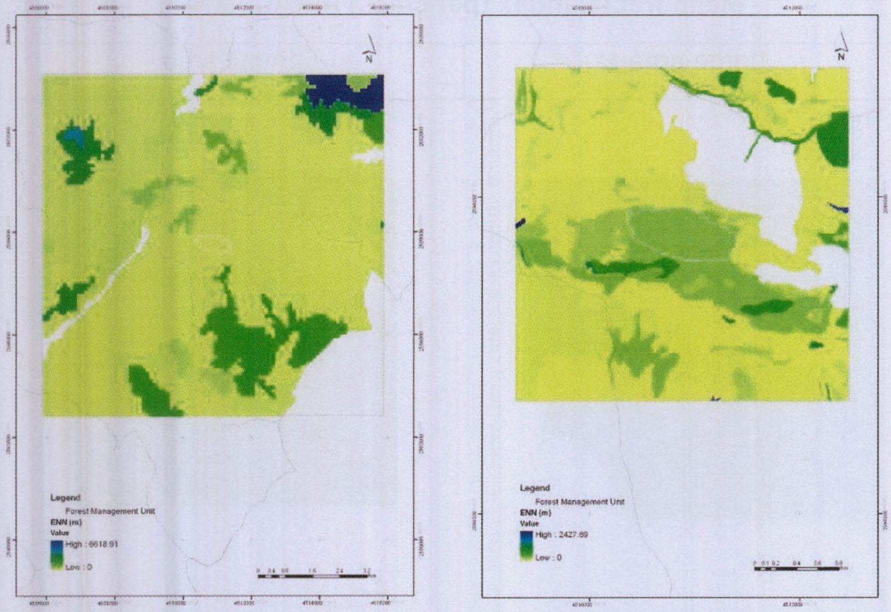


Figure 100: Euclidean nearest neighbor distances maps for “Lorenzago di Cadore forest” site.

2.2.4. Vallombrosa – Site 7

- **Evaluation of the landscape context and land uses changes: "large" area**

Figure 102 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

Table 33 shows as more than 50 % of Vallombrosa "large" area has been covered by broad-leaved forest (54.6 %; 5466 hectares) (Figure 101) at mean altitudes of 962 m.a.s.l. and on slope between 20-30 % (Table 34 and Table 35). Coniferous forests cover 18 % of total area (1816 hectares) and grow on same altitude range of broadleaved forests ,on very steep slopes (30-50 %). Mixed forests cover 12 % of total area (1268 hectares) and develop at lower altitudes (797 m.a.s.l.).

Land uses within Vallombrosa "large" area were right stable as showed by the rather insignificant changes occurred (Table 33).

Transitional woodland-shrubs (class 324) showed the greatest change rate (8.2 %).

Cross-tabulation analysis (Table 36 and Table 37) showed as this change depends on the transition from class 324 (transitional woodland-shrub) to class 311 (broad-leaved forest).

VALLOMBROSA (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	222	224	224	2.22	2.24	2.24	2	0	2	0.90
221	Vineyards	3	3	3	0.03	0.03	0.03	0	0	0	0.00
223	Olive groves	355	355	355	3.55	3.55	3.55	0	0	0	0.00
231	Pastures	161	161	161	1.61	1.61	1.61	0	0	0	0.00
242	Complex cultivation patterns	1	1	1	0.01	0.01	0.01	0	0	0	0.00
243	Land principally occupied by agriculture, with significant areas of natural vegetation	119	119	119	1.19	1.19	1.19	0	0	0	0.00
311	Broad-leaved forest	5423	5466	5466	54.23	54.66	54.66	43	0	43	0.79
312	Coniferous forest	1818	1816	1816	18.18	18.16	18.16	-2	0	-2	-0.11
313	Mixed forest	1268	1268	1268	12.68	12.68	12.68	0	0	0	0.00
321	Natural grasslands	109	109	109	1.09	1.09	1.09	0	0	0	0.00
324	Transitional woodland-shrub	521	478	478	5.21	4.78	4.78	-43	0	-43	-8.25
	Total	10000	10000	10000	100	100	100				

Table 33: Area values per class and per year and relative changes between dates for Vallombrosa "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

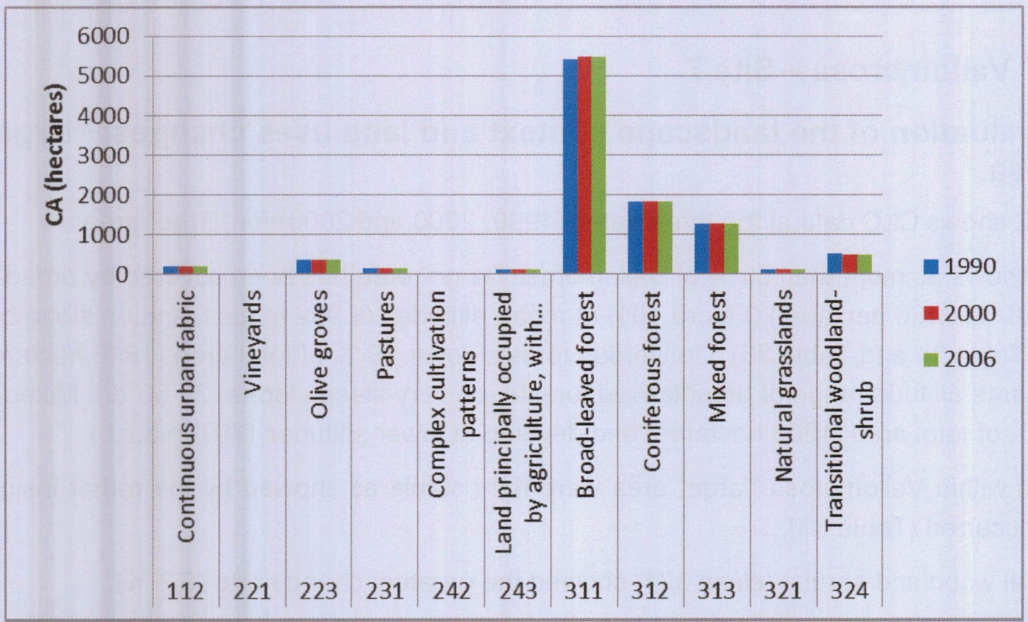


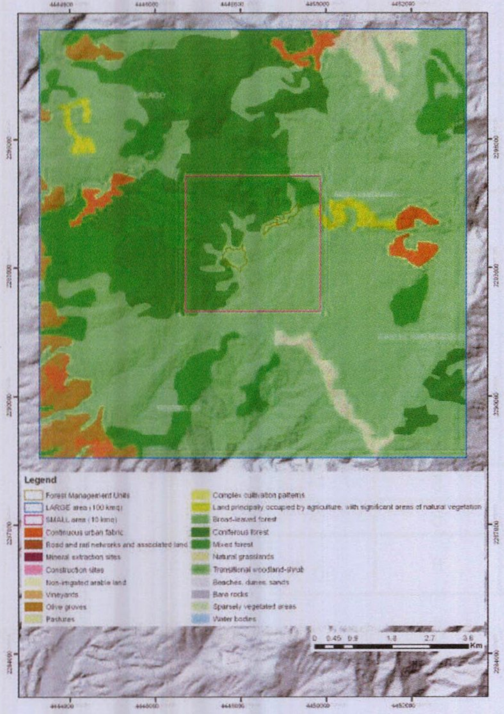
Figure 101: Vallombrosa "large" (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

VALLOMBROSA (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	5661	395	1059	664	706.42	1025	395	733
221	Vineyards	111	351	400	49	374.32	375	351	375
223	Olive groves	9167	274	681	407	462.98	425	274	454
231	Pastures	3885	793	1050	257	903.69	925	793	904
242	Complex cultivation patterns	31	450	484	34	473.16	475	458	476
243	Land principally occupied by agriculture, with significant areas of natural vegetation	3005	500	1184	684	843.76	1025	506	925
311	Broad-leaved forest	136389	273	1486	1213	950.83	950	275	962
312	Coniferous forest	44969	473	1400	927	962.11	950	492	967
313	Mixed forest	31921	275	1415	1140	797.57	925	283	825
321	Natural grasslands	2855	1300	1480	180	1389	1375	1307	1383
324	Transitional woodland-shrub	12006	599	1412	813	934.92	850	606	910

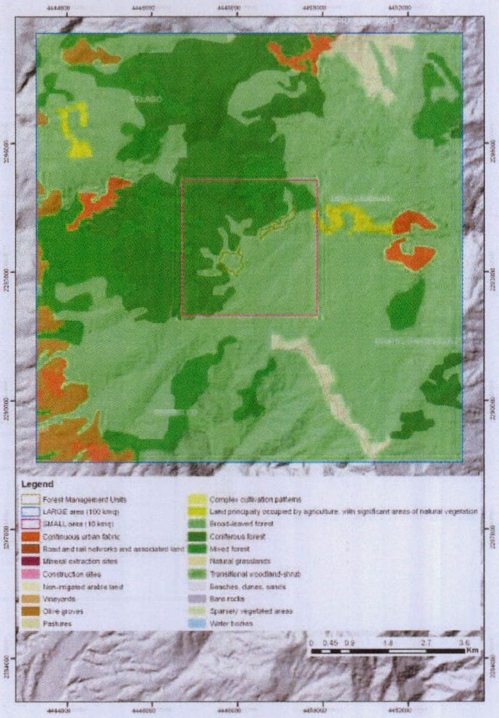
Table 34: Topographic features for each class within Vallombrosa "large" area: altitudes (m.a.s.l).

VALLOMBROSA (large area 100 kmq)			
Code	**Class**	**Class of majority presence**	**Slope values**
112	Continuous urban fabric	3	10 - 20 %
221	Vineyards	2	3 - 10 %
223	Olive groves	3	10 - 20 %
231	Pastures	3	10 - 20 %
242	Complex cultivation patterns	3	10 - 20 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	5	30 - 50 %
311	Broad-leaved forest	5	30 - 50 %
312	Coniferous forest	4	20 - 30 %
313	Mixed forest	5	30 - 50 %
321	Natural grasslands	5	30 - 50 %
324	Transitional woodland-shrub	6	> 50 %

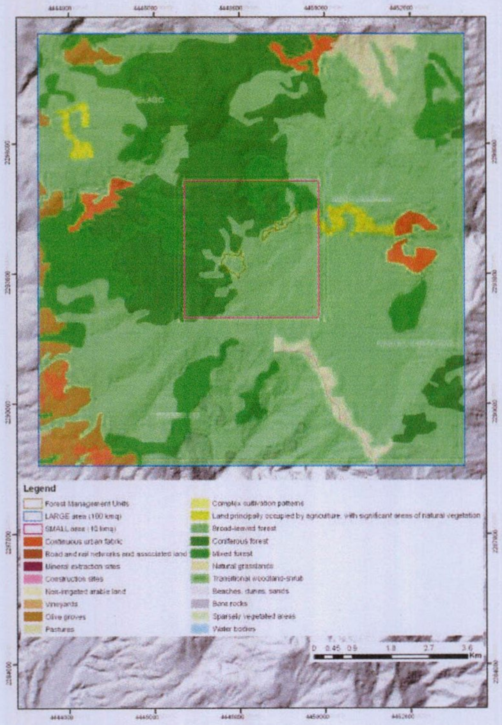
Table 35: Topographic features for each class within Vallombrosa “large” area: class of slopes (percentage).



CLC 1990



CLC 2000



CLC 2006

Figure 102: CORINE Land Cover data of Vallombrosa "large" area.

VALLOMBROSA (large area 100 kmq)												
Cross tabulation (percentage)												
	2006											
1990	112	221	223	231	242	243	311	312	313	321	324	Total
112	222	0	0	0	0	0	0	0	0	0	0	222
221	0	3	0	0	0	0	0	0	0	0	0	3
223	0	0	355	0	0	0	0	0	0	0	0	355
231	0	0	0	161	0	0	0	0	0	0	0	161
242	0	0	0	0	1	0	0	0	0	0	0	1
243	0	0	0	0	0	119	0	0	0	0	0	119
311	0	0	0	0	0	0	5408	0	0	0	15	5423
312	2	0	0	0	0	0	0	1816	0	0	0	1818
313	0	0	0	0	0	0	0	0	1268	0	0	1268
321	0	0	0	0	0	0	0	0	0	109	0	109
324	0	0	0	0	0	0	58	0	0	0	463	521
Total	224	3	355	161	1	119	5466	1816	1268	109	478	10000

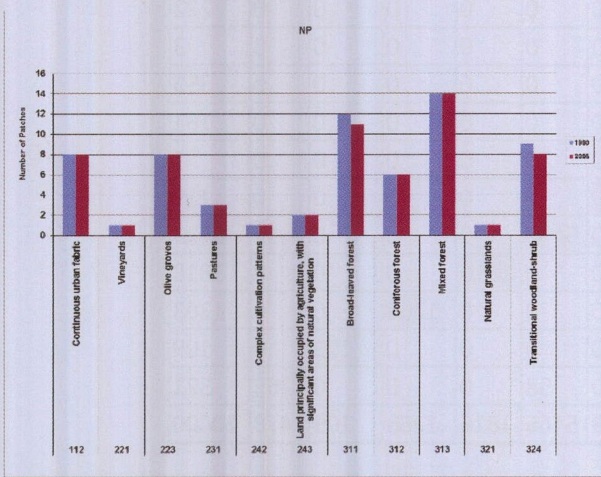
Tabella 36: contingency matrix of Vallombrosa large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

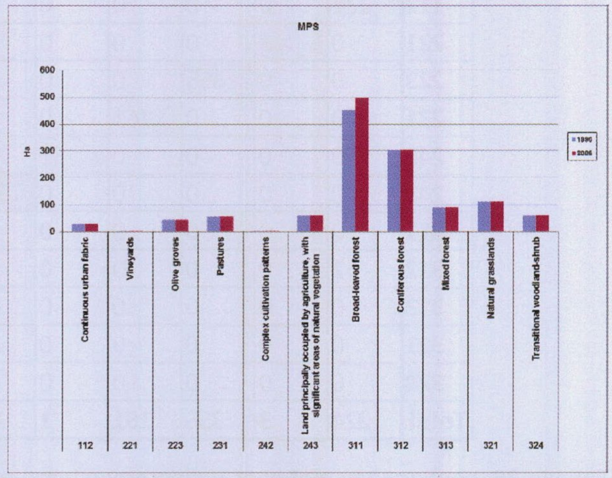
VALLOMBROSA (large area 100 kmq)												
Cross tabulation (percentage)												
	2006											
1990	112	221	223	231	242	243	311	312	313	321	324	Total
112	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
221	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
223	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
231	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
242	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
243	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0
311	0.0	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0	0.0	0.3	100.0
312	0.1	0.0	0.0	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.0	100.0
313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0
321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0
324	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	88.9	100.0

Tabella 37: contingency matrix of Vallombrosa large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

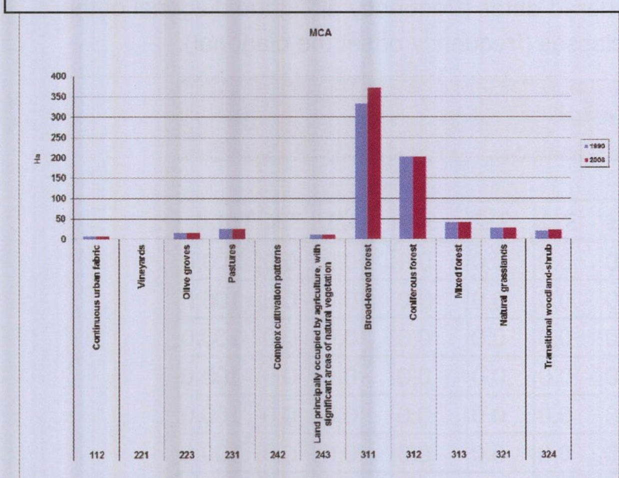
The analysis of landscape ecology metrics (Figure 103) showed a decreasing in number of patches (NP) only for broad-leaved forest (class 311) and transitional woodland-shrub (class 324). The most fragmented forest class is mixed forest (class 313) but the NP remained stable through the time.

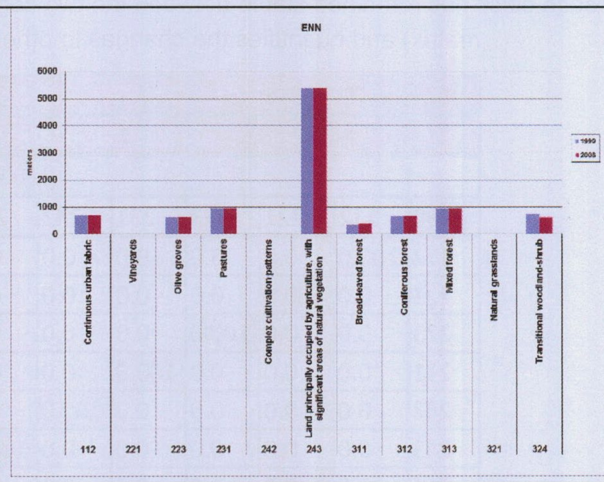
Broad-leaved forests (class 311) showed the highest mean patch size (MPS) values and the increasing in year 2006. Area increasing and decreasing of NP indicates a reduction of forest fragmentation fro this forest class. Broad-leaved forests have the highest mean core area (MCA) values.



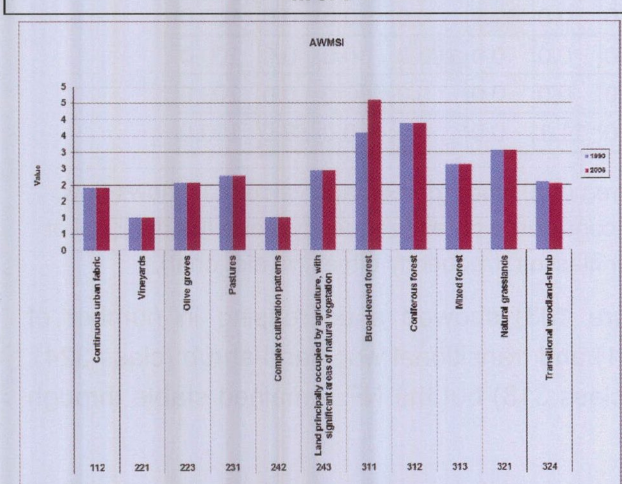


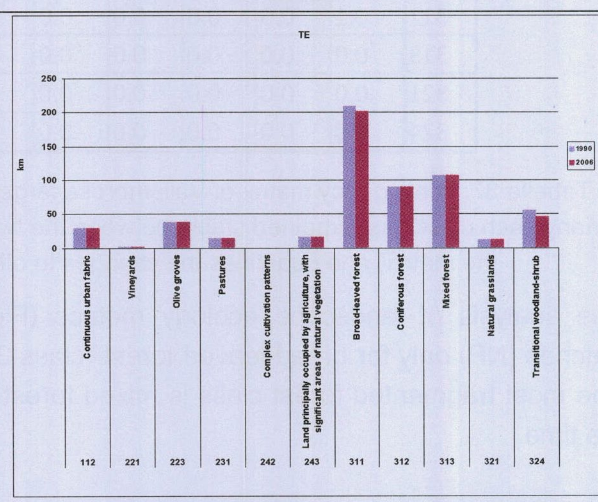
NP	MPS





MCA	ENN





AWMSI	TE

Figure 103: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Vallombrosa "large" area.

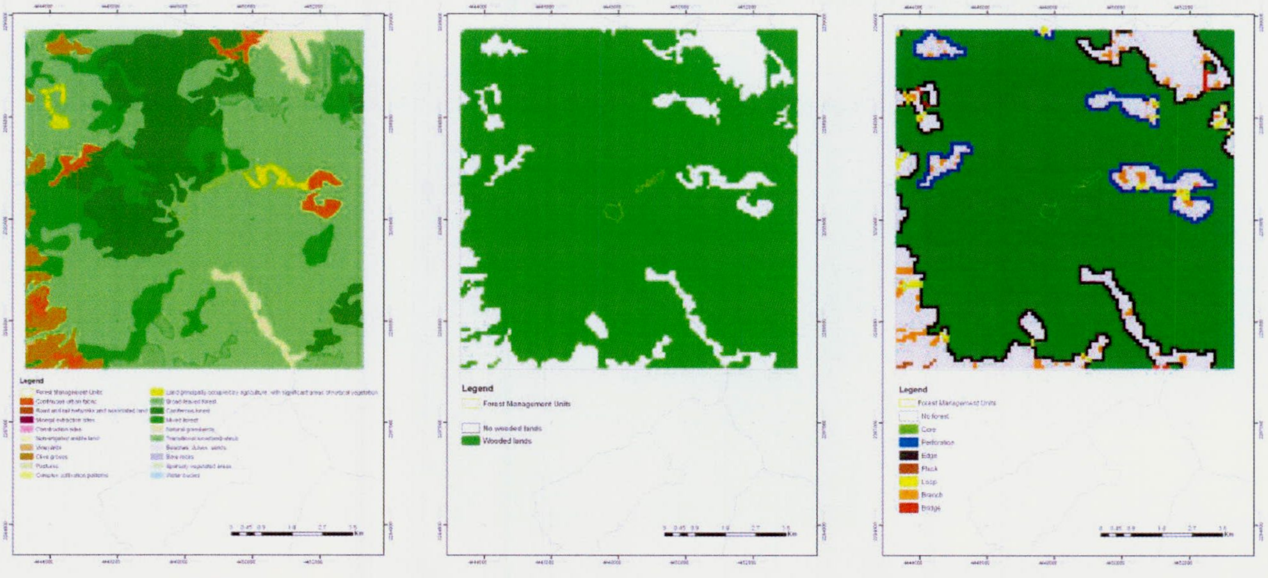
These forest patches are right aggregated within the landscape as showed by the Euclidean Nearest-Neighbor distance (ENN) which did not show significant changes. Class 243 is the most isolated within the landscape.

Patches of broad leaved forests showed the highest geometric complexity which depends on the increase of mean patch size as showed by the decrease of NP and total edge values.

- **Forest spatial pattern classification results: "large" area**

Figure 103 shows the input and output of GUIDOS forest spatial pattern classification for Vallombrosa "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006) | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 103: Inputs and outputs maps of GUIDOS classification for Vallombrosa forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

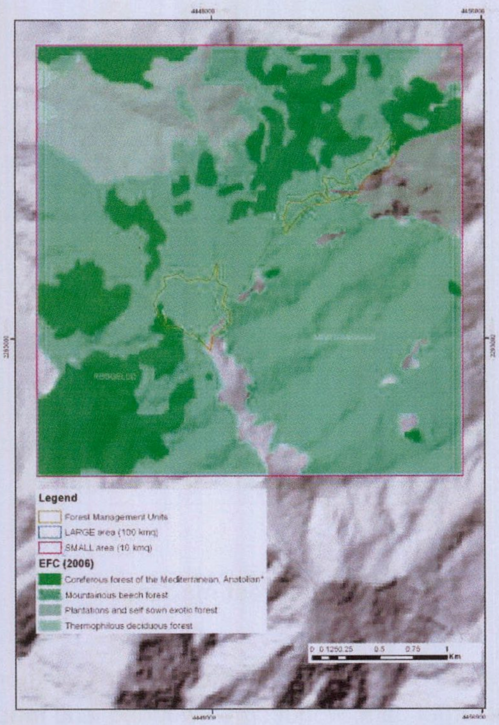
In Table 38, area (in hectares) of each forest spatial pattern class has been reported.

Vallombrosa (large area 100 kmq)			
Code	**Description**		**AREA (ha)**
1	Branch		140
3	Edge		597
5	Perforation		297
9	Islet		10
17	Core		7419
33	Bridge		6
35	Bridge in Edge		10
65	Loop		33
67	Loop in Edge		25
69	Loop in Perforation		15

Table 38: Area (hectares) of GUIDOS forest spatial pattern classes for Vallombrosa forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 104 show forest cover data of Vallombrosa "small" area.



European Forest Categories (2006)

Figure 104: European Forest Categories map (2006) for Vallombrosa "small" area.

On the basis of map of forest type of year 2006, within Vallombrosa "small" area, forest covers about 962 hectares of the area (Table 39 and Figure 105). The most representative forest categories are: mountainous beech forest (class 7) (597 hectares) with "Apennine Corsican mountainous beech forest" (class 73) and coniferous forest (class 10) with "Mediterranean and Anatolian fir forest" (class 106) (212 hectares).

VALLOMBROSA (small area 10 kmq)				
EFC Code	Class description	EFT Code	Class description	lass Area (CA) (hectare
7	Mountainous beech forest	73	Apennine Corsican mountainous beech forest	597.15
			sub total	597.15
8	Thermophilous deciduous forest	87	Chestnut forest	4.05
			sub total	4.05
10	Coniferous forest of the Mediterranean, Anatolian*	106	Mediterranean and Anatolian fir forest	212.16
			sub total	212.16
14	Plantations and self sown exotic forest	141	Plantations of site-native species	136.49
			sub total	136.49
NA*	"Shrubs formation"	NA*		12.61
			sub total	12.61
			TOTAL	962.46
(*) NA: not applicable.				

Table 39: Vallombrosa "small" area. Area (hectares) for EFC and EFT classes. Forest Types date: 2006. NA: not applicable, means the impossibility to reclassification for that level.

These typology grow at mean altitudes of about 1100 and over 1200 m.a.s.l. (Table 40) and on very steep slope (30-50 %) (Table 41).

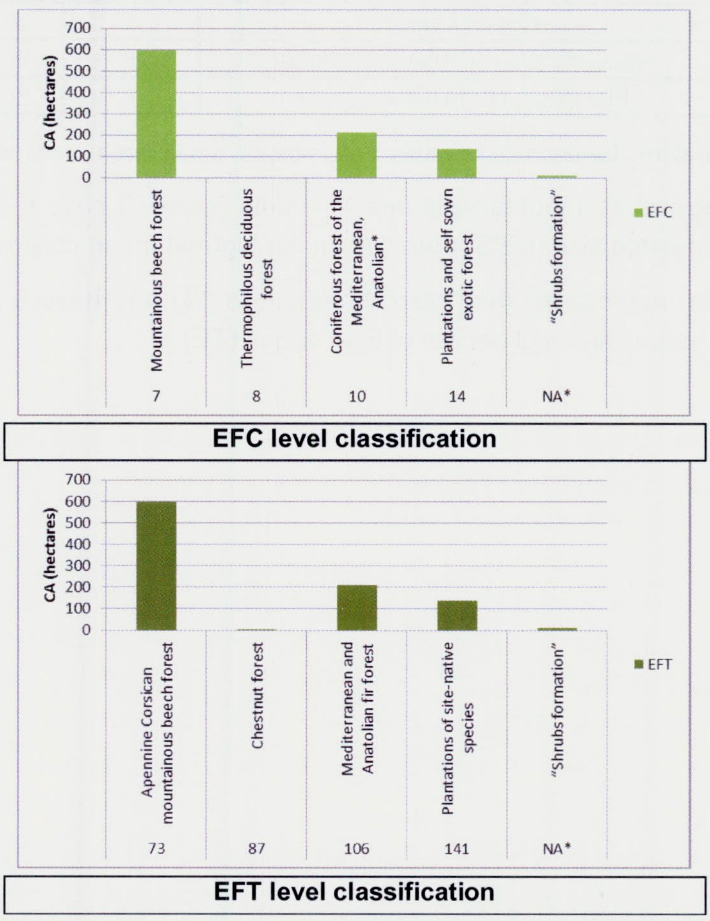


Figure 105: Vallombrosa "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

VALLOMBROSA (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFT	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
NA*	"Shrubs formation"	311	1020	1310	290	1178.19	1200	1020	1200
73	Apennine Corsican mountainous beech forest	14920	850	1450	600	1218.67	1225	850	1228
87	Chestnut forest	100	850	957	107	905.77	900	850	900
106	Mediterranean and Anatolian fir forest	5306	839	1428	589	1134.16	1150	839	1150
141	Plantations of site-native species	3424	891	1257	366	1075.59	1125	892	1087

Table 40: Topographic features for each class within Vallombrosa "small" area: altitudes (m.a.s.l).

VALLOMBROSA (small area 10 kmq)			
Code	EFT	Class of majority presence	Slope values
N/A	"Shrubs formation"	5	30 - 50 %
73	Apennine Corsican mountainous beech forest	5	30 - 50 %
87	Chestnut forest	5	30 - 50 %
106	Mediterranean and Anatolian fir forest	5	30 - 50 %
141	Plantations of site-native species	5	30 - 50 %

Table 41: Topographic features for each class within Vallombrosa "small" area: class of slopes (percentage).

Landscape metrics showed as mountainous beech forests (class 7) have the highest number of patches (NP) and mean patch size (MPS) and contain the highest mean core area value (MCA).

Beech forests are more aggregated than plantations (class 14) and have a high level of shape complexity as AWMSI values and high length of total edges (TE).

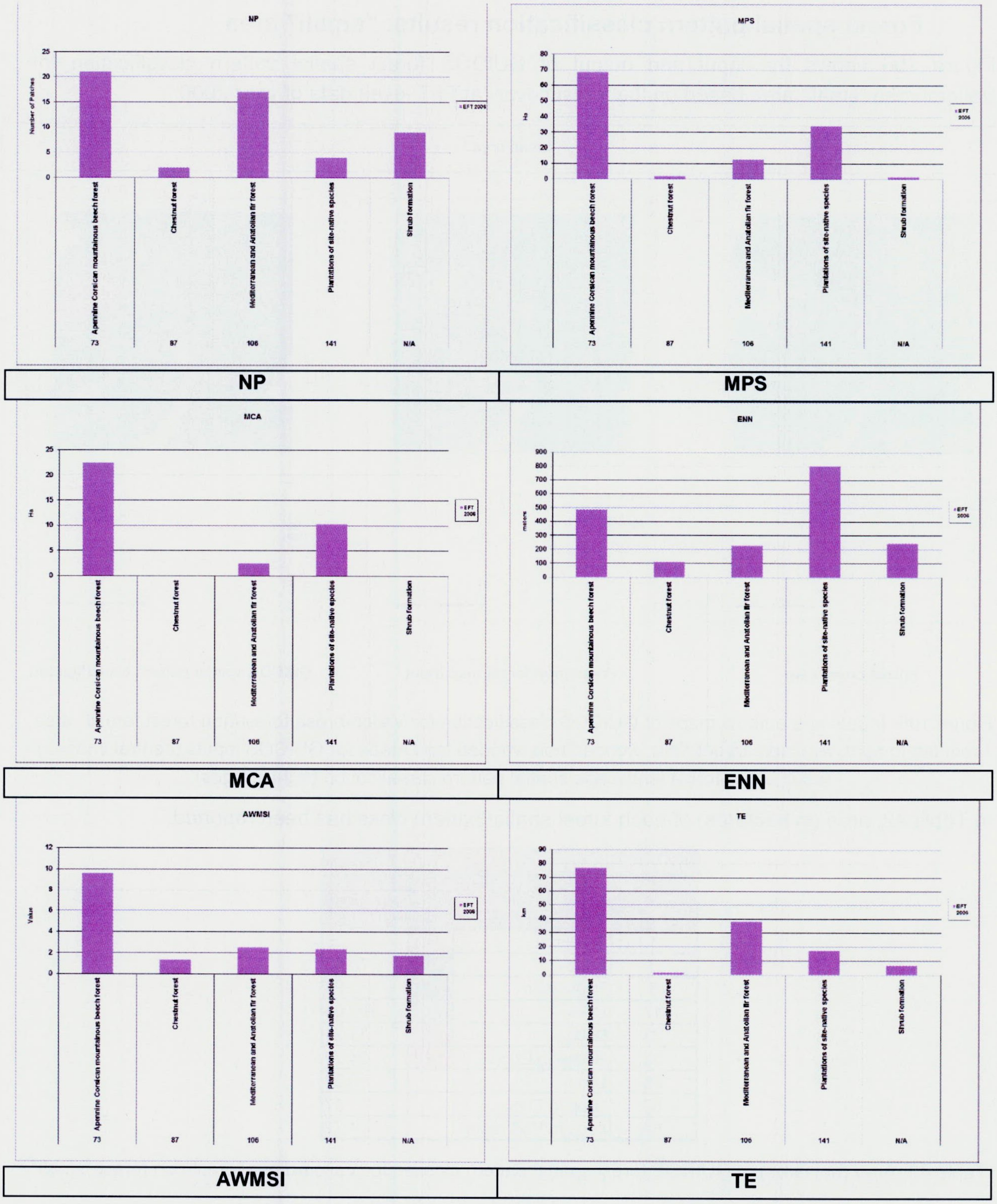
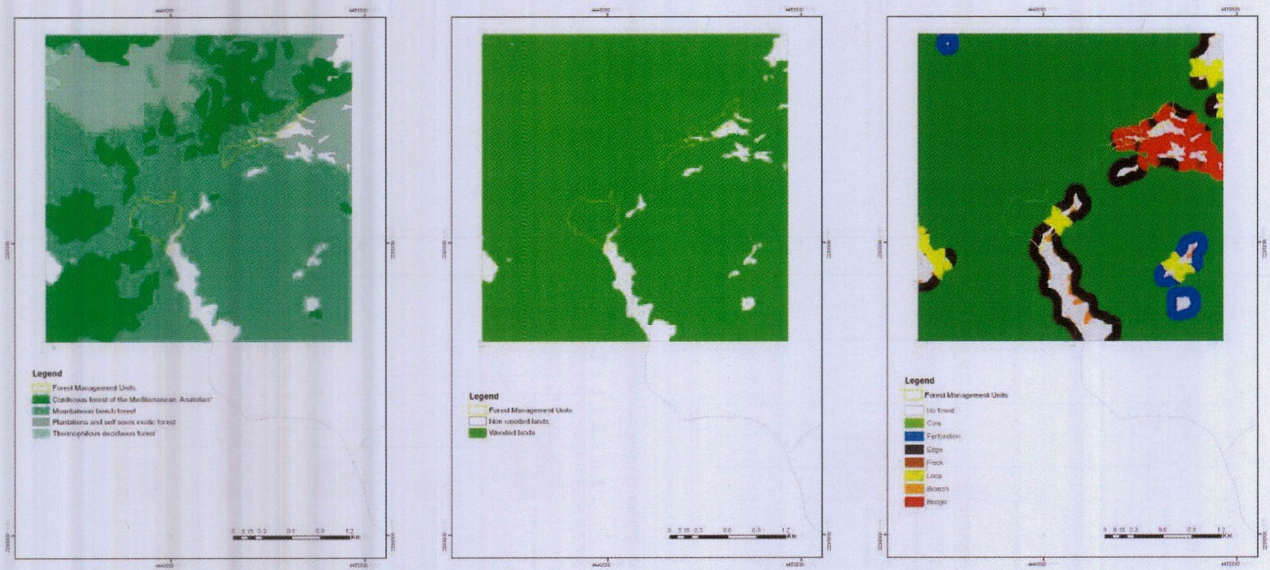


Figure 105 Results of landscape ecology metrics for forest cover (year 2006) within "small" area of Vallombrosa site.

- Forest spatial pattern classification results: “small” area

Figure 106 shows the input and output of GUIDOS forest spatial pattern classification for Vallombrosa “small” area based on the forest cover (at EFT level) data of year 2006.

Small area



Forest cover map **Forest/non forest map input** **GUIDOS spatial pattern classification**

Figure 106: Inputs and outputs maps of GUIDOS classification for Vallombrosa forest/non forest “small” area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 42, area (in hectares) of each forest spatial pattern class has been reported.

Vallombrosa (small area 10 kmq)			
Code	Description		AREA (ha)
1	Branch		5
3	Edge		70.43
5	Perforation		24
17	Core		789.55
33	Bridge		11.21
35	Bridge in Edge		24.72
65	Loop		3.22
67	Loop in Edge		17
69	Loop in Perforation		4.72

Table 42: Area (hectares) of GUIDOS forest spatial pattern classes for Vallombrosa forest/non forest “small” area.

- **Maps of landscape metrics**

Patch area (ha) (*per patch*) (AREA)

Large area	Small area

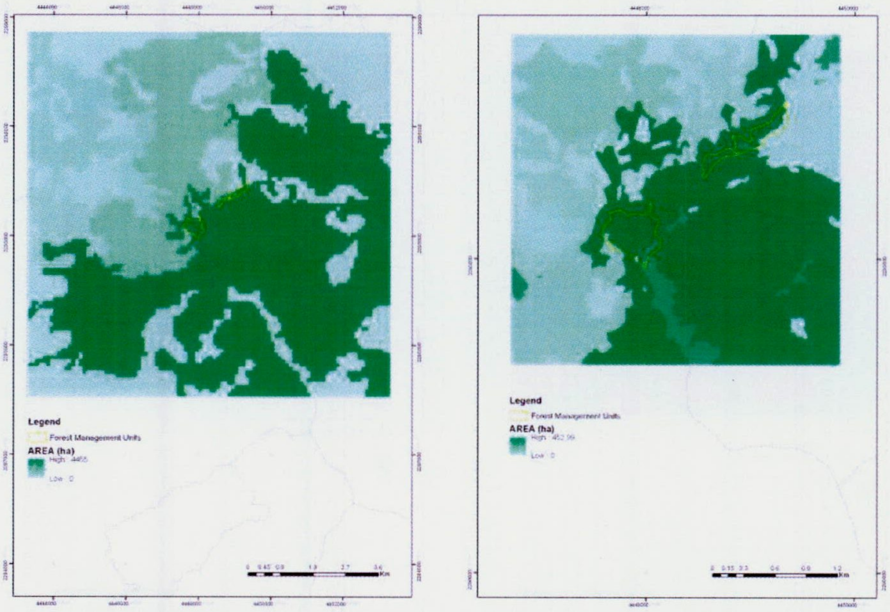


Figure 106: Patch area metrics resulting maps for “Vallombrosa forest” site.

Class area (ha) (per class) (CA)

Large area	Small area

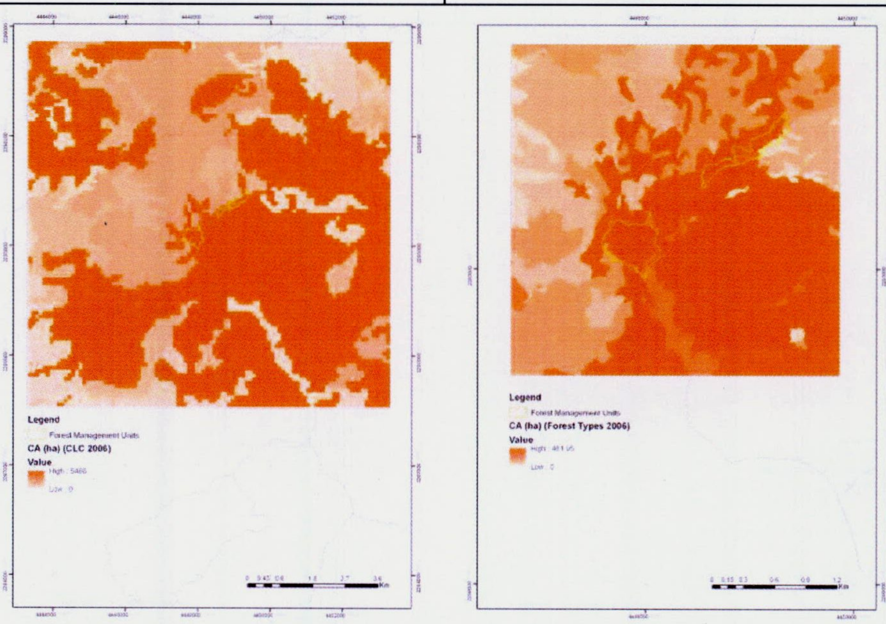


Figure 107: Class area metrics resulting maps for “Vallombrosa forest” site.

Class area (ha) (*per class*) (CA)

Large area	Small area

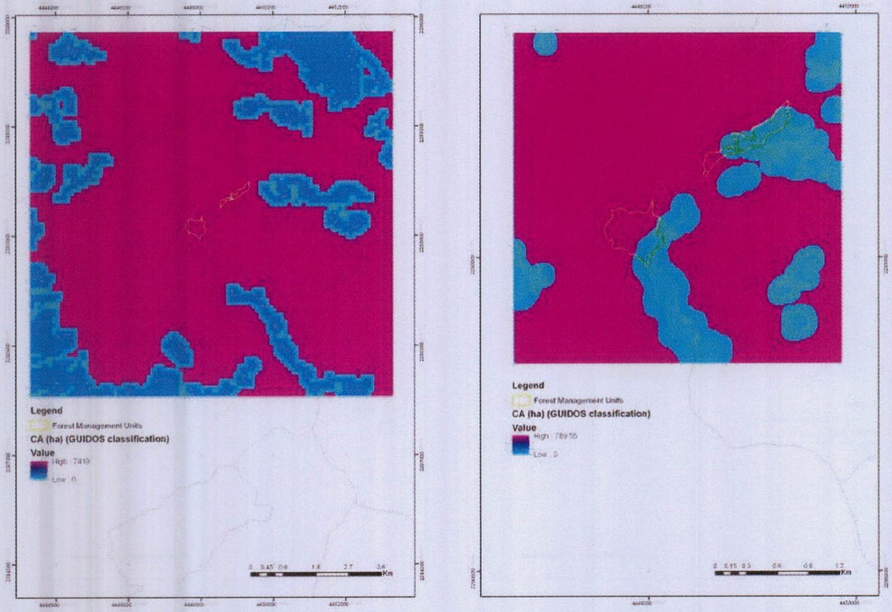


Figure 108: Class area size metrics resulting maps for “Vallombrosa forest” site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

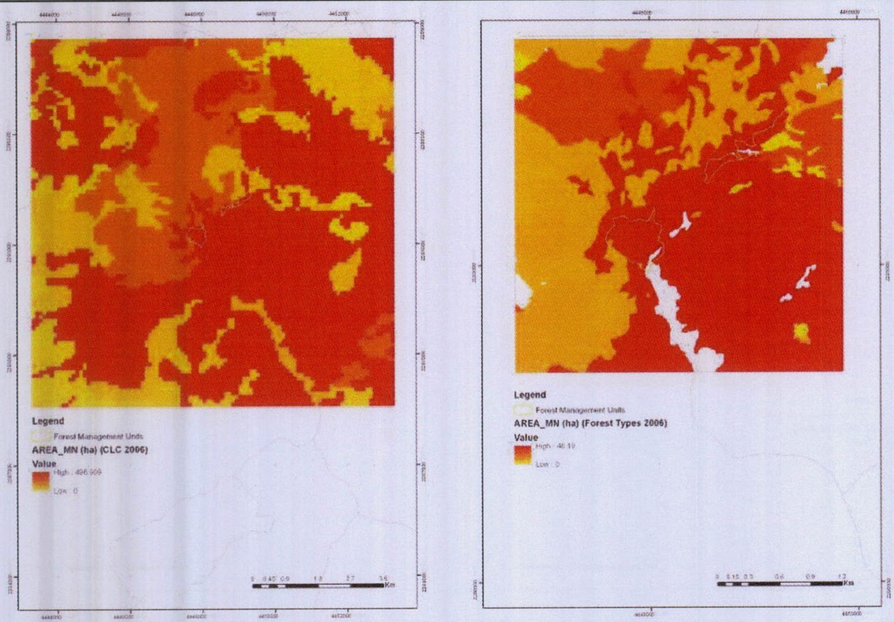


Figure 109: Mean patch size metrics resulting maps for “Vallombrosa forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

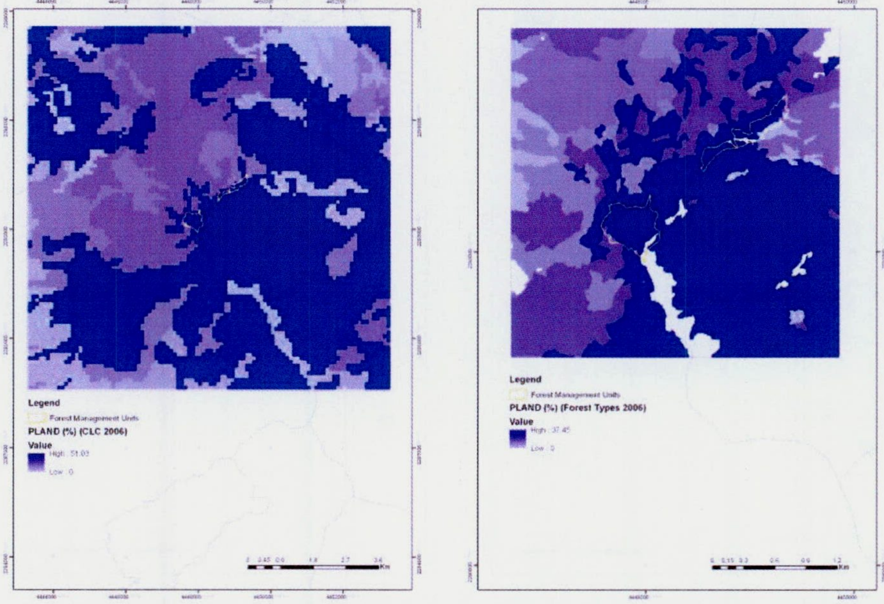


Figure 110: Percentage of landscape metrics resulting maps for “Vallombrosa forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

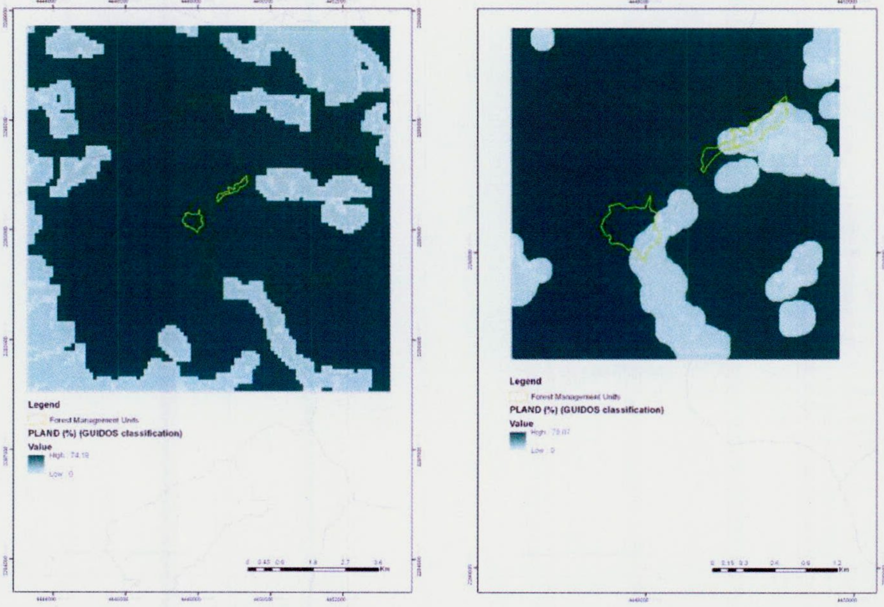


Figure 111: Percentage of landscape metrics resulting maps for “Vallombrosa forest” site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

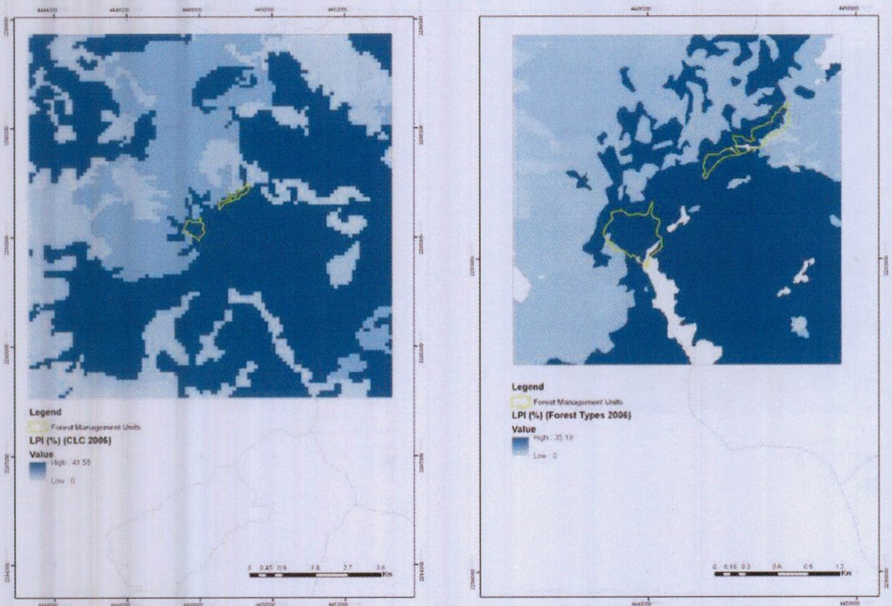


Figure 112: Largest patch index metrics resulting maps for "Vallombrosa forest" site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

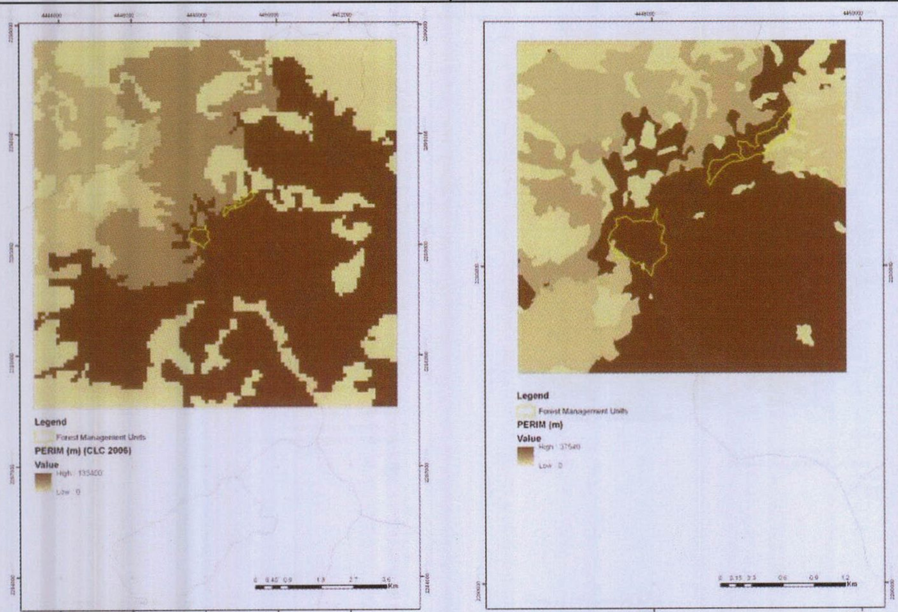


Figure 113: Edge metrics resulting maps for "Vallombrosa forest" site.

Total core area (ha) (per class) (TCA)

Large area	Small area

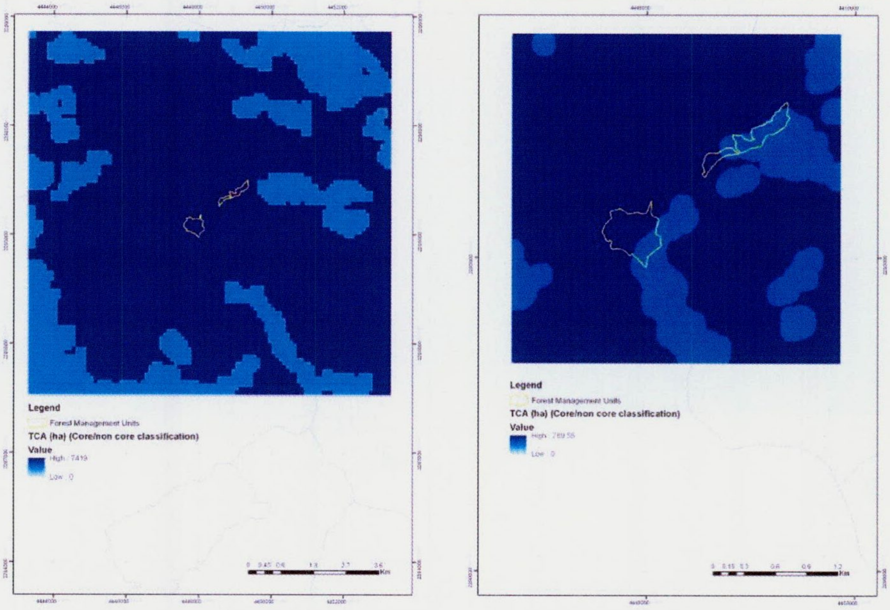


Figure 114: Total core area metrics resulting maps for “Vallombrosa forest” site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

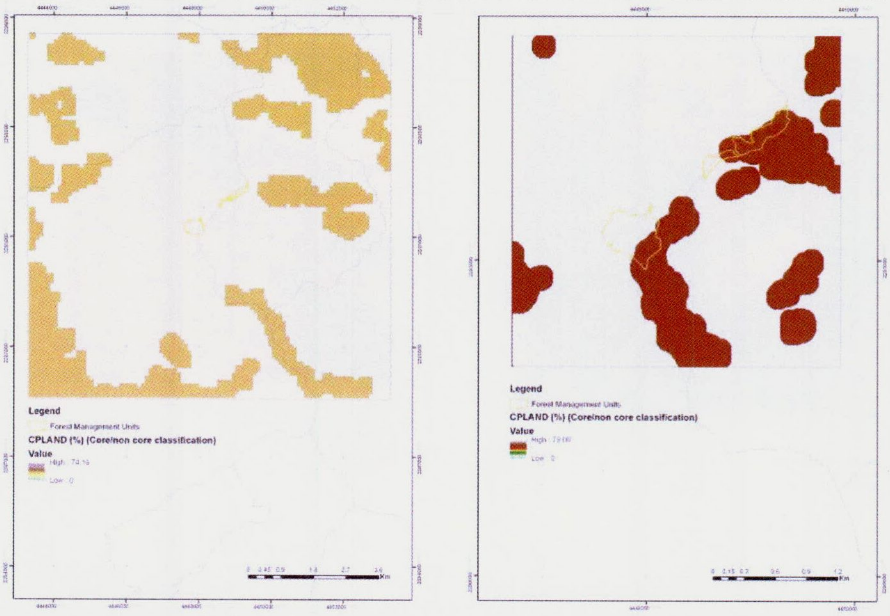


Figure 115: Core Area Percentage of Landscape metrics resulting maps for “Vallombrosa forest” site.

Number of patches (per patch) (NP)

Large area	Small area

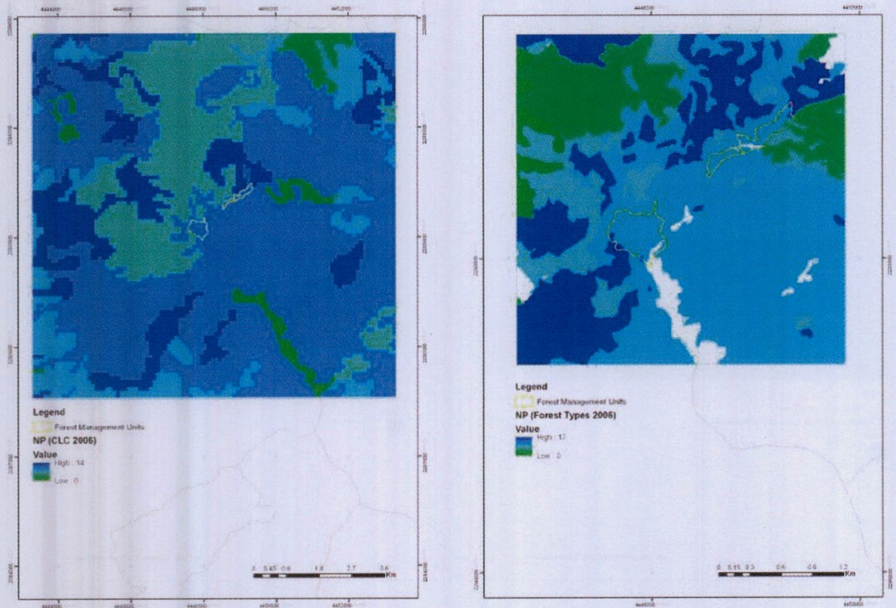


Figure 116: Number of patches in the landscape resulting maps for "Vallombrosa forest" site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

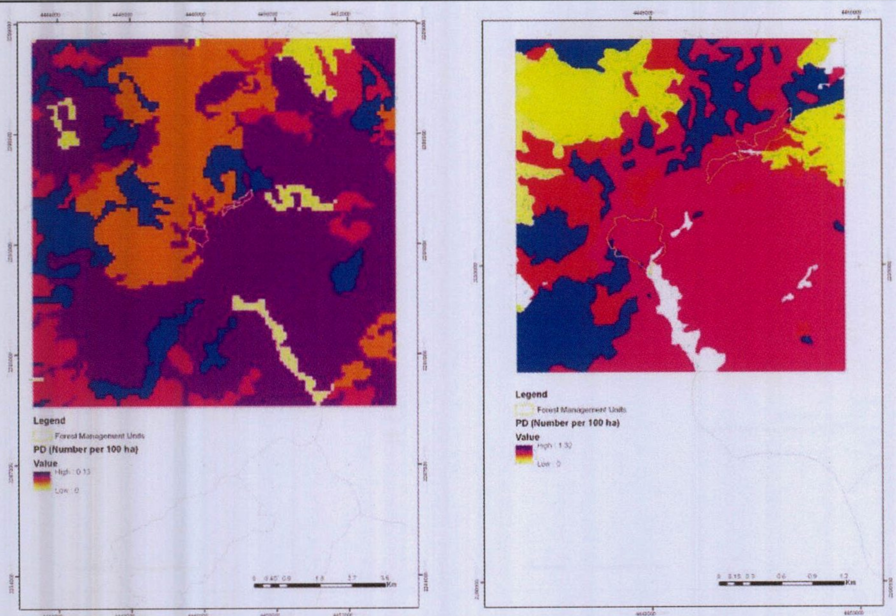


Figure 117: Patch density metrics resulting maps for "Vallombrosa forest" site.

Shape (per patch) (SHAPE)

Large area	Small area

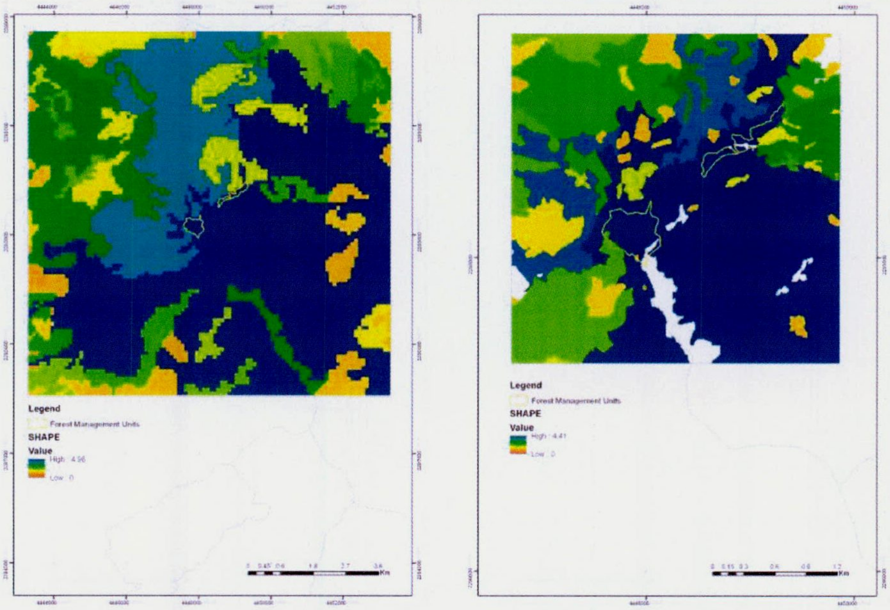


Figure 118: Shape metrics resulting maps for “Vallombrosa forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

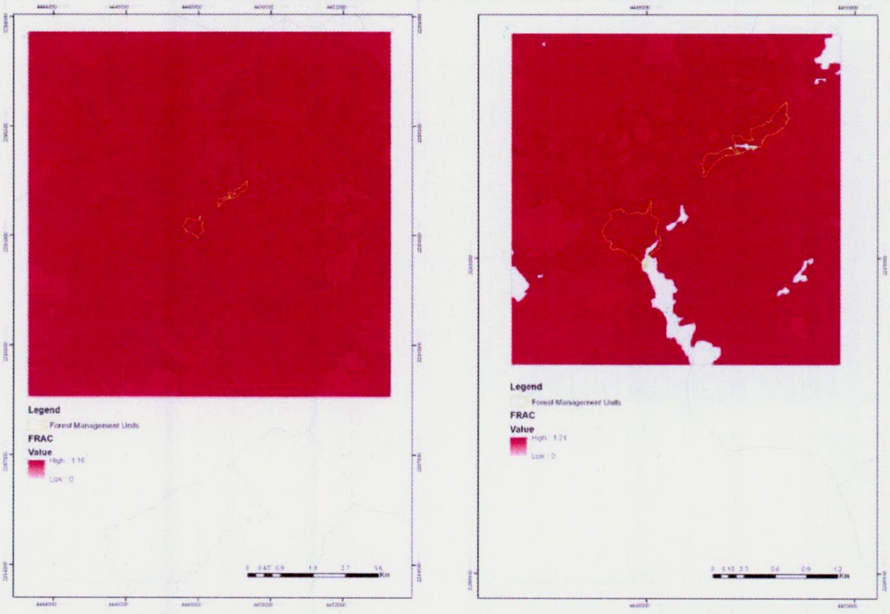


Figure 119: Fractal dimension metrics resulting maps for “Vallombrosa forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

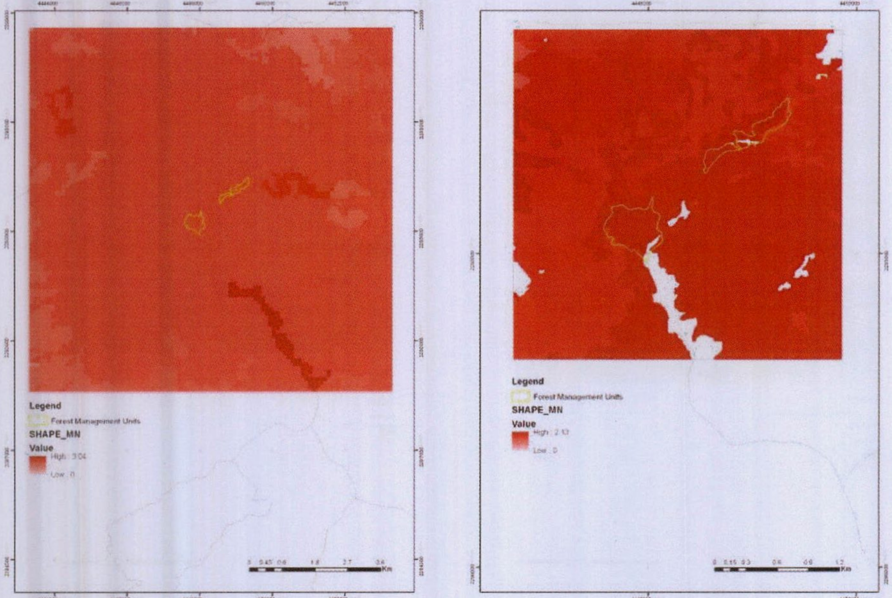


Figure 120: Mean shape indexes resulting maps for “Vallombrosa forest” site.

Mean fractal index (per class) (FRAC_MN)

Large area	Small area

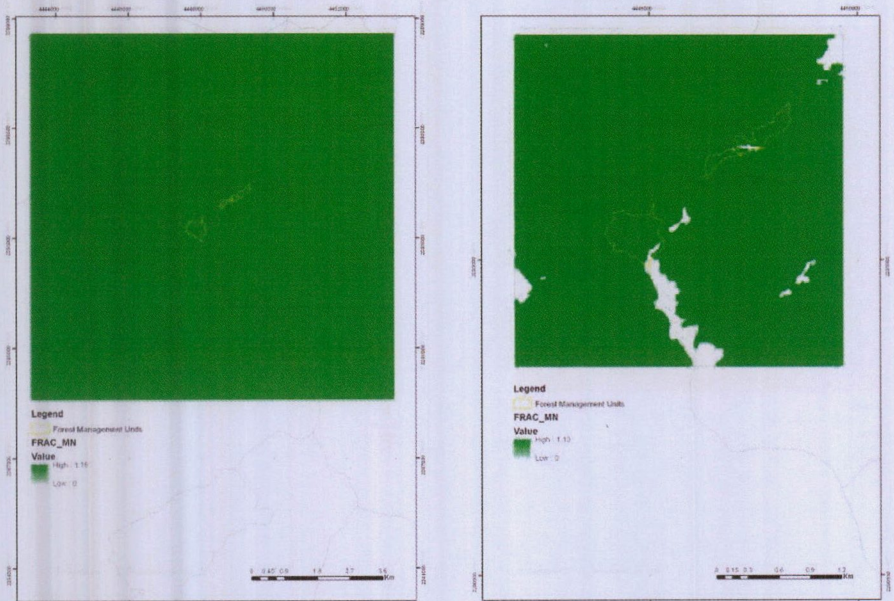


Figure 121: Mean fractal dimensions resulting maps for “Vallombrosa forest” site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

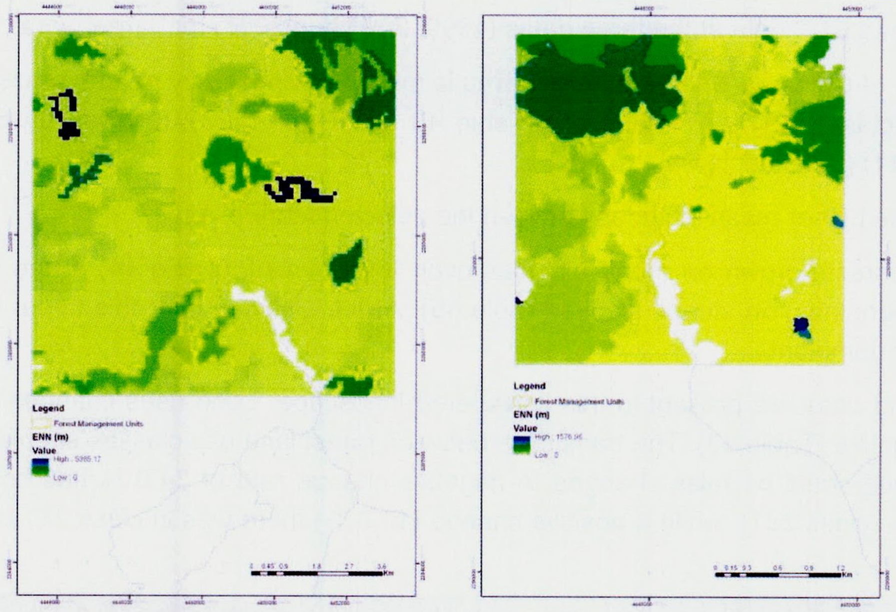


Figure 122: Euclidean nearest neighbor distances maps for "Vallombrosa forest" site.

2.2.5. Chiarano – Sparvera – Site 2

- Evaluation of the landscape context and land uses changes: "large" area

Figure 124 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

The landscape of Chiarano-Sparvera "large" area is mainly composed by natural grasslands (class 321) (4905 hectares; 49 % of total area) (Table 43 and Figure 123), followed by broad-leaved forest (class 311) (3128 hectares).

This site has the higher mean altitudes between the selected ManFor sites.

Broad leaved forests grown on mean altitudes over 1600 m.a.s.l. (Table 44) at the upper forest limit on the Apennines, on steeps slopes (Table 45). At the altitudes over this upper limit, natural grasslands are dominant.

No artificial land uses are present in this considered landscape. Land uses changes for this area are mainly negative (Table 43). The transitions between forest land use classes should be carefully considered since could be false changes. A negative change rate of 34.8 % has been identified within pastures (class 231), while a positive change (13.3 %) there was in class 211 (non-irrigated arable land).

CHIARANO-SPARVERA (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/1990 (%)
211	Non-irrigated arable land	653	653	740	6.53	6.53	7.4	0	87	87	13.32
231	Pastures	250	250	163	2.5	2.5	1.63	0	-87	-87	-34.80
311	Broad-leaved forest	3128	3128	3395	31.28	31.28	33.95	0	267	267	8.54
313	Mixed forest	350	350	83	3.5	3.5	0.83	0	-267	-267	-76.29
321	Natural grasslands	4905	4905	4905	49.05	49.05	49.05	0	0	0	0.00
324	Transitional woodland-shrub	237	237	237	2.37	2.37	2.37	0	0	0	0.00
332	Bare rocks	380	380	380	3.8	3.8	3.8	0	0	0	0.00
333	Sparsely vegetated areas	97	97	97	0.97	0.97	0.97	0	0	0	0.00
	Total	10000	10000	10000	100	100	100				

Table 43: Area values per class and per year and relative changes between dates for Chiarano-Sparvera "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

Contingency matrix (Table 46 and Table 47) showed as the negative change rate of pastures was due mainly to the transition toward class 211.

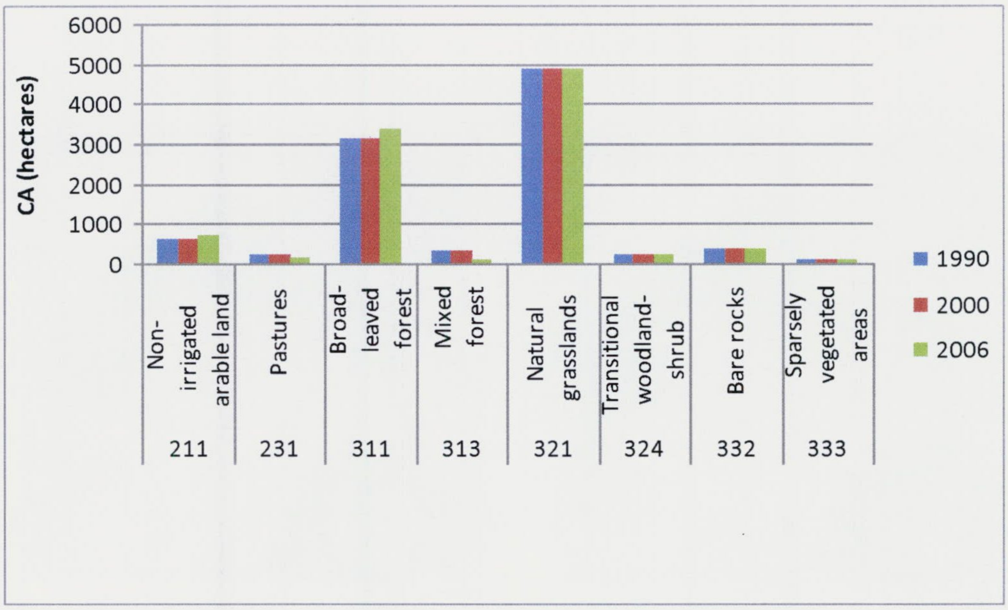


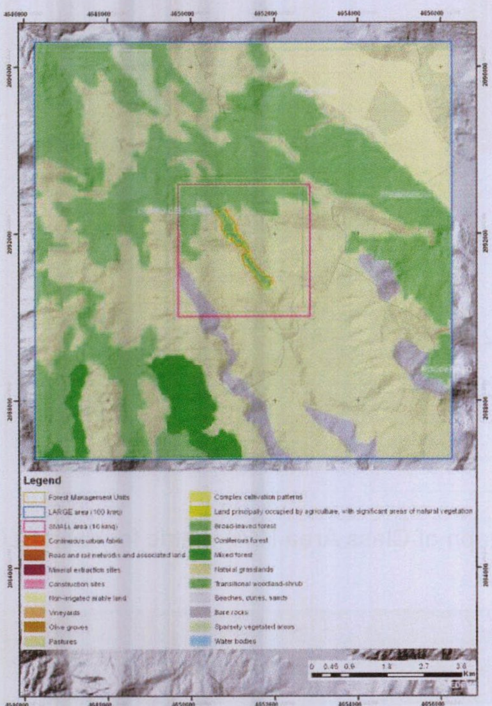
Figure 123: Chiarano-Sparvera "large" (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

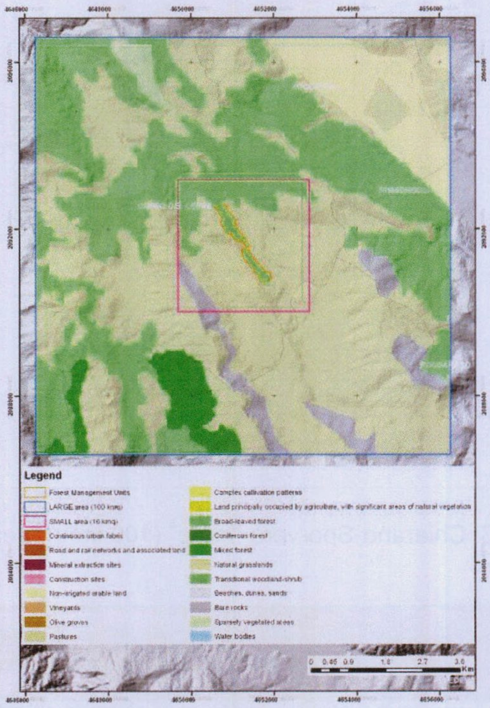
CHIARANO-SPARVERA (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	**Class**	**COUNT**	**MIN**	**MAX**	**RANGE**	**MEAN**	**MAJORITY**	**MINORITY**	**MEDIAN**
321	Natural grasslands	1	1224	2253	1029	1763.64	1875	1391	1811
211	Non-irrigated arable land	2	1249	1350	101	1268.83	1250	1331	1264
311	Broad-leaved forest	3	1099	2063	964	1610.14	1575	1104	1612
333	Sparsely vegetated areas	4	1675	1978	303	1849.18	1850	1675	1850
324	Transitional woodland-shrub	5	1125	1753	628	1492.16	1625	1129	1563
313	Mixed forest	6	1472	1902	430	1756.98	1800	1472	1795
332	Bare rocks	7	1766	2229	463	1991.5	2000	1766	1990
231	Pastures	8	1524	1750	226	1566.72	1550	1586	1550

Table 44: Topographic features for each class within Chiarano-Sparvera "large" area: altidudes (m.a.s.l).

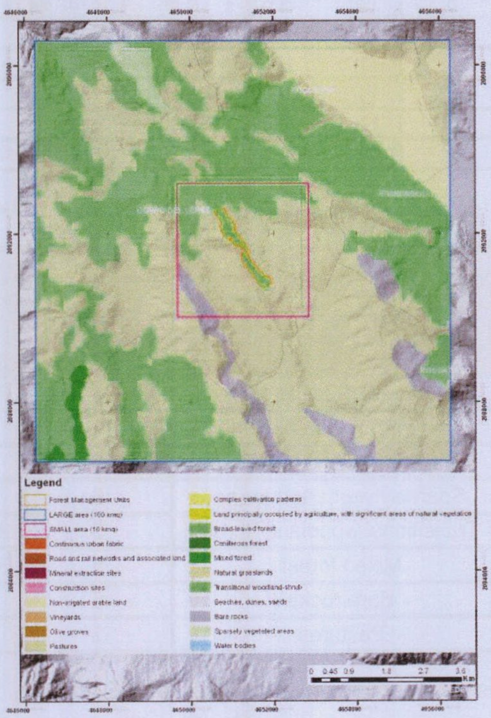
CHIARANO-SPARVERA (large area 100 kmq)			
Code	**Class**	**Class of majority presence**	**Slope values**
321	Natural grasslands	5	30 - 50 %
211	Non-irrigated arable land	1	< 3%
311	Broad-leaved forest	6	> 50 %
333	Sparsely vegetated areas	6	> 50 %
324	Transitional woodland-shrub	5	30 - 50 %
313	Mixed forest	5	30 - 50 %
332	Bare rocks	6	> 50 %
231	Pastures	1	< 3%

Table 45: Topographic features for each class within Chiarano-Sparvera "large" area: class of slopes (percentage).





CLC 1990	**CLC 2000**



CLC 2006

Figure 124: CORINE Land Cover data of Chiarano-Sparvera "large" area.

CHIARANO-SPARVERA (large area 100 kmq)									
Cross tabulation (percentage)									
	2006								
1990	211	231	311	313	321	324	332	333	Total
211	653	0	0	0	0	0	0	0	653
231	87	163	0	0	0	0	0	0	250
311	0	0	3128	0	0	0	0	0	3128
313	0	0	267	83	0	0	0	0	350
321	0	0	0	0	4905	0	0	0	4905
324	0	0	0	0	0	237	0	0	237
332	0	0	0	0	0	0	380	0	380
333	0	0	0	0	0	0	0	97	97
Total	740	163	3395	83	4905	237	380	97	10000

Tabella 46: contingency matrix of Chiarano-Sparvera large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

CHIARANO-SPARVERA (large area 100 kmq)									
Cross tabulation (percentage)									
	2006								
1990	211	231	311	313	321	324	332	333	Total
211	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
231	34.8	65.2	0.0	0.0	0.0	0.0	0.0	0.0	100.0
311	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0
313	0.0	0.0	76.3	23.7	0.0	0.0	0.0	0.0	100.0
321	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
324	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0
332	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0
333	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0

Tabella 47: contingency matrix of Chiarano-Sparvera large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered date (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

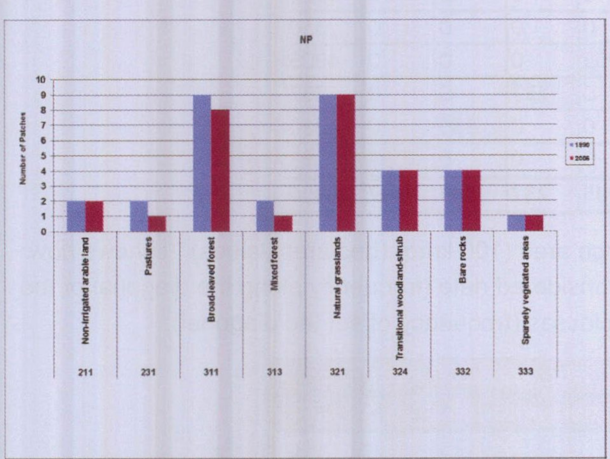
Analysis of landscape metrics (Figure 125) showed as broad-leaved forests (class 311), have the higher number of patches (NP) but between the two dates there was a slightly decrease as soon as for mixed forests (class 313) and for pastures (class 321).

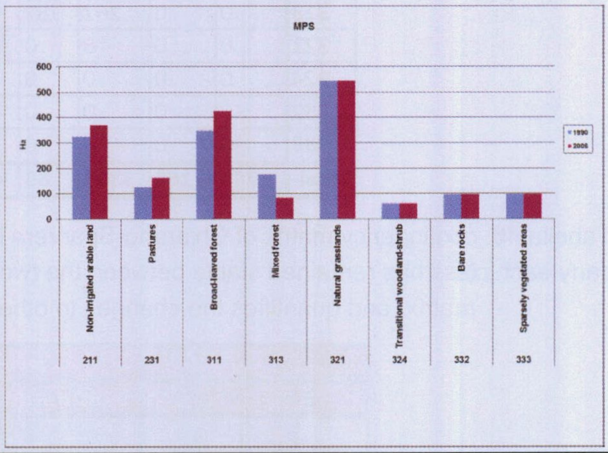
Natural grasslands showed the highest mean patch size (MPS). Broad-leaved forests (class 311) showed a decrease of MPS value, as soon as pastures (class 321) and non-irrigated lands (class 211).

Broad leaved forest contain most of the forest core area, as showed by the mean core area index (MCA).

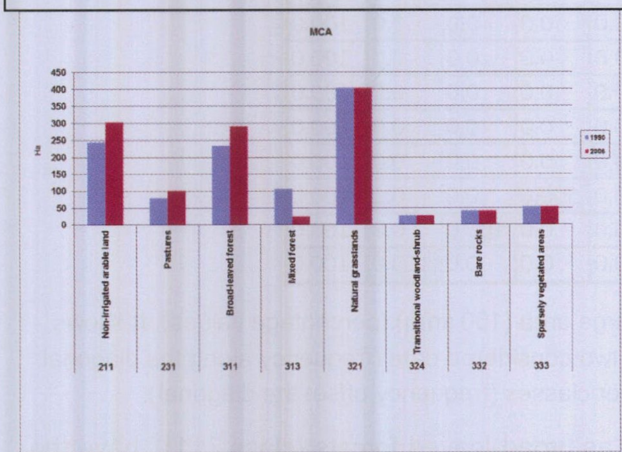
The Euclidean Nearest-Neighbor distance (ENN) index showed as pasture have the most isolated patches within the analysed landscape.

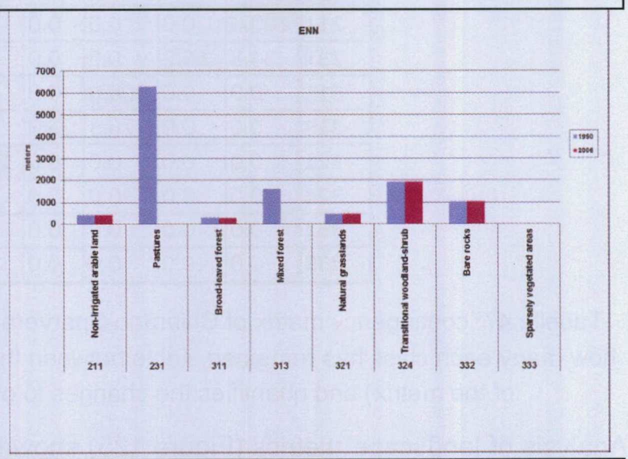
Broad-leaved forests have the highest shape complexity (AWMSI). Total edge (TE) for this class increased slightly. Natural grasslands showed the highest TE length within the landscape but this class remained stable through the considered time.



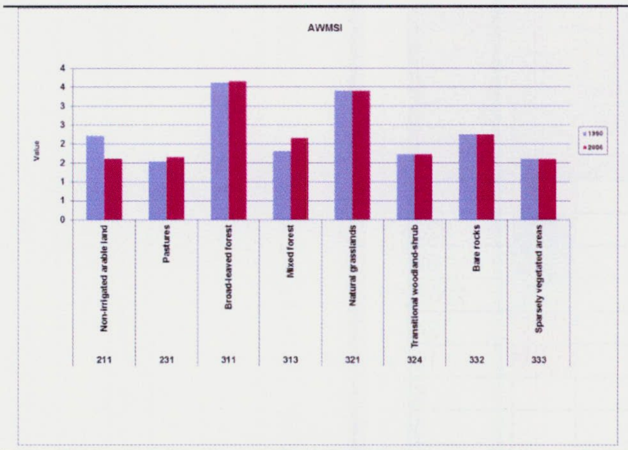


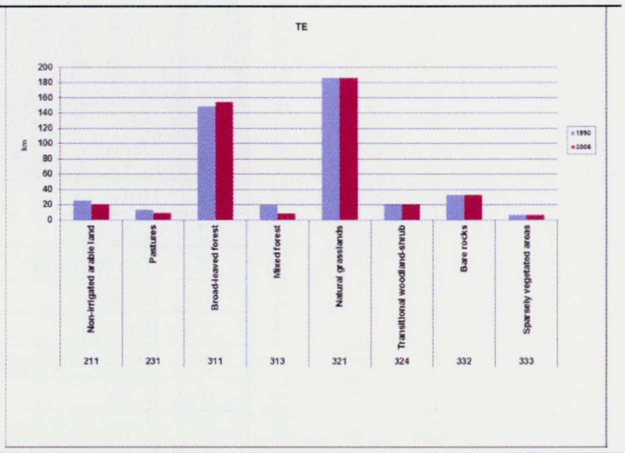
NP	MPS





MCA	ENN





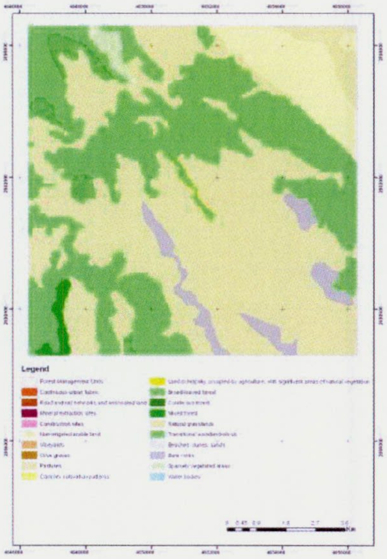
AWMSI	TE

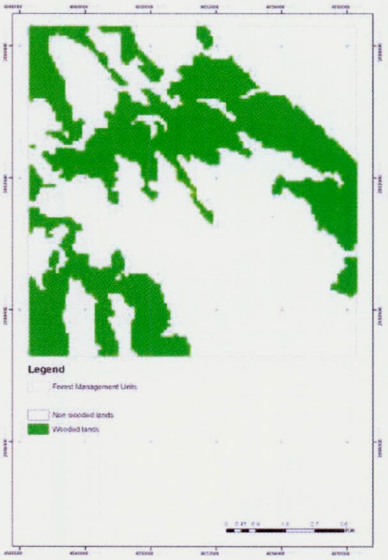
Figure 125: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Chiarano-Sparvera "large" area.

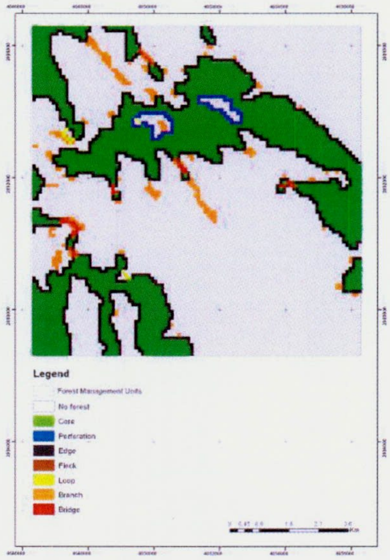
- ### Forest spatial pattern classification results: "large" area

Figure 126 shows the input and output of GUIDOS forest spatial pattern classification for Chiarano-Sparvera "large" area based on the CLC data of year 2006.

Large area







CLC map (year 2006)	Forest/non forest map input	GUIDOS spatial pattern classification

Figure 126: Inputs and outputs maps of GUIDOS classification for Chiarano-Sparvera forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

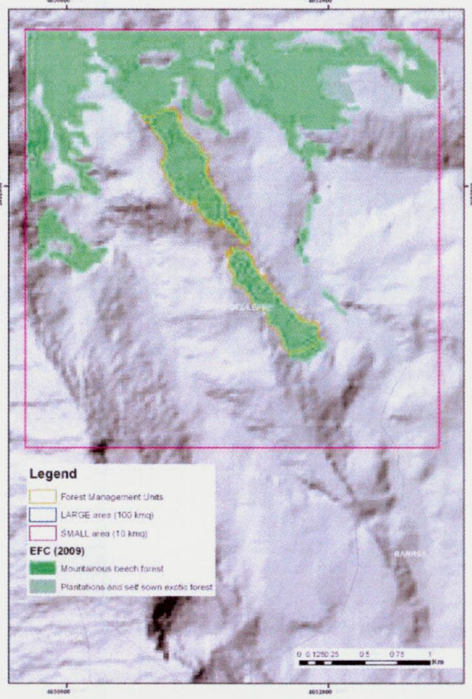
In Table 48, area (in hectares) of each forest spatial pattern class has been reported.

Chiarano-Sparvera (large area 100 kmq)			
Code	Description		AREA (ha)
1	Branch		210
3	Edge		928
5	Perforation		82
17	Core		2205
33	Bridge		24
35	Bridge in Edge		16
65	Loop		6
67	Loop in Edge		5
69	Loop in Perforation		2

Table 48: Area (hectares) of GUIDOS forest spatial pattern classes for Chiarano-Sparvera forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 127 shows forest cover data of Chiarano-Sparvera "small" area.



European Forest Categories (2009)

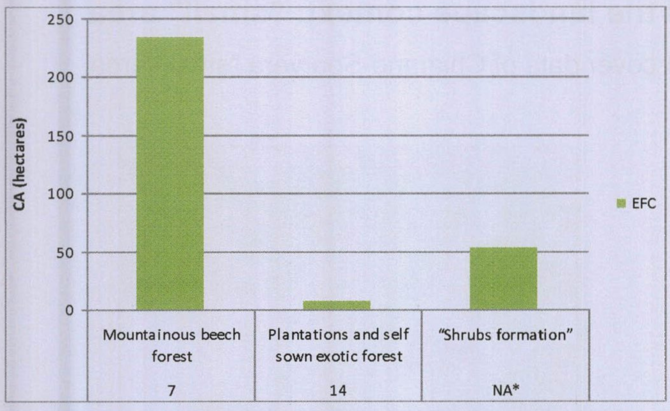
Figure 127: European Forest Categories map (2009) for Chiarano-Sparvera "small" area.

On the basis of the map of forest type of year 2009 forest within "small" area covers 294.7 hectares and the "Apennine Corsican mountainous beech forest" (class 73) is the dominant EFT (235 hectares) (Table 49 and Figure 128).

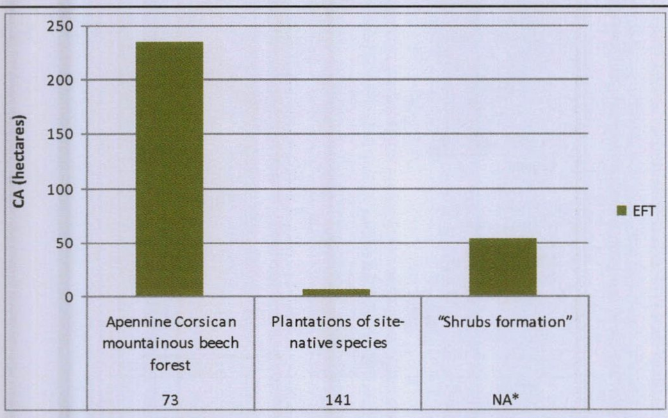
CHIARANO-SPARVERA (small area 10 kmq)				
EFC Code	**Class description**	**EFT Code**	**Class description**	**Class Area (CA) (hectares)**
7	Mountainous beech forest	73	Apennine Corsican mountainous beech forest	235.1
			sub total	**235.1**
14	Plantations and self sown exotic forest	141	Plantations of site-native species	6.34
			sub total	**6.34**
NA*	"Shrubs formation"	NA*		53.3
			sub total	**53.3**
			TOTAL	**294.74**

Table 49: Chiarano-Sparvera "small" area. Area (hectares) for EFC and EFT classes. Forest Types date: 2009. NA: not applicable, means the impossibility to reclassification for that level.

Beech forest grows at mean altitudes of 1600 m.a.s.l. (Table 50) on very steeps slopes (30-50 %) (Table 51). Over this upper altitudinal limit shrubs formations are dominant (53 hectares).



EFC level classification



EFT level classification

Figure 128: Chiarano-Sparvera "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

CHIARANO-SPARVERA (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFC	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
NA*	"Shrubs formation"	1326	1625	2085	460	1838.45	1775	1625	1808
73	Apennine Corsican mountainous beech forest	5809	1525	1850	325	1684.8	1650	1532	1688
141	Plantations of site-native species	159	1625	1763	138	1725.81	1725	1631	1737

Table 50: Topographic features for each class within Chiarano-Sparvera "small" area: altidudes (m.a.s.l).

CHIARANO-SPARVERA (small area 10 kmq)			
Code	EFC	Class of majority presence	Slope values
NA*	"Shrubs formation"	6	> 50 %
73	Apennine Corsican mountainous beech forest	5	30 - 50 %
141	Plantations of site-native species	3	10 - 20 %

Table 51: Topographic features for each class within Chiarano-Sparvera "small" area: class of slopes (percentage).

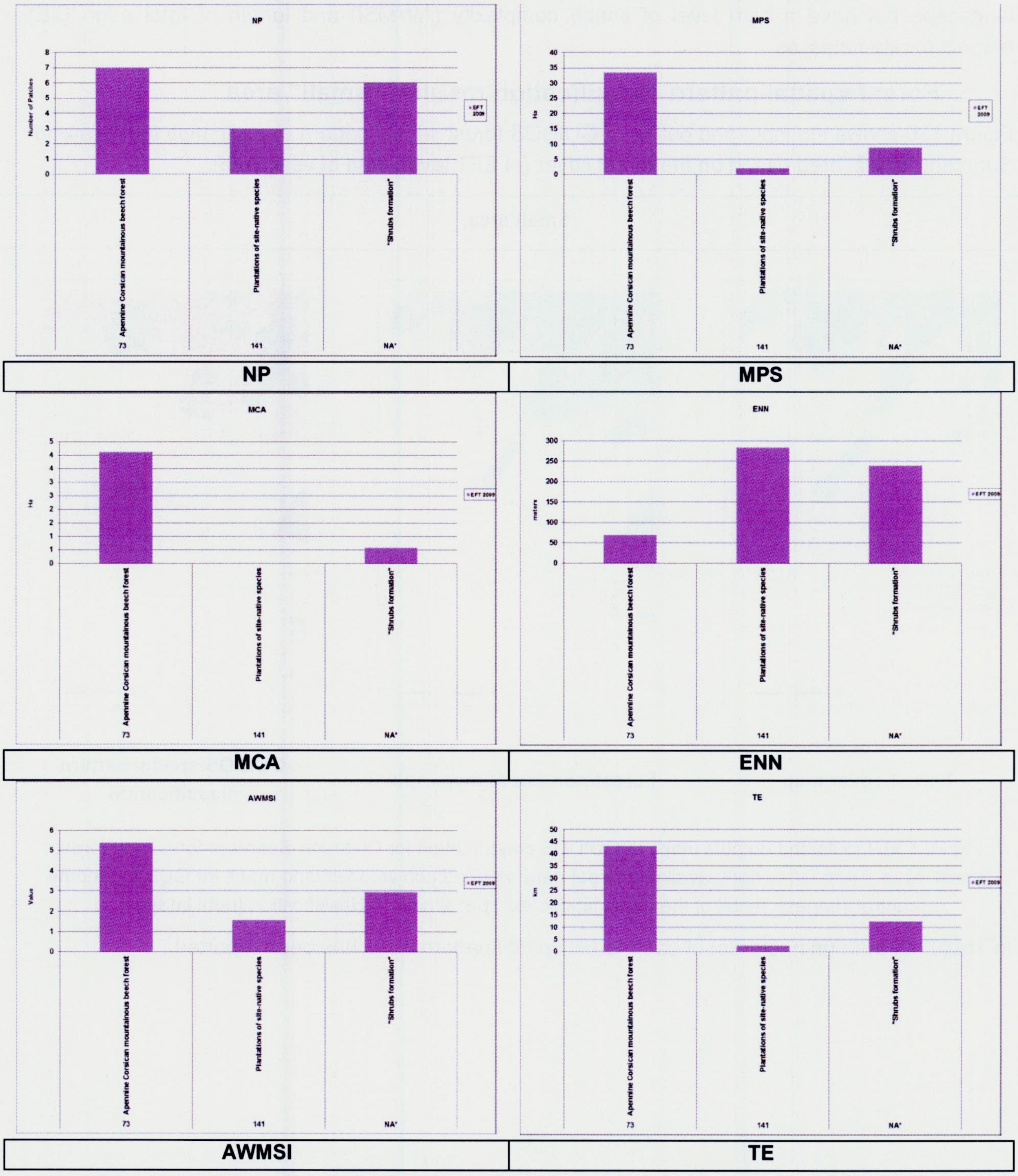


Figure 129: Results of landscape ecology metrics for forest cover (year 1998) within "small" area of Chiarano-Sparvera site.

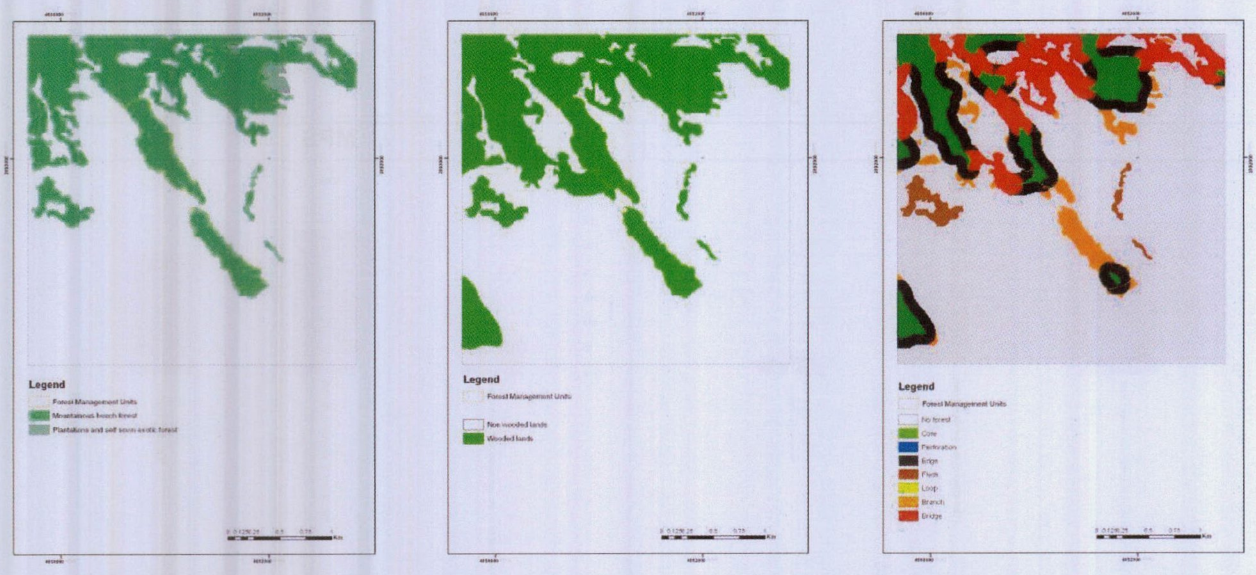
Landscape metrics (Figure 129) showed as beech forests (class 73) have the highest number of patches (NP), the highest mean patch size (MPS) value and contain the most of core area (MCA).

The ENN index showed as beech forests patches are more aggregated than other types within the landscape but have a high level of shape complexity (AWMSI) and length of total edge (TE) respect to other classes.

- ### Forest spatial pattern classification results: "small" area

Figure 130 shows the input and output of GUIDOS forest spatial pattern classification for Chiarano-Sparvera "small" area based on the forest cover (at EFT level) data of year 2009.

Small area



Forest cover map	**Forest/non forest map input**	**GUIDOS spatial pattern classification**

Figure 130: Inputs and outputs maps of GUIDOS classification for Chiarano-Sparvera forest/non forest "small" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 52, area (in hectares) of each forest spatial pattern class has been reported.

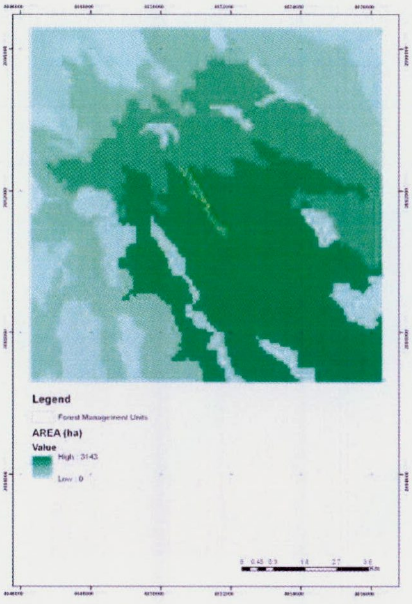
Chiarano-Sparvera (small area 10 kmq)			
Code	**Description**		**AREA (ha)**
1	Branch		32.47
3	Edge		86.48
9	Islet		15.09
17	Core		63.48
33	Bridge		49.52
35	Bridge in Edge		47.7

Table 52: Area (hectares) of GUIDOS forest spatial pattern classes for Chiarano-Sparvera forest/non forest "small" area.

- **Maps of landscape metrics**

Patch area (ha) (*per patch*) (AREA)

Large area	Small area



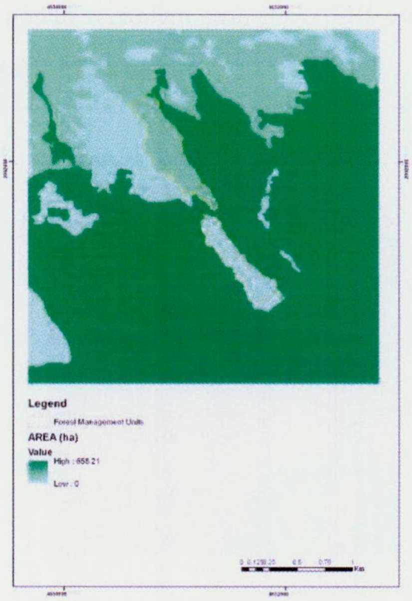


Figure 131: Patch area metrics resulting maps for "Chiarano-Sparvera forest" site.

Class area (ha) (per class) (CA)

Large area	Small area

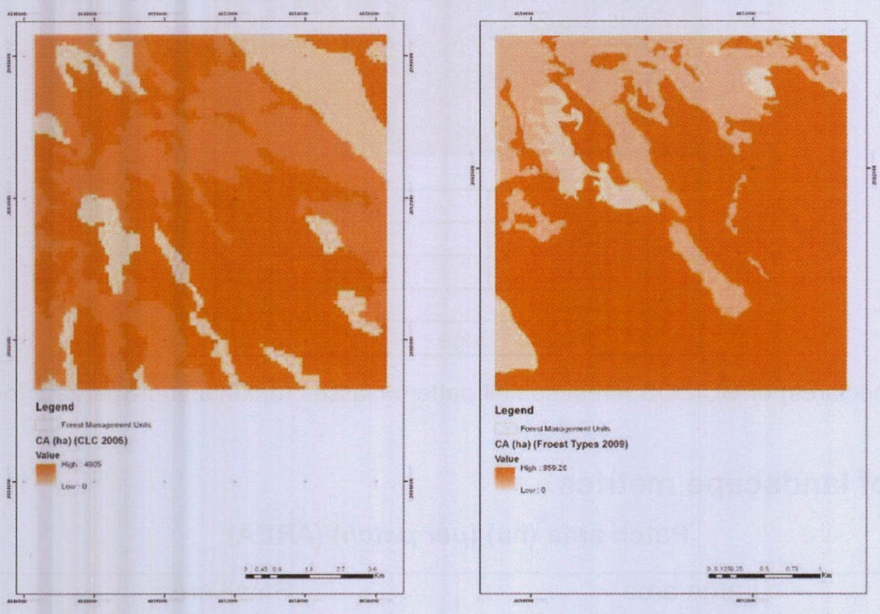


Figure 132: Class area metrics resulting maps for ""Chiarano-Sparvera forest" site.

Class area (ha) (*per class*) (CA)

Large area	Small area

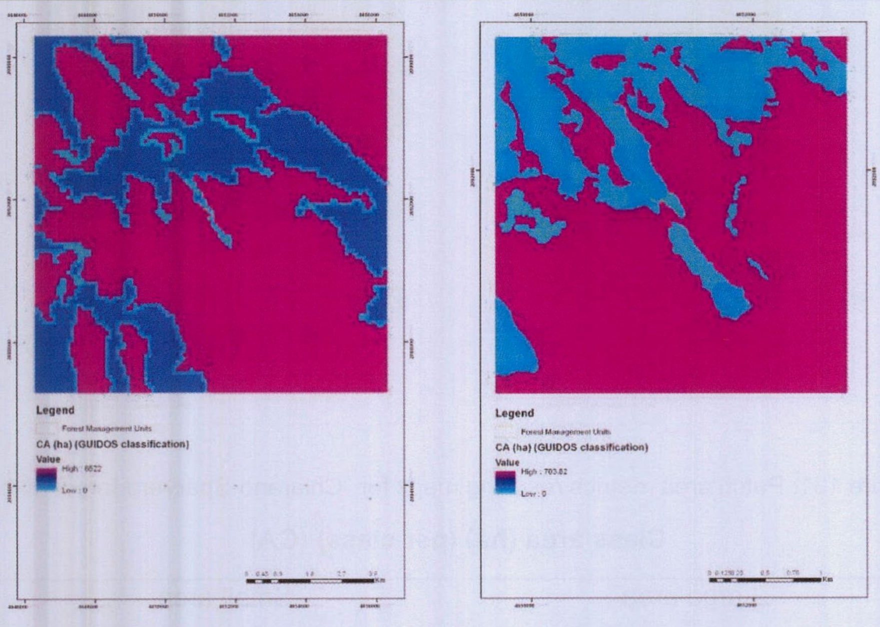


Figure 133: Class area size metrics resulting maps for "Chiarano-Sparvera forest" site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

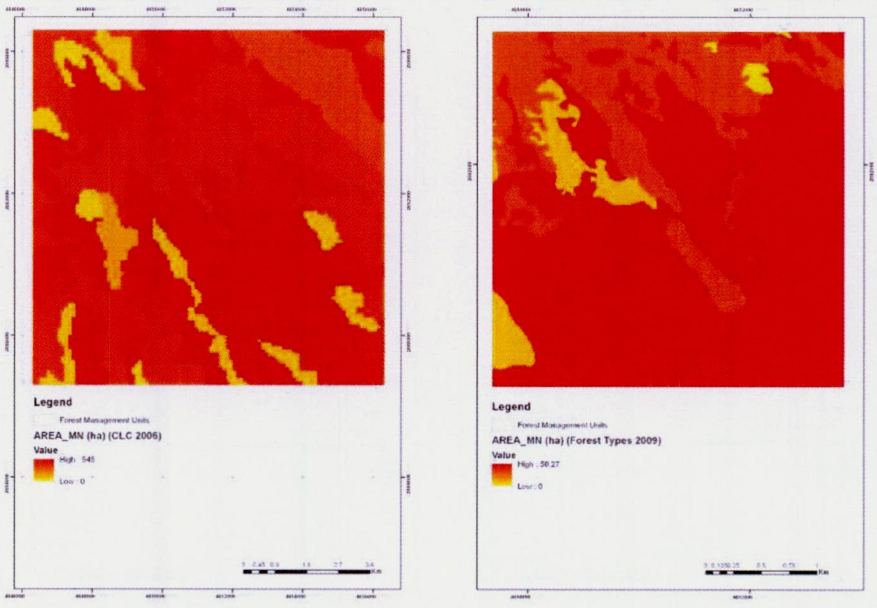


Figure 134: Mean patch size metrics resulting maps for "Chiarano-Sparvera forest" site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

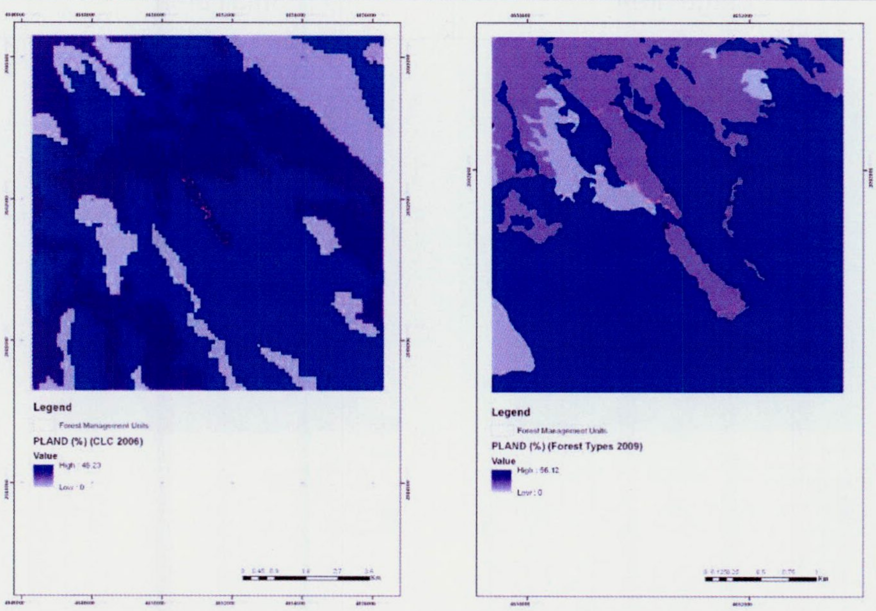


Figure 135: Percentage of landscape metrics resulting maps for "Chiarano-Sparvera forest" site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

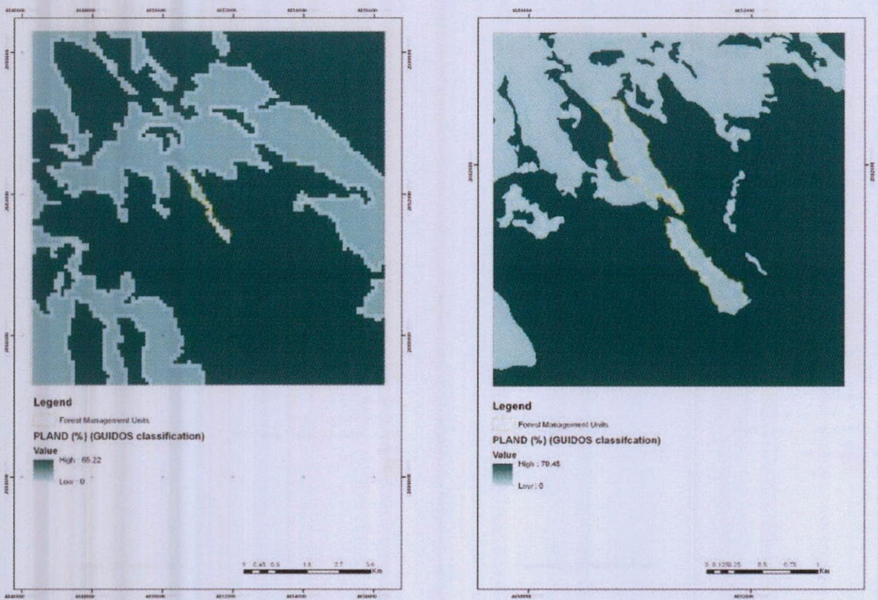


Figure 136: Percentage of landscape metrics resulting maps for "Chiarano-Sparvera forest" site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

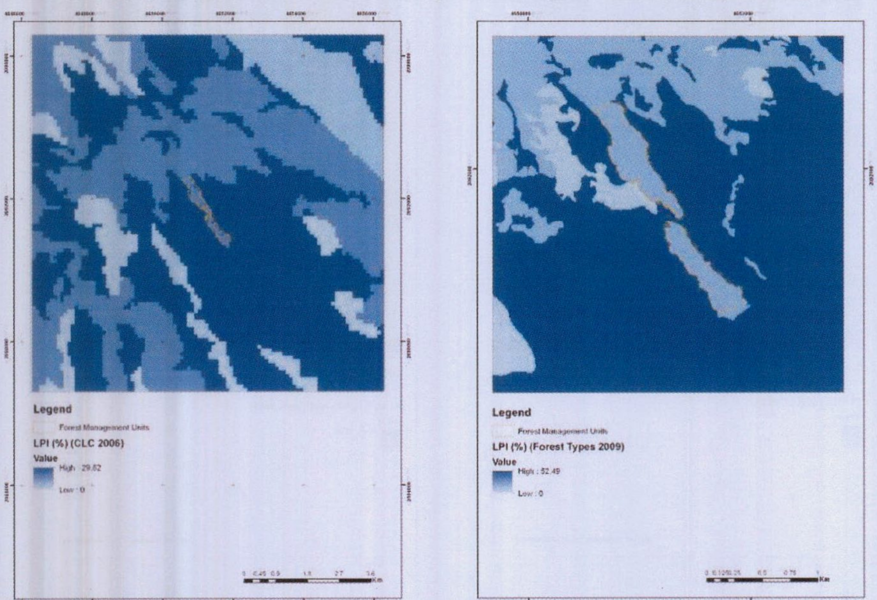


Figure 137: Largest patch index metrics resulting maps for "Chiarano-Sparvera forest" site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

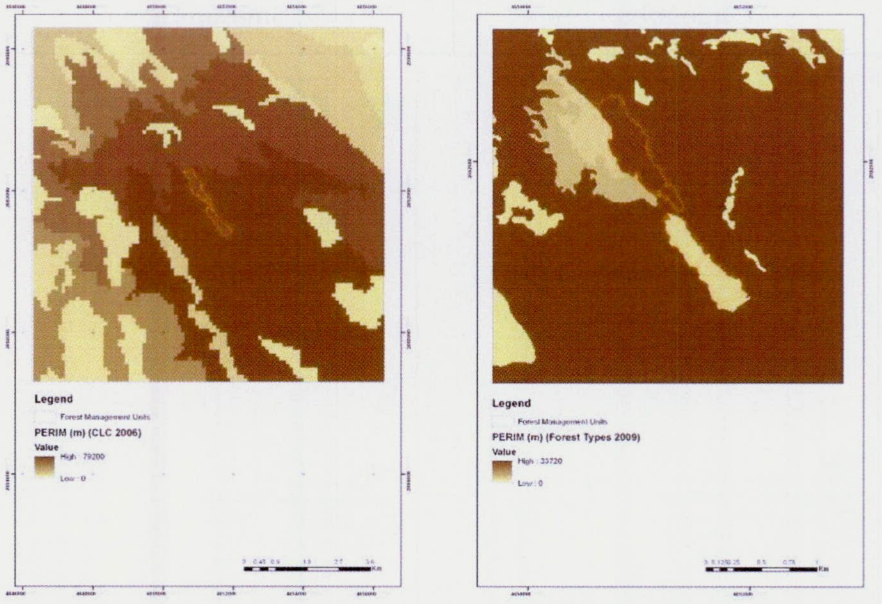


Figure 138: Edge metrics resulting maps for "Chiarano-Sparvera forest" site.

Total core area (ha) (per class) (TCA)

Large area	Small area

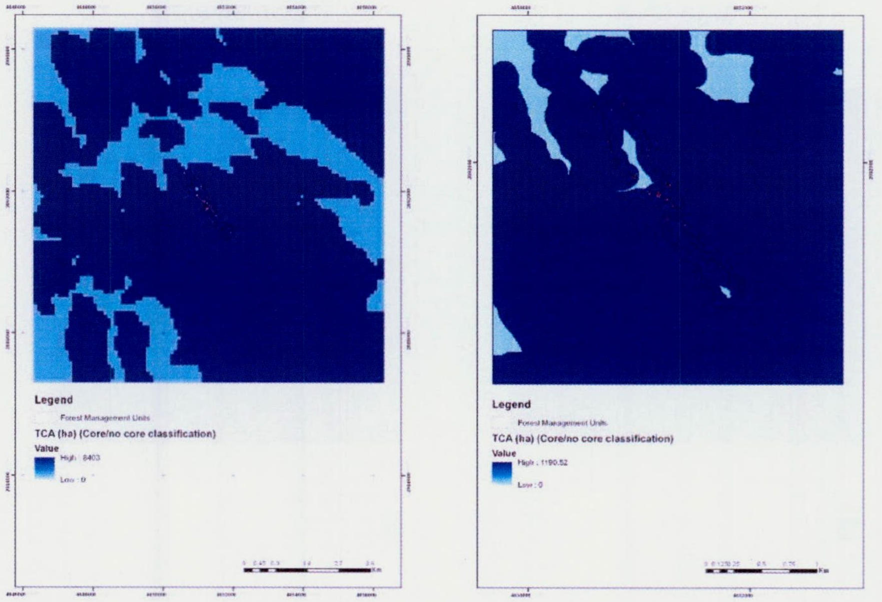


Figure 139: Total core area metrics resulting maps for "Chiarano-Sparvera forest" site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

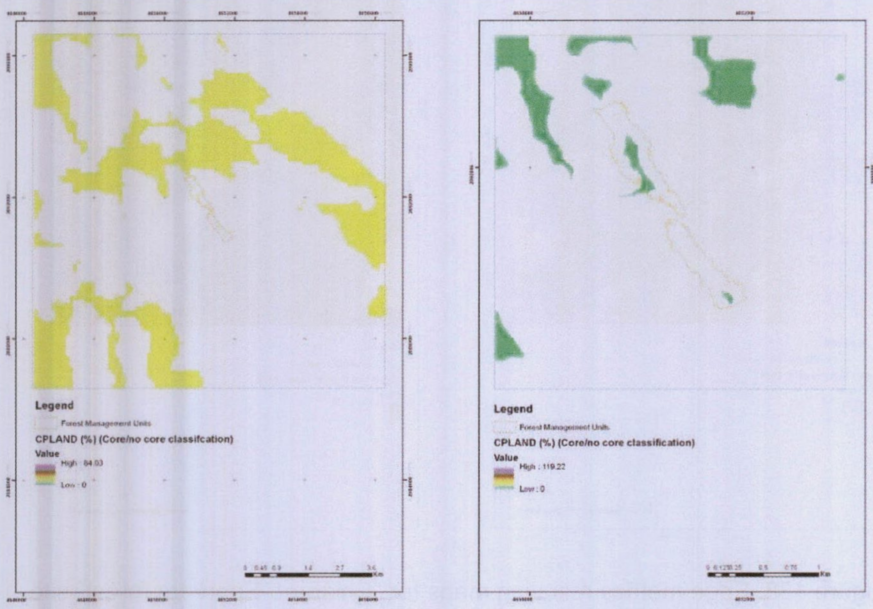


Figure 140: Core Area Percentage of Landscape metrics resulting maps for “Chiarano-Sparvera forest” site.

Number of patches (per patch) (NP)

Large area	Small area

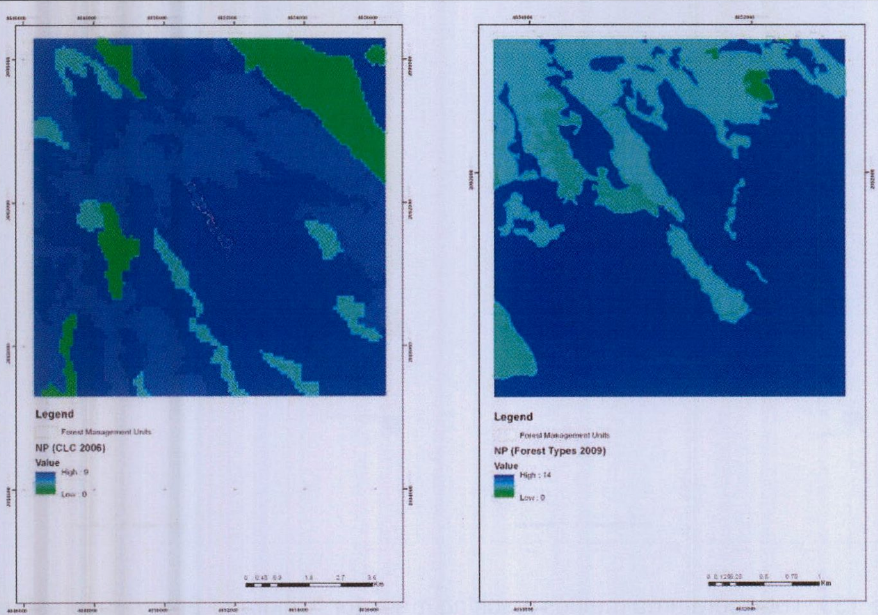


Figure 141: Number of patches in the landscape resulting maps for “Chiarano-Sparvera forest” site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

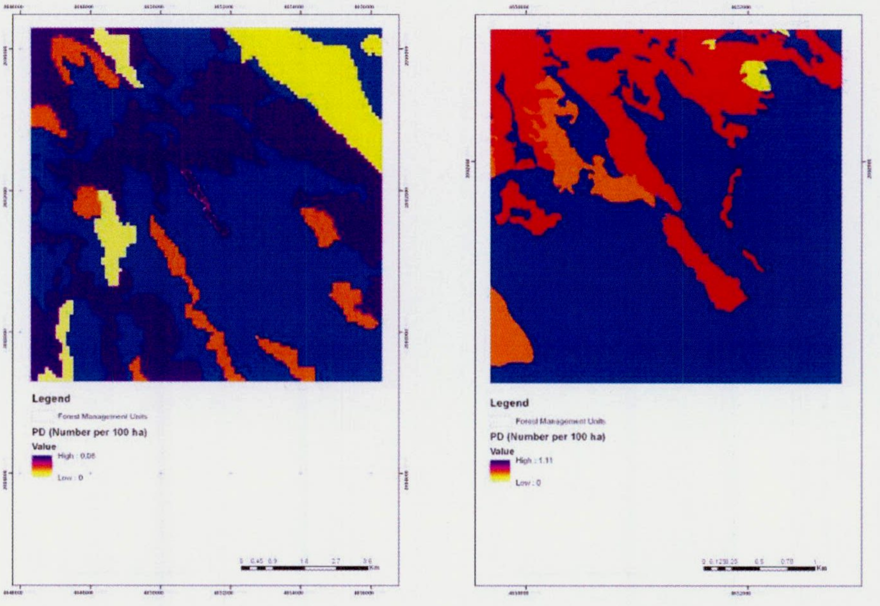


Figure 142: Patch density metrics resulting maps for “Chiarano-Sparvera forest” site.

Shape (per patch) (SHAPE)

Large area	Small area

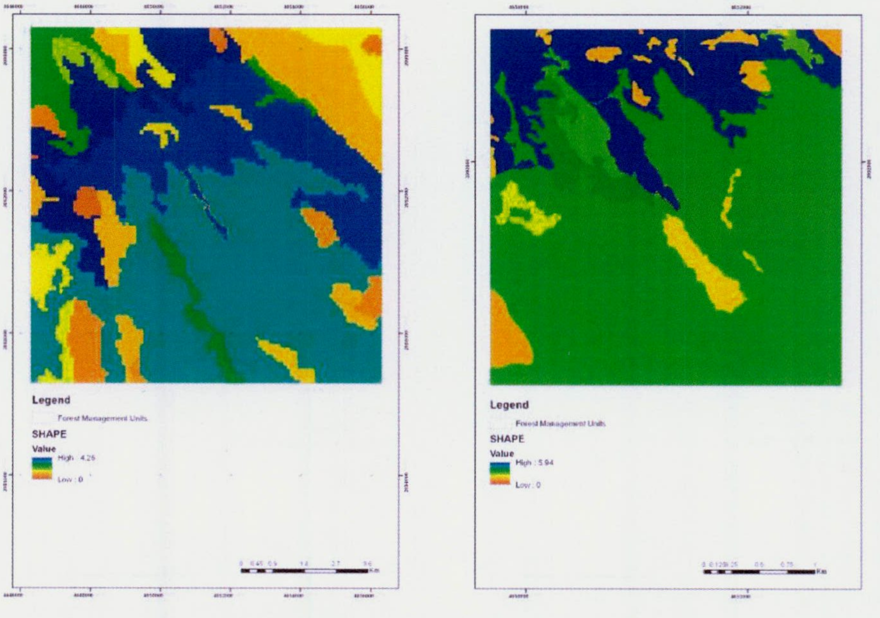


Figure 143: Shape metrics resulting maps for “Chiarano-Sparvera forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

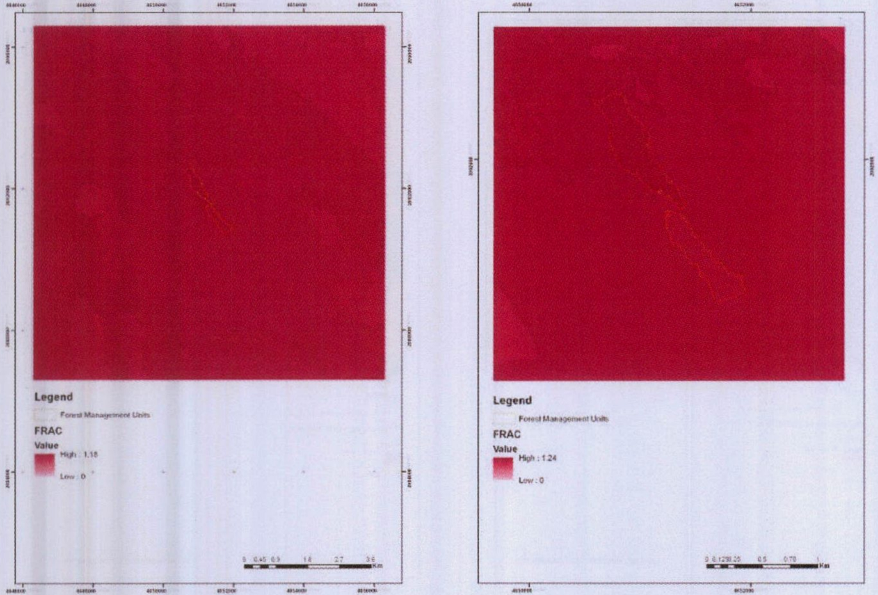


Figure 144: Fractal dimension metrics resulting maps for “Chiarano-Sparvera forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

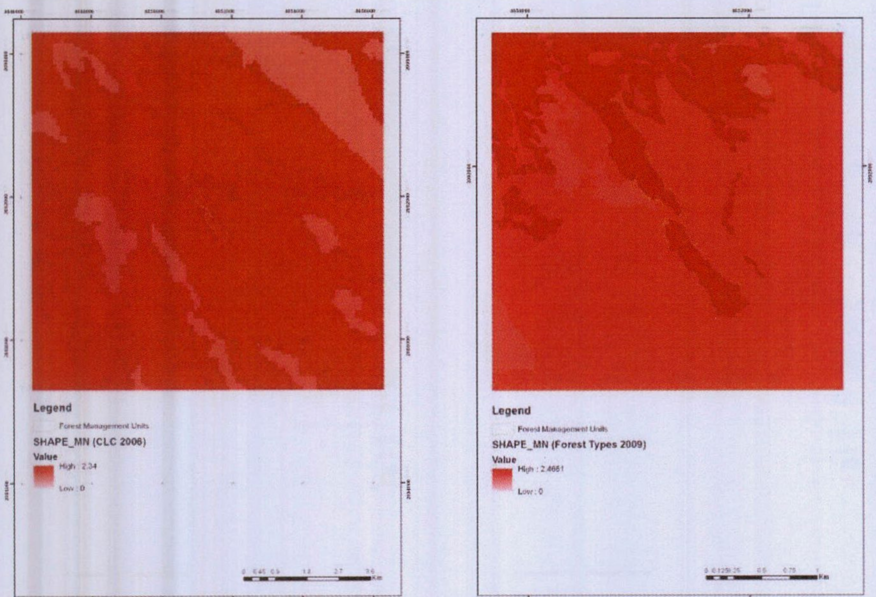


Figure 145: Mean shape indexes resulting maps for “Chiarano-Sparvera forest” site.

Mean fractal index (per class) (FRAC_MN)

Large area	Small area

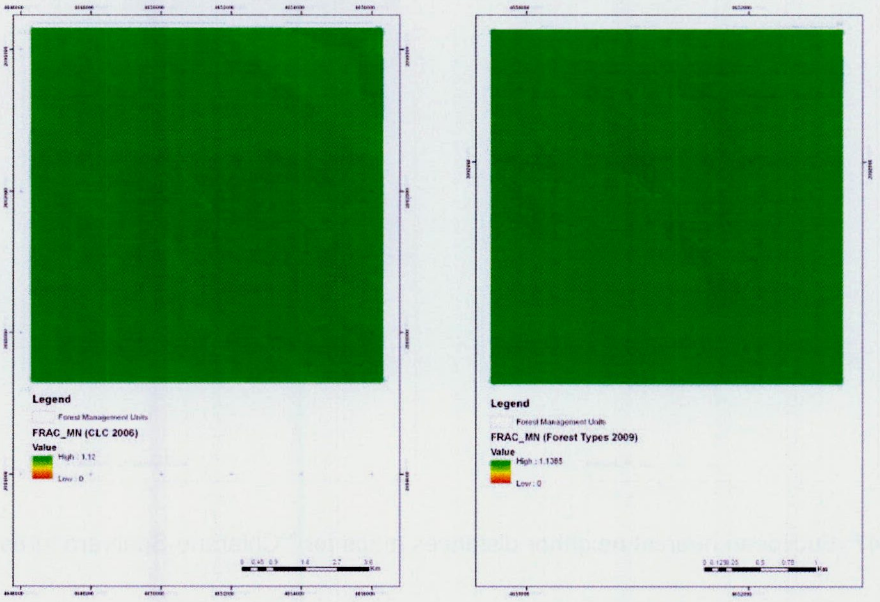


Figure 146: Mean fractal dimensions resulting maps for “Chiarano-Sparvera forest” site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

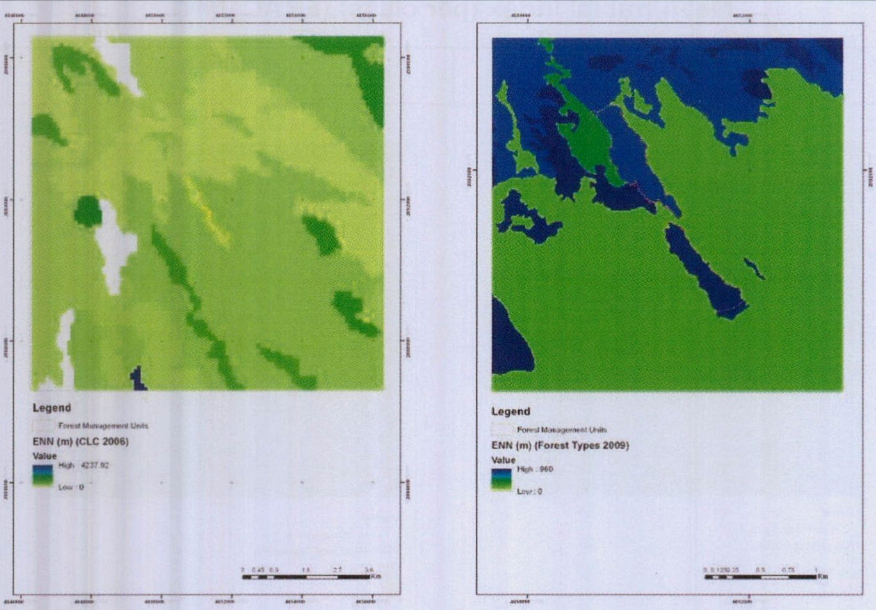


Figure 147: Euclidean nearest neighbor distances maps for ““Chiarano-Sparvera forest” site.

2.2.6. Pennataro – Site 5

- **Evaluation of the landscape context and land uses changes: "large" area**

Figure 149 shows CLC data at the three dates (1990, 2000 and 2006) for "large" area.

PENNATARO (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	53	53	53	0.53	0.53	0.53	0	0	0	0.00
211	Non-irrigated arable land	714	1680	1680	7.21	16.96	16.96	966	0	966	135.29
231	Pastures	136	136	136	1.37	1.37	1.37	0	0	0	0.00
242	Complex cultivation patterns	239	433	433	2.41	4.37	4.37	194	0	194	81.17
243	Land principally occupied by agriculture, with significant areas of natural vegetation	2496	2137	2137	25.19	21.57	21.57	-359	0	-359	-14.38
311	Broad-leaved forest	5093	4240	4166	51.40	42.79	42.05	-853	-74	-927	-18.20
312	Coniferous forest	52	52	52	0.52	0.52	0.52	0	0	0	0.00
313	Mixed forest	28	28	28	0.28	0.28	0.28	0	0	0	0.00
321	Natural grasslands	660	751	751	6.66	7.58	7.58	91	0	91	13.79
322	Moors and heathland	437			4.41	0.00	0.00	-437	0	-437	-100.00
324	Transitional woodland-shrub		398	472	0.00	4.02	4.76	398	74	472	
	Total	9908	9908	9908	100	100	100				

Table 53: Area values per class and per year and relative changes between dates for Pennataro "large" area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

Broad-leaved forests (class 311) are dominant within the Pennataro "large" area (Table 53 and Figure 148) and cover 42 % of total area (4166 hectares at year 2006). The second main represented land use class are agriculture lands with significant areas of natural vegetation (class 243) which cover 2135 hectares (21.5 %) of the considered area.

Broad-leaved forests grow at mean altitudes under 1000 m.a.s.l (Table 54) on moderately steep slopes (20-30 %) (Table 55). Class 243 is present at lower mean altitudes (under 900 m.a.s.l.).

Coniferous forest (class 312) and mixed forest (class 313) cover respectively 0.52 % and 0.28 % of total area.

Changes analysis between considered dates (Table 53) showed as there were positive changes of agricultural areas (class 211 and 242) (change rate of 135 % and 81 % respectively). Moors and heathland) (class 322) showed a negative change rate (100 %). They were completely transformed in other land use classes. Natural grasslands (class 321) showed a positive change rate (13.7 %) in year 2006.

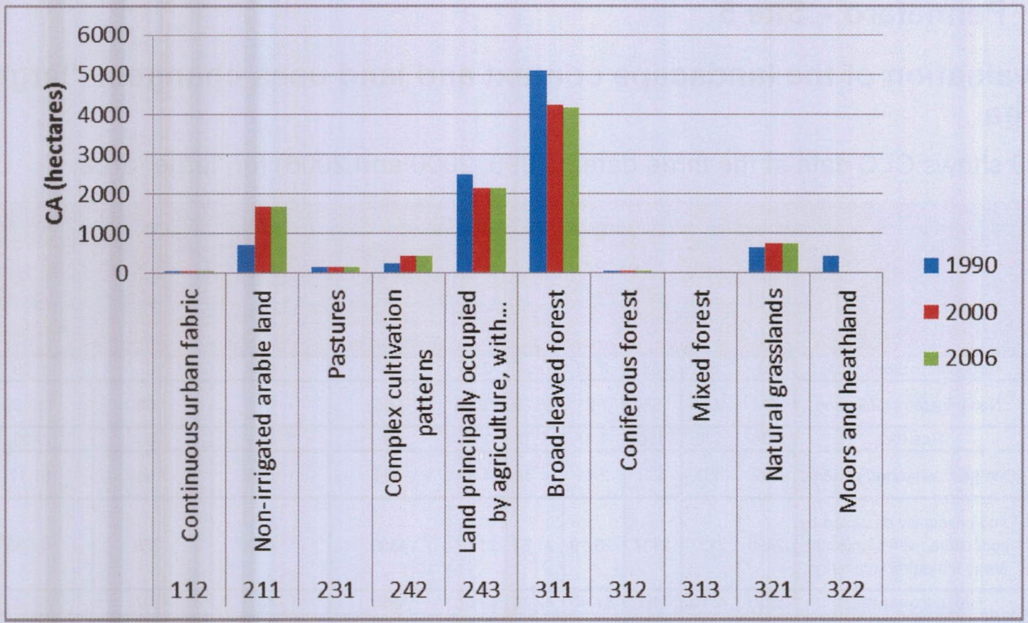


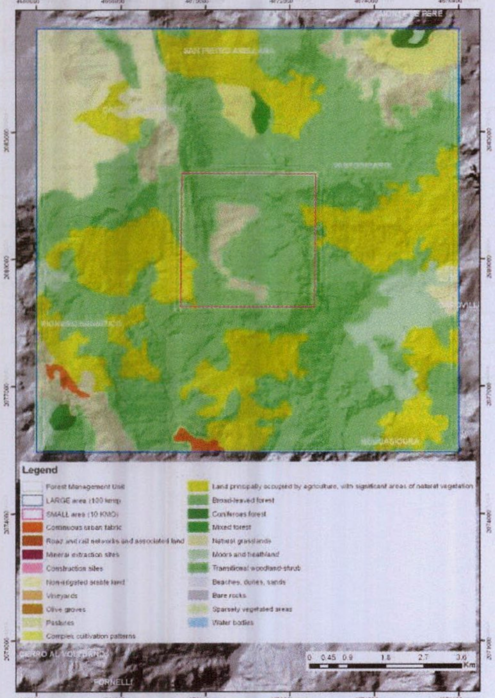
Figure 148: Pennataro “large” (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

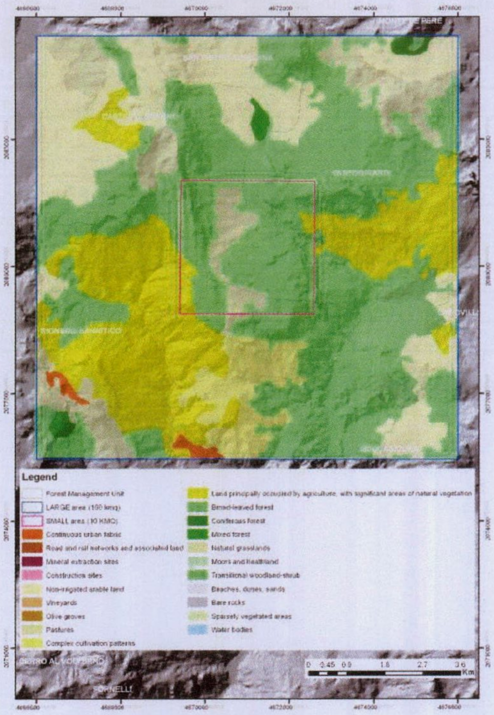
PENNATARO (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	1419	570	1062	492	784.672	600	570	631
211	Non-irrigated arable land	42423	600	1253	653	959.702	925	600	940
231	Pastures	3450	824	1025	201	922.439	875	824	920
242	Complex cultivation patterns	10976	575	1060	485	779.535	775	581	777
243	Land principally occupied by agriculture, with significant areas of natural vegetation	53299	571	1201	630	861.414	925	571	867
311	Broad-leaved forest	105505	471	1350	879	933.217	1075	471	983
312	Coniferous forest	1401	925	1300	375	1119.54	1000	945	1174
313	Mixed forest	715	899	923	24	904.344	900	917	903
321	Natural grasslands	19039	810	1303	493	1068.59	1075	810	1075
324	Moors and heathland	11773	598	1285	687	841.859	750	598	760

Table 54: Topographic features for each class within Pennataro “large” area: altidudes (m.a.s.l).

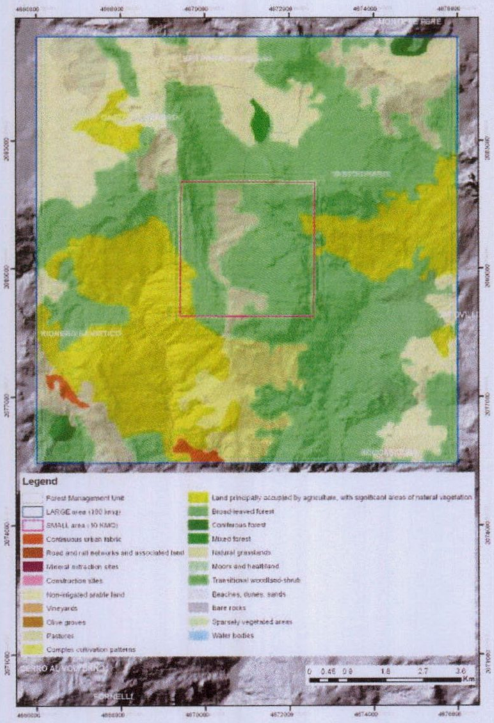
PENNATARO (large area 100 kmq)			
Code	Class	Class of majority presence	Slope values
112	Continuous urban fabric	4	20 - 30 %
211	Non-irrigated arable land	3	10 - 20 %
231	Pastures	3	10 - 20 %
242	Complex cultivation patterns	4	20 - 30 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	4	20 - 30 %
311	Broad-leaved forest	4	20 - 30 %
312	Coniferous forest	5	30 - 50 %
313	Mixed forest	2	3 - 10 %
321	Natural grasslands	3	10 - 20 %
324	Moors and heathland	3	10 - 20 %

Table 56: Topographic features for each class within Pennataro “large” area: class of slopes (percentage).





CLC 1990	CLC 2000



CLC 2006

Figure 149: CORINE Land Cover data of Pennataro "large" area.

Cross tabulation analysis (Table 56 and Table 57) showed as the increase of class 211 (non-irrigated arable land) derived mainly from transitions in this category from class 242 (complex cultivation patterns) and class 243 (land principally occupied by agriculture, with significant areas of natural vegetation). Class 322 has completely changed in class 324 and a little part has been converted in class 211.

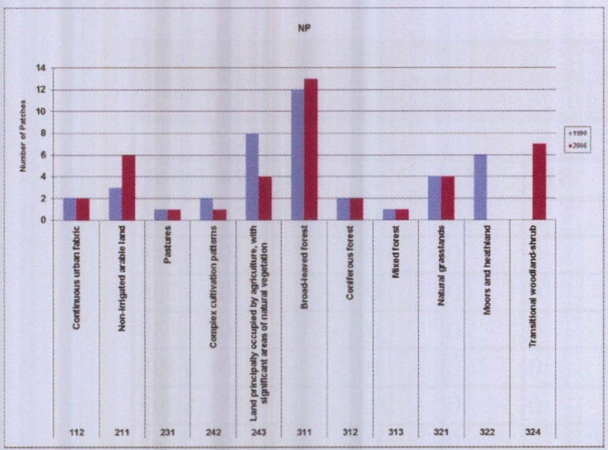
PENNATARO (large area 100 kmq)												
Cross tabulation (hectares)												
	2006											
1990	112	211	231	242	243	311	312	313	321	322	324	Total
112	53	0	0	0	0	0	0	0	0		0	53
211	0	714	0	0	0	0	0	0	0		0	714
231	0	0	136	0	0	0	0	0	0		0	136
242	0	239	0	0	0	0	0	0	0		0	239
243	0	679	0	433	1384	0	0	0	0		0	2496
311	0	9	0	0	753	4166	0	0	91		74	5093
312	0	0	0	0	0	0	52	0	0		0	52
313	0	0	0	0	0	0	0	28	0		0	28
321	0	0	0	0	0	0	0	0	660		0	660
322	0	39	0	0	0	0	0	0	0		398	437
324												
Total	53	1680	136	433	2137	4166	52	28	751		472	9908

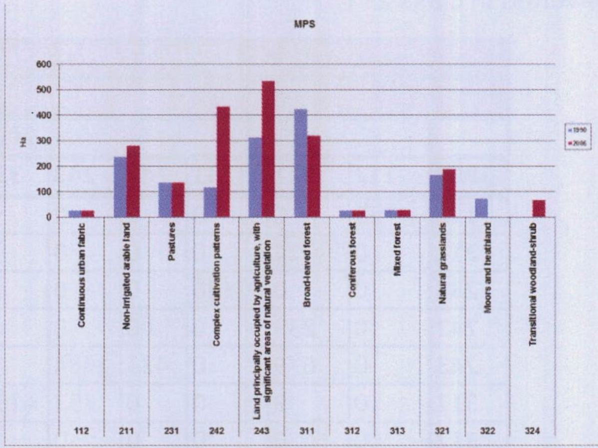
Tabella 56: contingency matrix of Pennataro large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

PENNATARO (large area 100 kmq)												
Cross tabulation (percentage)												
	2006											
1990	112	211	231	242	243	311	312	313	321	322	324	Total
112	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	100.0
211	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	100.0
231	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	100.0
242	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	100.0
243	0.0	27.2	0.0	17.3	55.4	0.0	0.0	0.0	0.0		0.0	100.0
311	0.0	0.2	0.0	0.0	14.8	81.8	0.0	0.0	1.8		1.5	100.0
312	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0		0.0	100.0
313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0		0.0	100.0
321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0		0.0	100.0
322	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0		91.1	100.0
324												

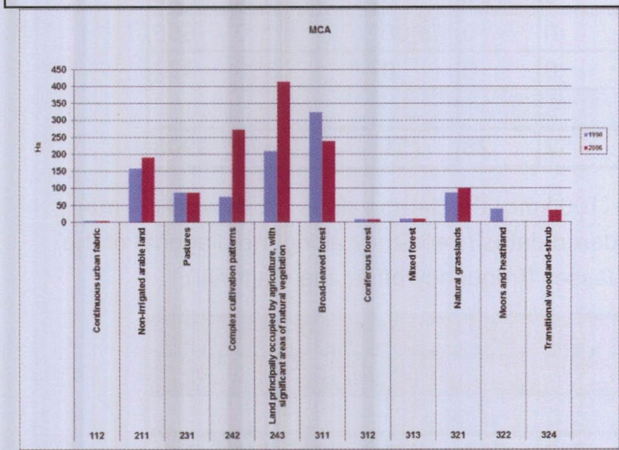
Tabella 57: contingency matrix of Pennataro large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

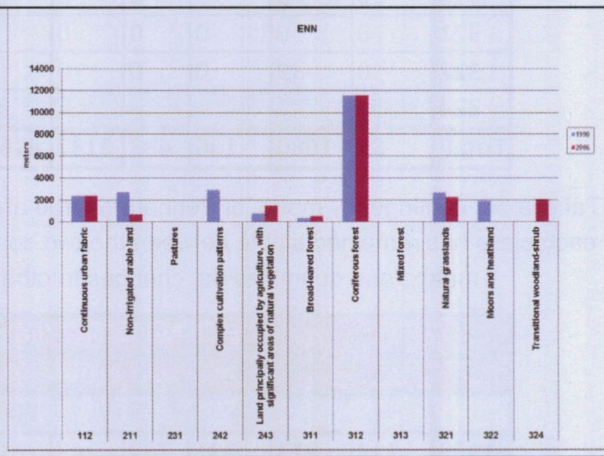
Landscape metrics analysis (Figure 150) showed as broad-leaved forests (class 311) have the highest number of patches (NP). Land principally occupied by agriculture (class 243) showed the loss of NP and the increase for class 211 (non-irrigated arable land) and broad-leaved forest (class 311).



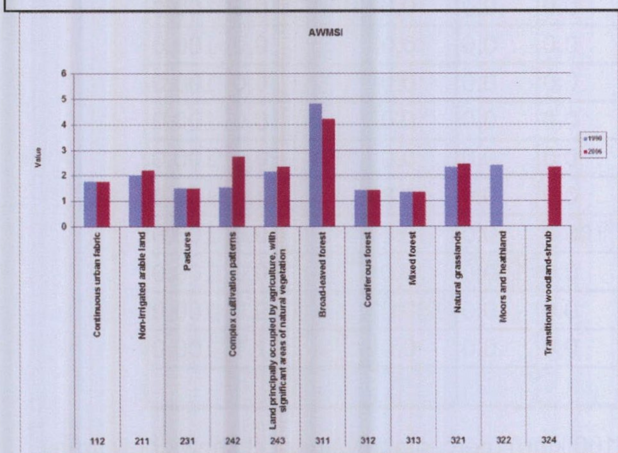


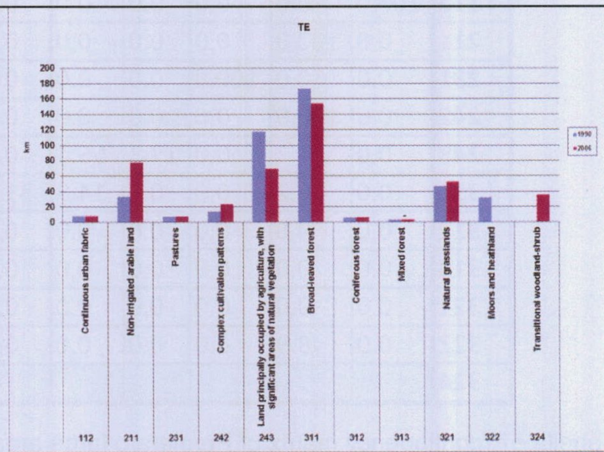
NP	MPS





MCA	ENN





AWMSI	TE

Figure 150: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Pennataro "large" area.

The opposite trends have been identified in MPS metric for class 243 and 311.

Broad leaved forests contain the highest forest mean core area (MCA).

The Euclidean Nearest-Neighbor distance (ENN) metric showed as the more isolated forest patches are coniferous forest (class 312), while class 211 showed a decrease of mean ENN distances.

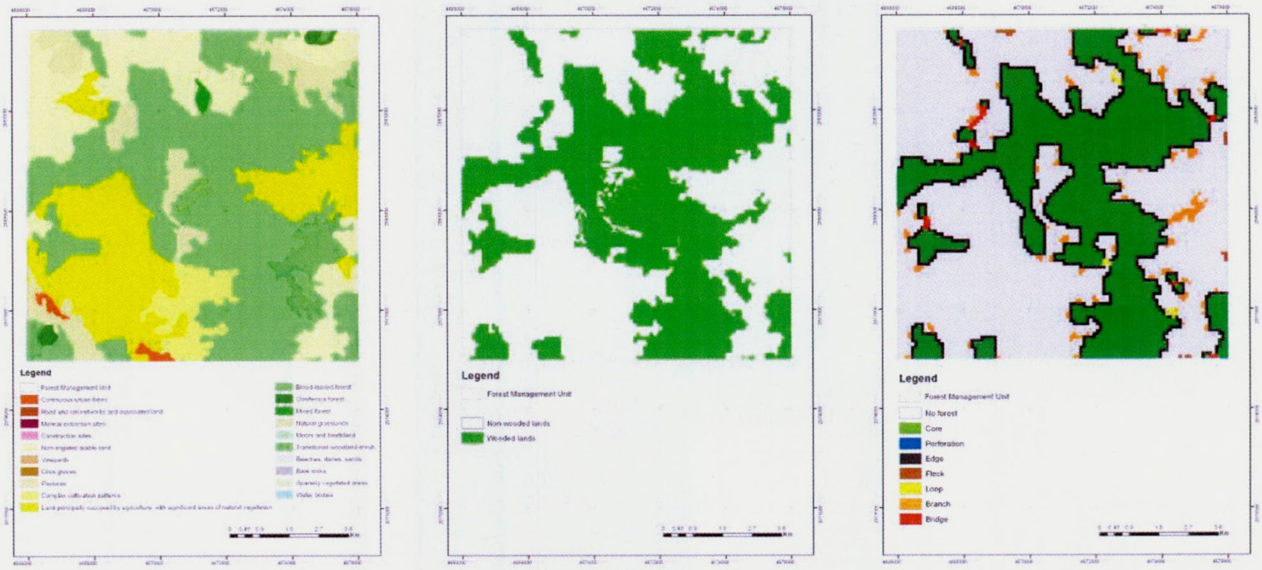
Broad-leaved forests have the more complex shape (AWMSI), but the metric values comparison between the two years showed a decrease in year 2006, as soon as in total edge (TE).

The class 243 showed the increasing of TE between considered periods.

- **Forest spatial pattern classification results: "large" area**

Figure 151 shows the input and output of GUIDOS forest spatial pattern classification for Pennataro "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006)	Forest/non forest map input	GUIDOS spatial pattern classification

Figure 151: Inputs and outputs maps of GUIDOS classification for Pennataro forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

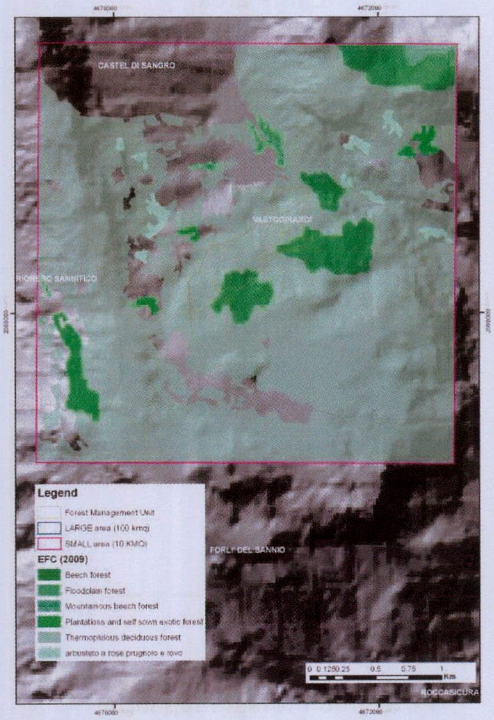
In Table 58, area (in hectares) of each forest spatial pattern class has been reported.

Pennataro (large area 100 kmq)			
Code	**Description**		**AREA (ha)**
1	Branch		222
3	Edge		1093
5	Perforation		100
9	Islet		24
17	Core		3668
33	Bridge		27
35	Bridge in Edge		27
65	Loop		7
67	Loop in Edge		5

Table 58: Area (hectares) of GUIDOS forest spatial pattern classes for Pennataro forest/non forest "large" area.

- **Evaluation of the landscape context: "small" area**

Figure 152 show forest cover data of Pennataro "small" area.



European Forest Categories (2009)

Figure 152: European Forest Categories map (2009) for Pennataro "small" area.

According to map of forest types (year 2009), forest covers about 801 hectares of the considered "small" landscape of Pennataro site (Table 59 and Figure 153). The main EFT is class 81 (downy oak forest) which covers 705 hectares of the small area. The second main representative EFT is class 63 (subatlantic submountainous beech forest) which covers 59 hectares.

PENNATARO (small area 10 kmq)				
EFC Code	Class description	EFT Code	Class description	Class Area (CA) (hectares)
6	Beech forest	63	Subatlantic submountainous beech forest	59.24
			sub total	**59.24**
7	Mountainous beech forest	73	Apennine Corsican mountainous beech forest	3.64
			sub total	**3.64**
8	Thermophilous deciduous forest	81	Downy oak forest	705.94
			sub total	**705.94**
12	Floodplain forest	121	Riparian forest	6.17
			sub total	**6.17**
14	Plantations and self sown exotic forest	141	Plantations of site-native species	15.98
			sub total	**15.98**
NA*	"Shrubs formation"	NA*		10.95
			sub total	**10.95**
			TOTAL	**801.91**
(*) NA: not applicable.				

Table 59: Pennataro "small" area. Area (hectares) for EFC and EFT classes. Forest type date: 2009. NA: not applicable, means the impossibility to reclassification for that level.

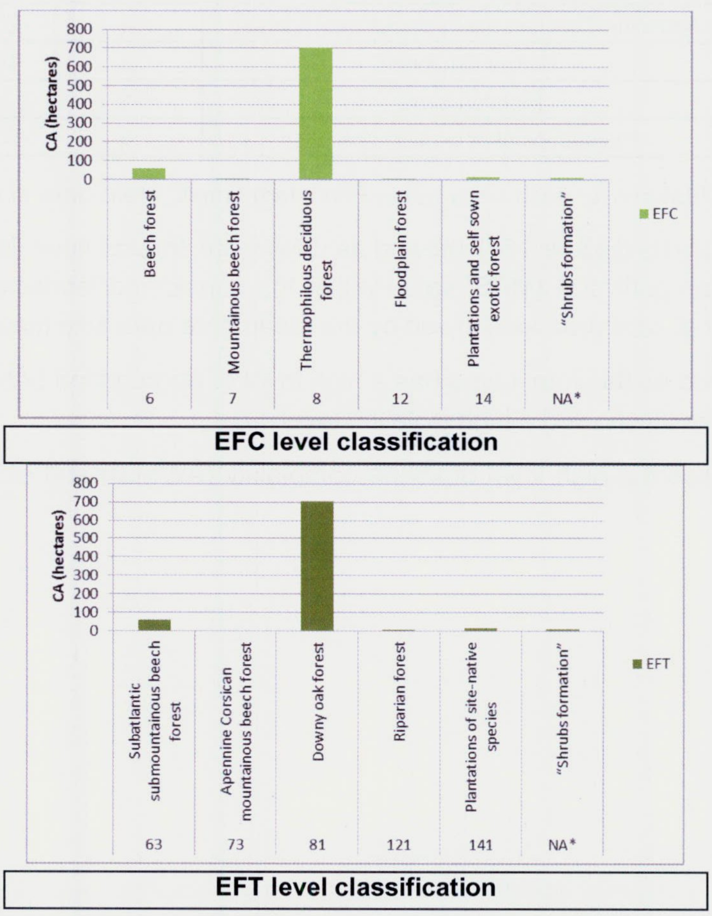


Figure 153: Pennataro "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

These two forest types grow at mean altitudes of 1000 m.a.s.l. (Table 60) on gently undulating slopes (10-20 %) (Table 61).

PENNATARO (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	EFT	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
NA*	"Shrubs formation"	268	825	1063	238	959.09	975	842	971
63	Subatlantic submountainous beech forest	1479	874	1203	329	1044.54	1025	874	1039
73	Apennine Corsican mountainous beech forest	88	1079	1150	71	1107.25	1100	1081	1105
81	Downy oak forest	17665	821	1206	385	1027.99	1075	821	1050
121	Riparian forest	153	899	975	76	908.935	900	905	900
141	Plantations of site-native species	402	950	1081	131	1021.72	1025	963	1021

Table 60: Topographic features for each class within Pennataro "small" area: altidudes (m.a.s.l).

PENNATARO (small area 10 kmq)			
Code	EFT	Class of majority presence	Slope values
NA*	"Shrubs formation"	3	10 - 20 %
63	Subatlantic submountainous beech forest	3	10 - 20 %
73	Apennine Corsican mountainous beech forest	4	20 - 30 %
81	Downy oak forest	3	10 - 20 %
121	Riparian forest	1	< 3%
141	Plantations of site-native species	5	30 - 50 %

Table 61: Topographic features for each class within Pennataro "small" area: class of slopes (percentage).

Landscape metrics analysis (Figure 154) showed as downy oak forests have the highest number of patches (NP) and mean path size (MPS) value within the considered landscape. This forest type contains also the most of core area as showed by the mean core area size metric (MCA).

The ENN metric showed as this forest type has a high level of aggregation between patches, while submountain beech forests showed a high isolation level.

Downy oak forests present a high level of shape complexity (AWMSI) and of length of total edge (TE).

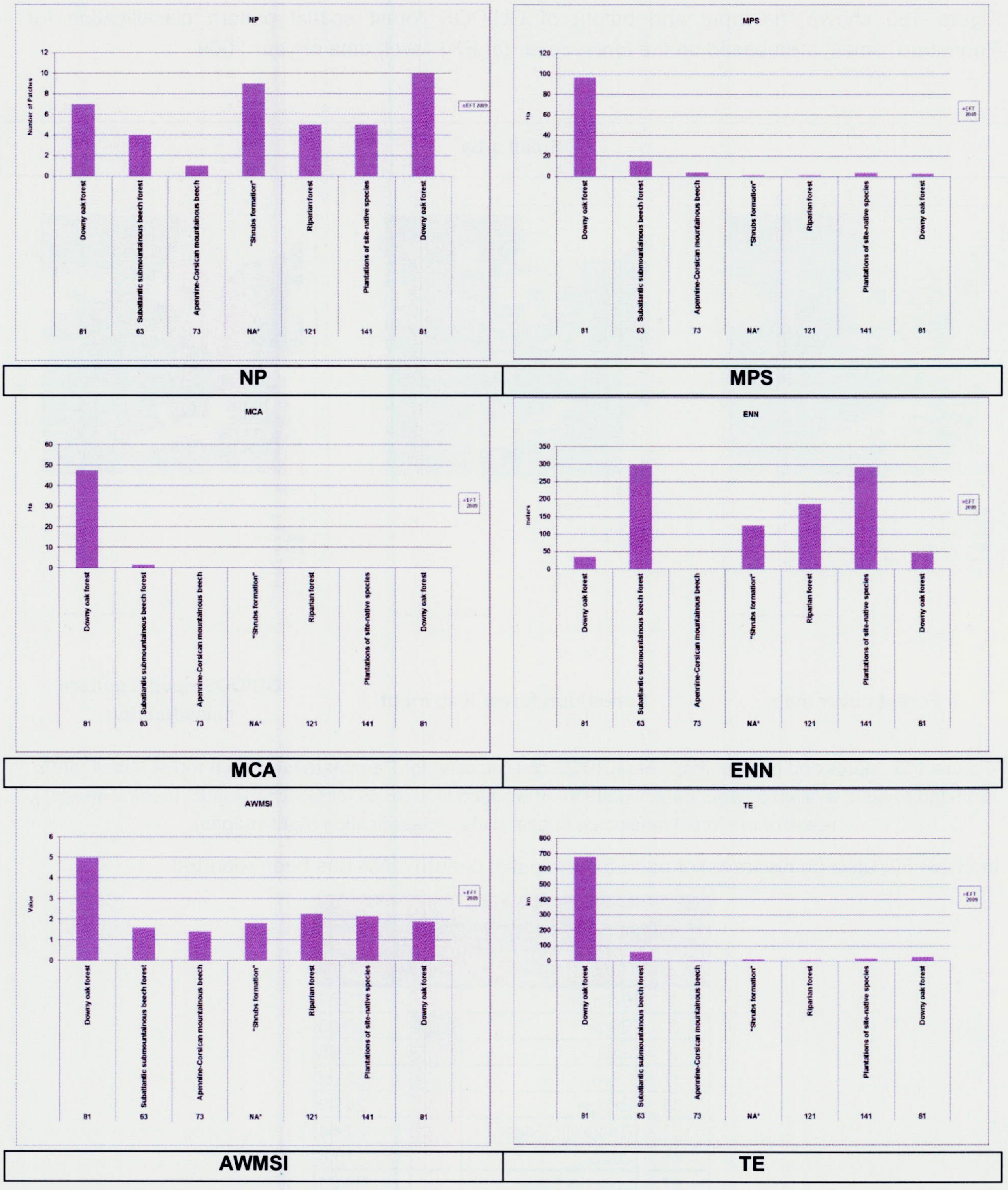
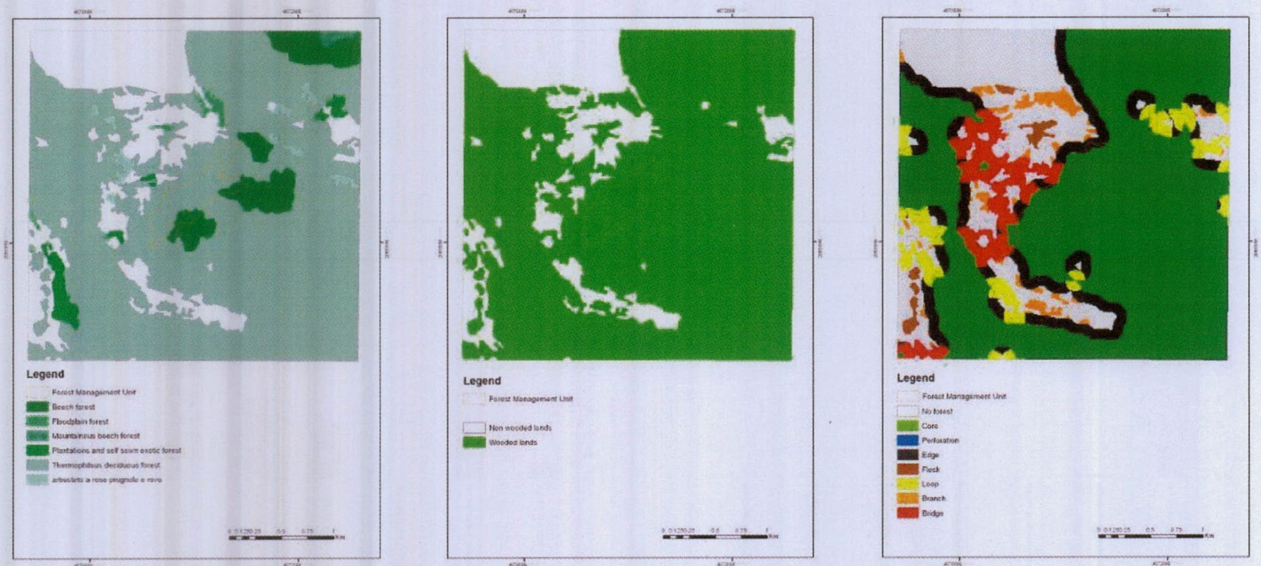


Figure 154: Results of landscape ecology metrics for forest cover (year 2009) within "small" area of Pennataro site.

- Forest spatial pattern classification results: “small” area

Figure 155 shows the input and output of GUIDOS forest spatial pattern classification for Pennataro “small” area based on the forest cover (at EFT level) data of year 2009.

Small area



Forest cover map | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 155: Inputs and outputs maps of GUIDOS classification for Pennataro forest/non forest “small” area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 62, area (in hectares) of each forest spatial pattern class has been reported.

Pennataro (small area 10 kmq)			
Code	***Description***		***AREA (ha)***
1	Branch		23.67
3	Edge		109.03
9	Islet		9.68
17	Core		552.85
33	Bridge		24.49
35	Bridge in Edge		32.61
65	Loop		13.6
67	Loop in Edge		36.21

Table 62: Area (hectares) of GUIDOS forest spatial pattern classes for Pennataro forest/non forest “small” area

- **Maps of landscape metrics**

Patch area (ha) (*per patch*) (AREA)

Large area	Small area

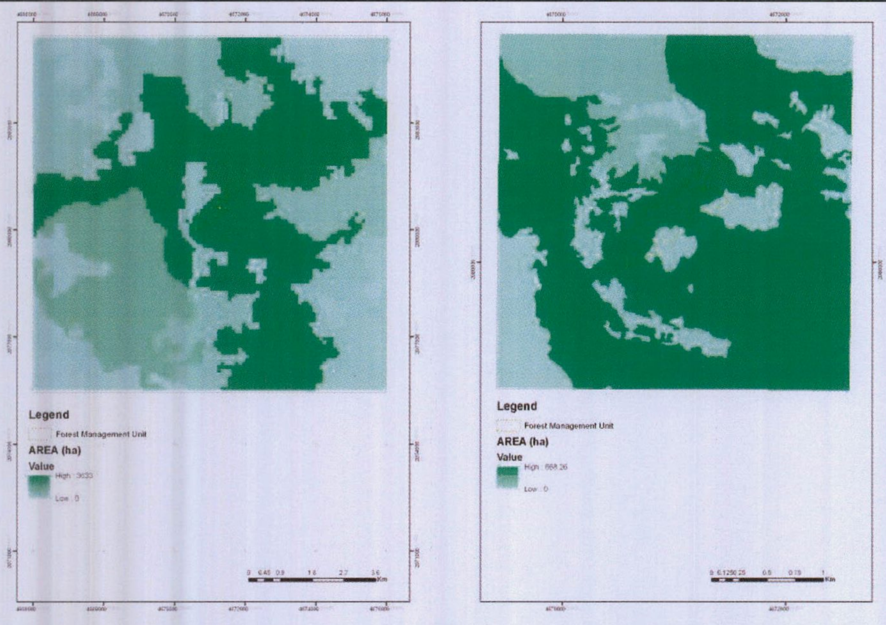


Figure 156: Patch area metrics resulting maps for “Pennataro forest” site.

Class area (ha) (per class) (CA)

Large area	Small area

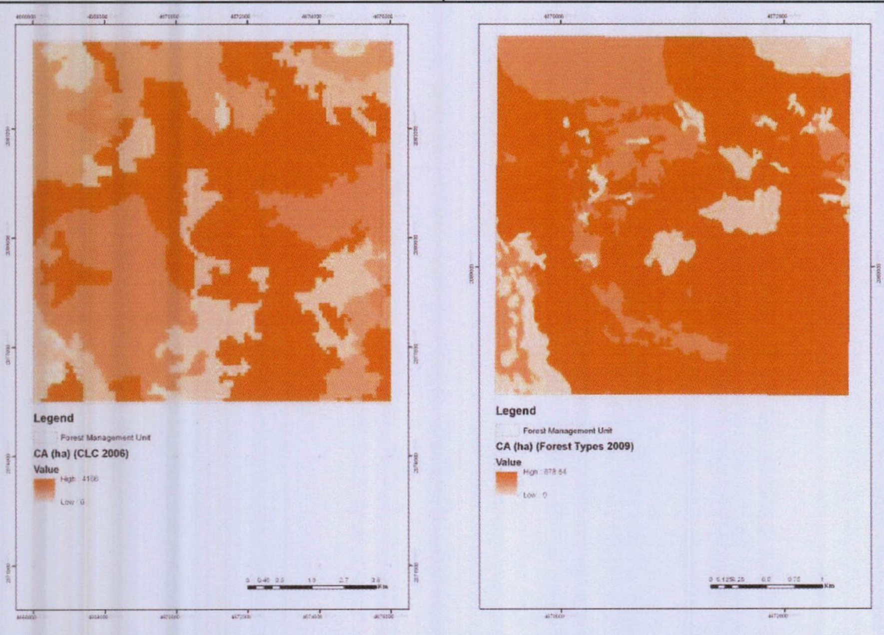
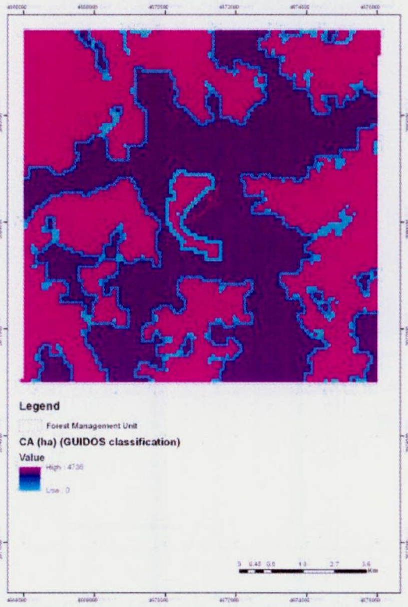


Figure 157: Class area metrics resulting maps for “Pennataro forest” site.

Class area (ha) (*per class*) (CA)

Large area	Small area



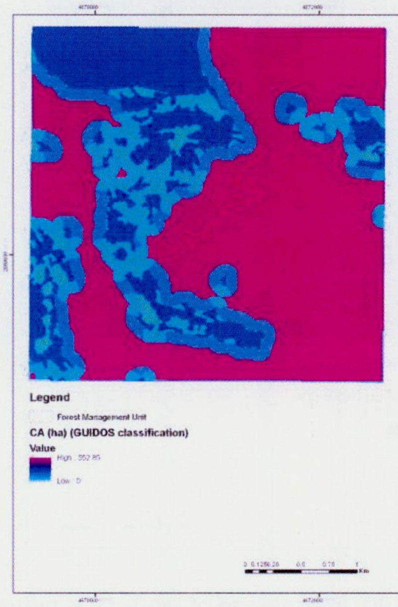
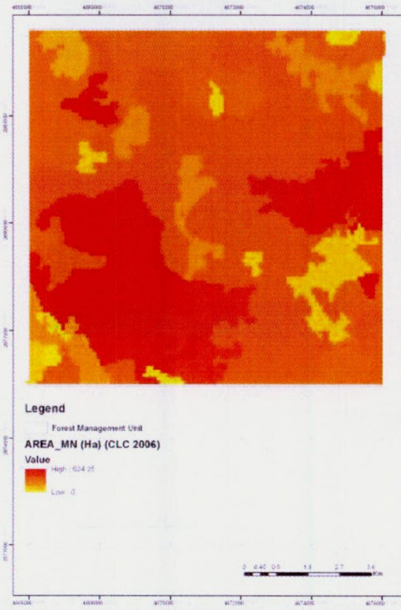


Figure 158: Class area size metrics resulting maps for “Pennataro forest” site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area



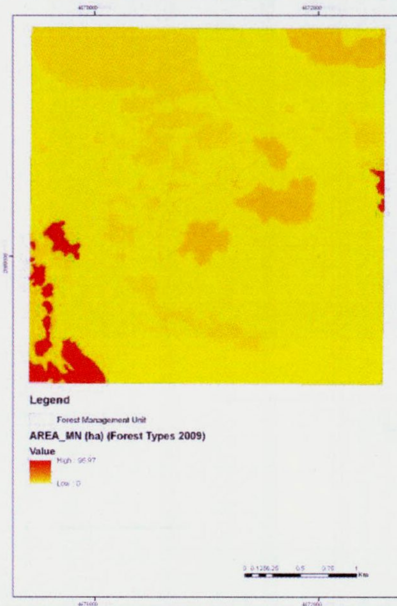


Figure159: Mean patch size metrics resulting maps for “Pennataro forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

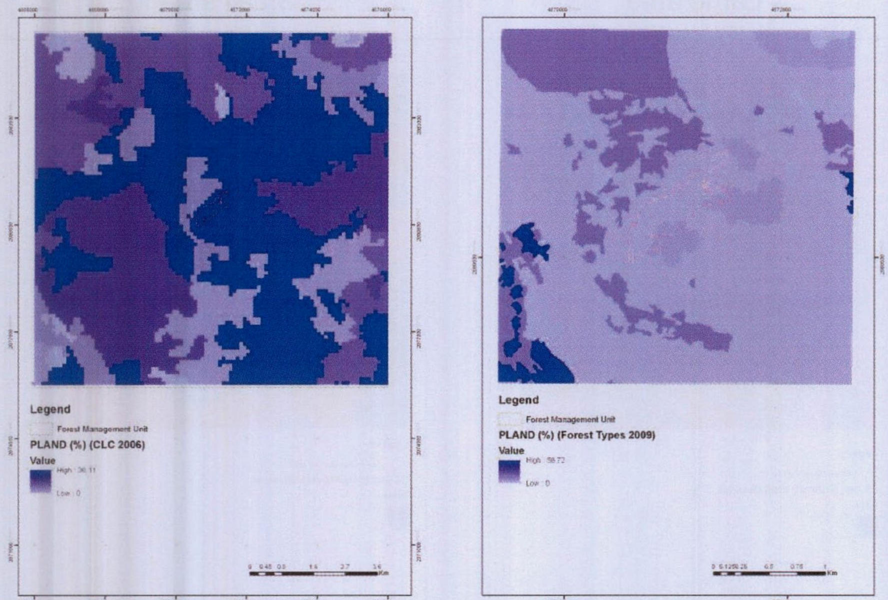


Figure 160: Percentage of landscape metrics resulting maps for “Pennataro forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

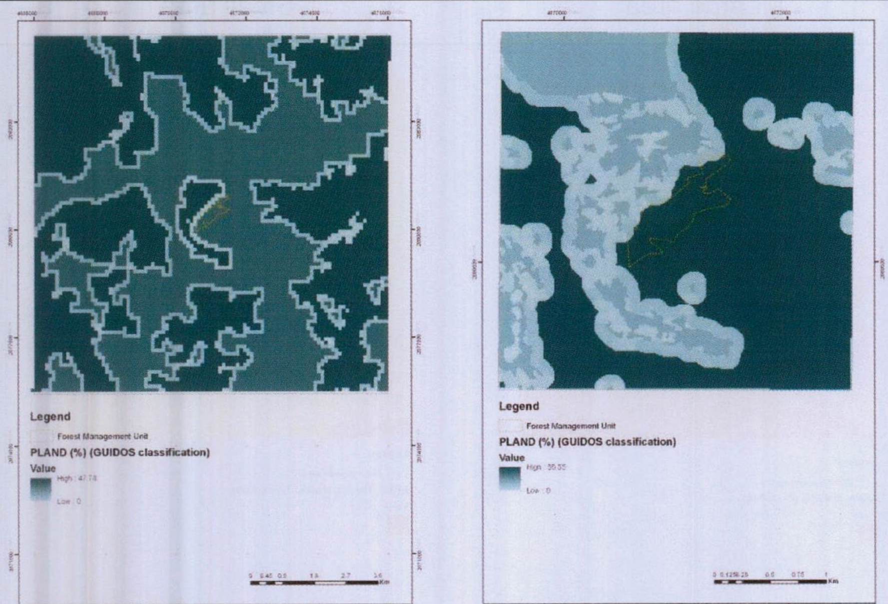


Figure 161: Percentage of landscape metrics resulting maps for “Pennataro forest” site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

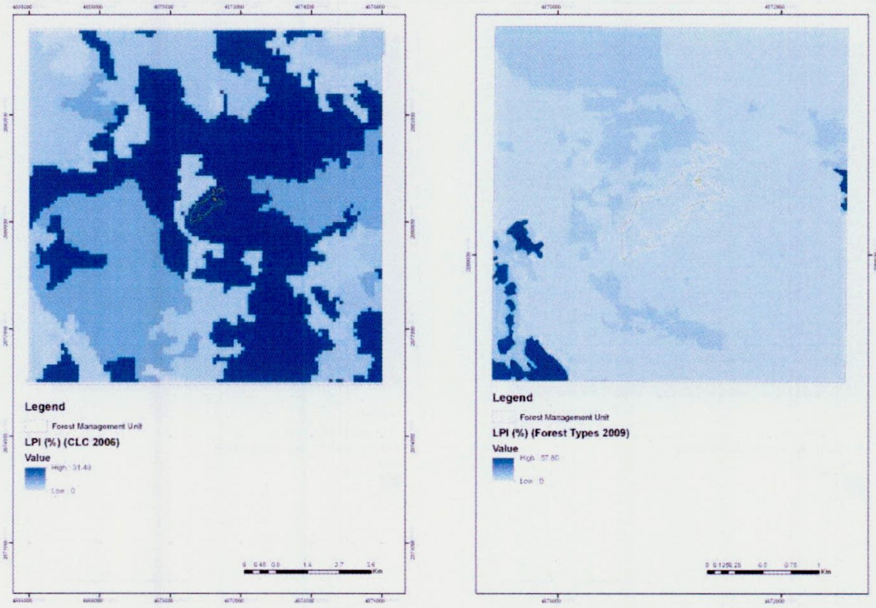


Figure 162: Largest patch index metrics resulting maps for "Pennataro forest" site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

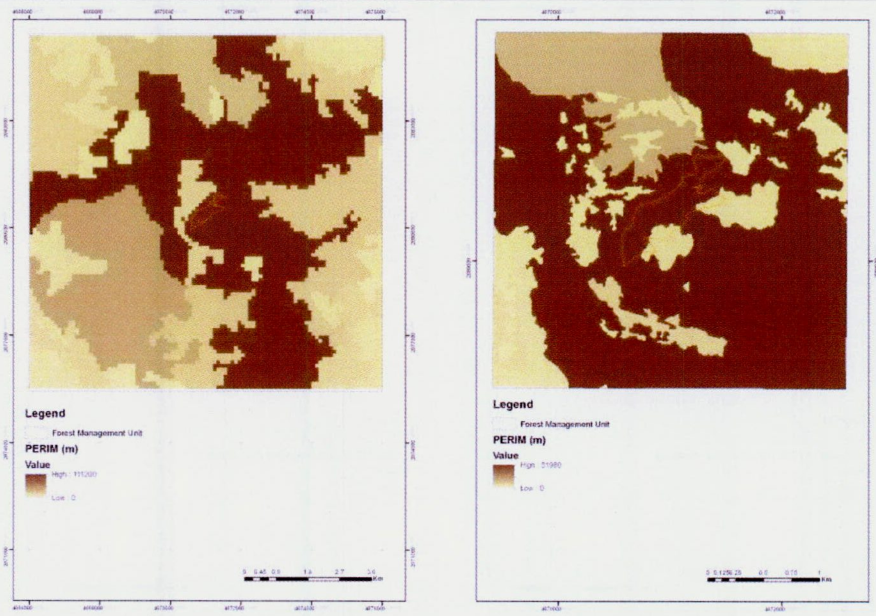


Figure 163: Edge metrics resulting maps for "Pennataro forest" site.

Total core area (ha) (per class) (TCA)

Large area	Small area

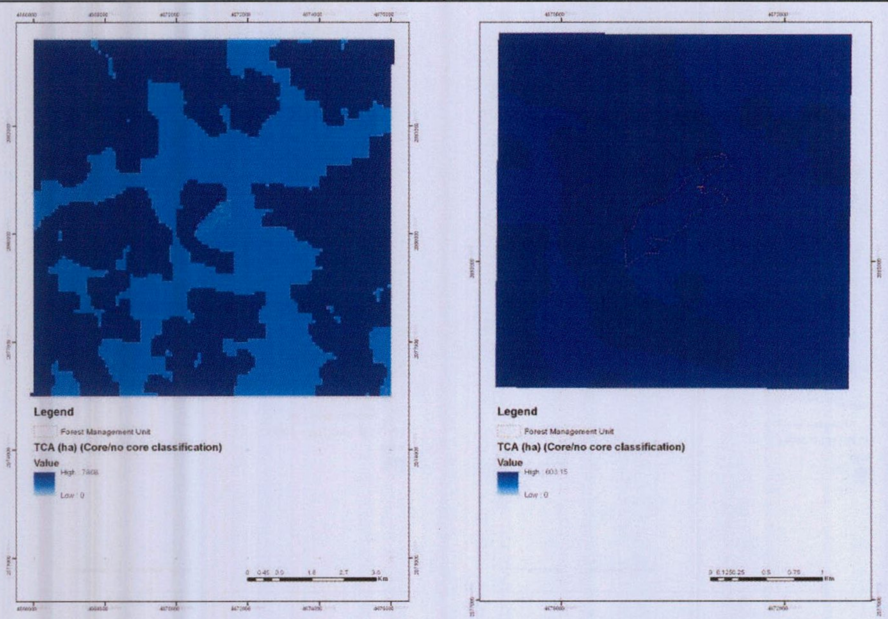


Figure 164: Total core area metrics resulting maps for “Pennataro forest” site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

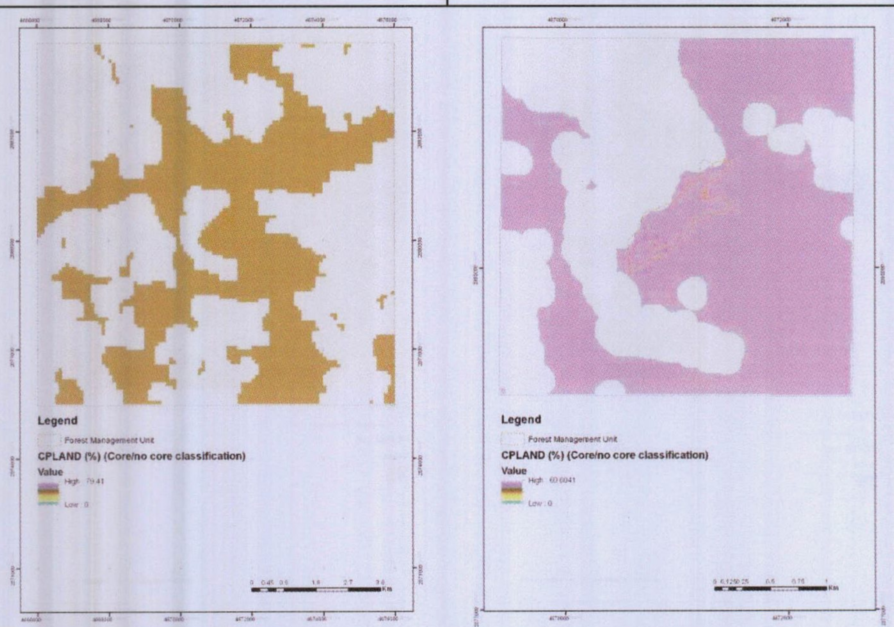


Figure 165: Core Area Percentage of Landscape metrics resulting maps for “Pennataro forest” site.

Number of patches (per patch) (NP)

Large area	Small area

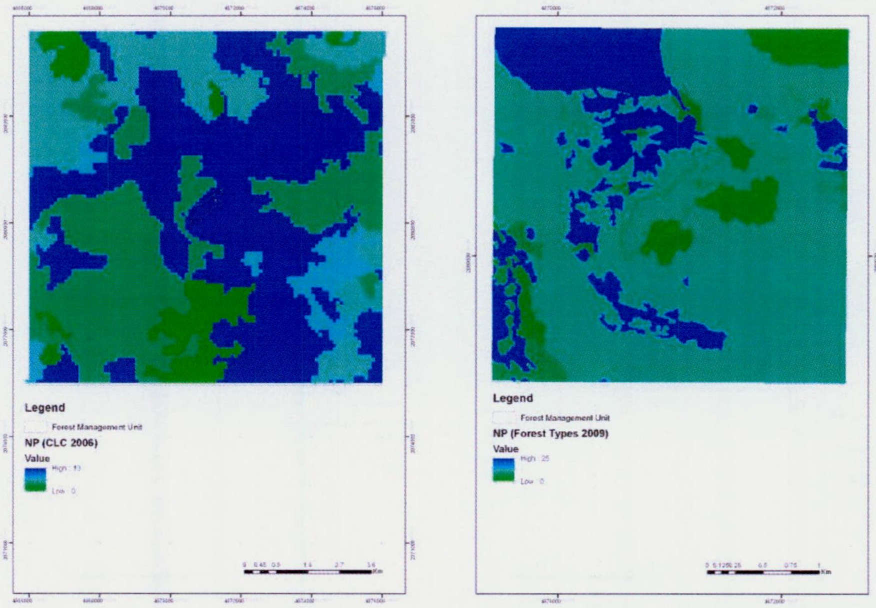


Figure 166: Number of patches in the landscape resulting maps for "Pennataro forest" site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

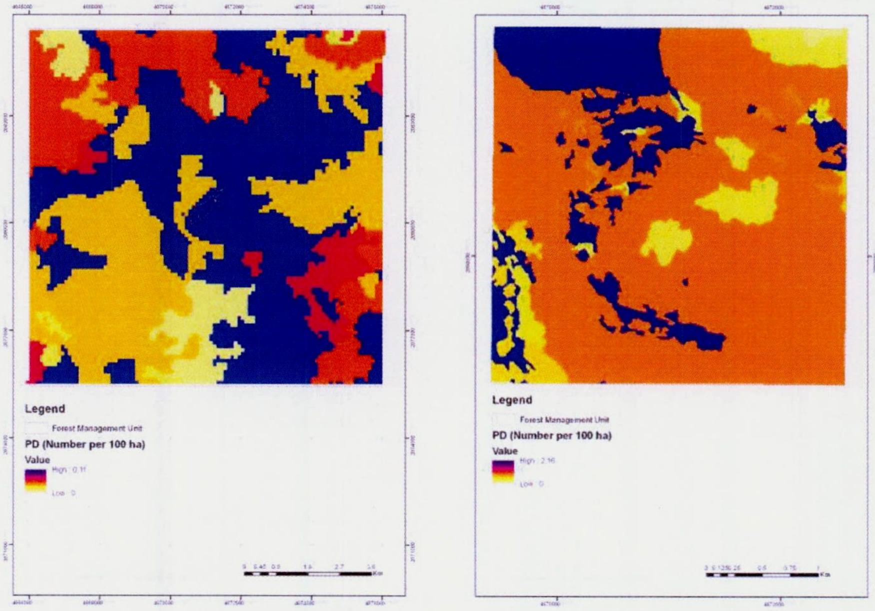


Figure 167: Patch density metrics resulting maps for "Pennataro forest" site.

Shape (per patch) (SHAPE)

Large area	Small area

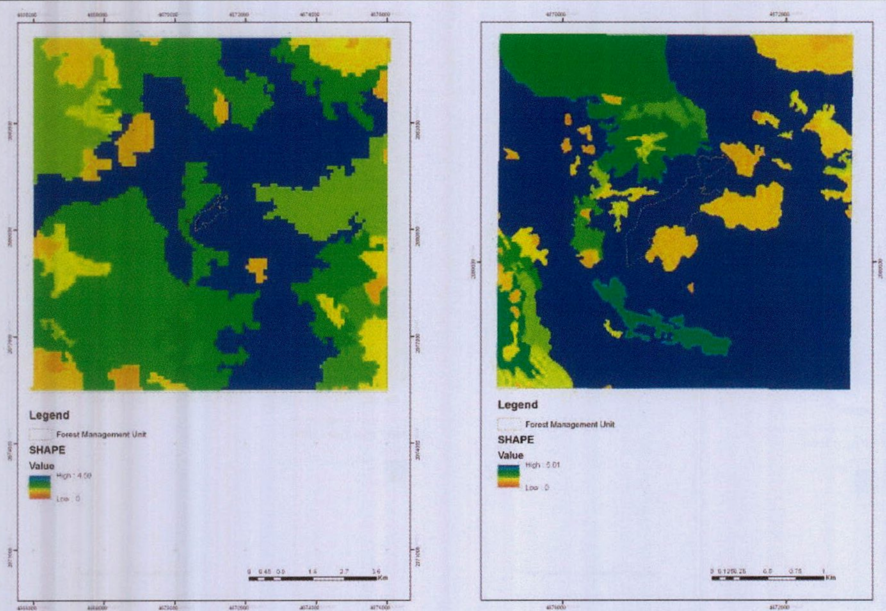


Figure 168: Shape metrics resulting maps for “Pennataro forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

Figure 169: Fractal dimension metrics resulting maps for “Pennataro forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

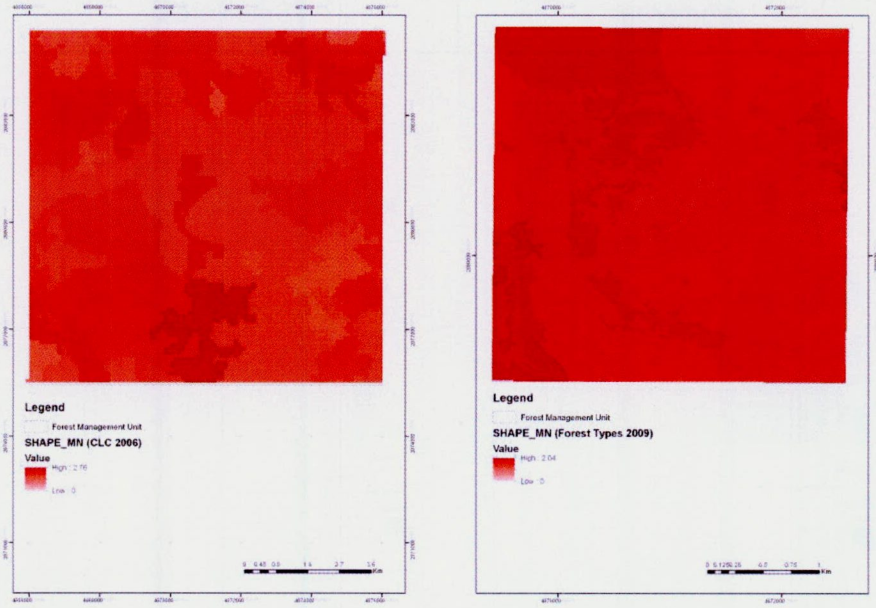


Figure 170: Mean shape indexes resulting maps for "Pennataro forest" site.

Mean fractal index (per class) (FRAC_MN)

Large area	Small area

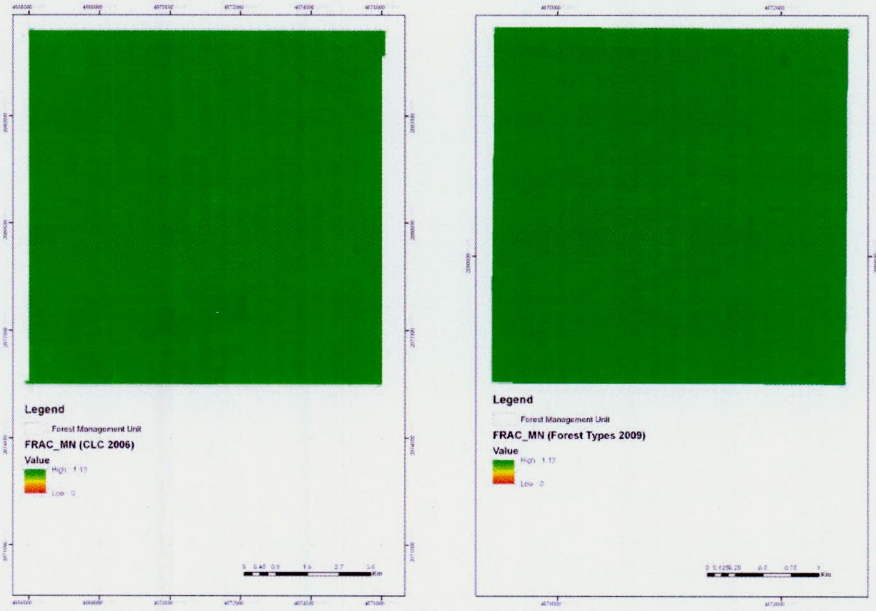


Figure 171: Mean fractal dimensions resulting maps for "Pennataro forest" site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

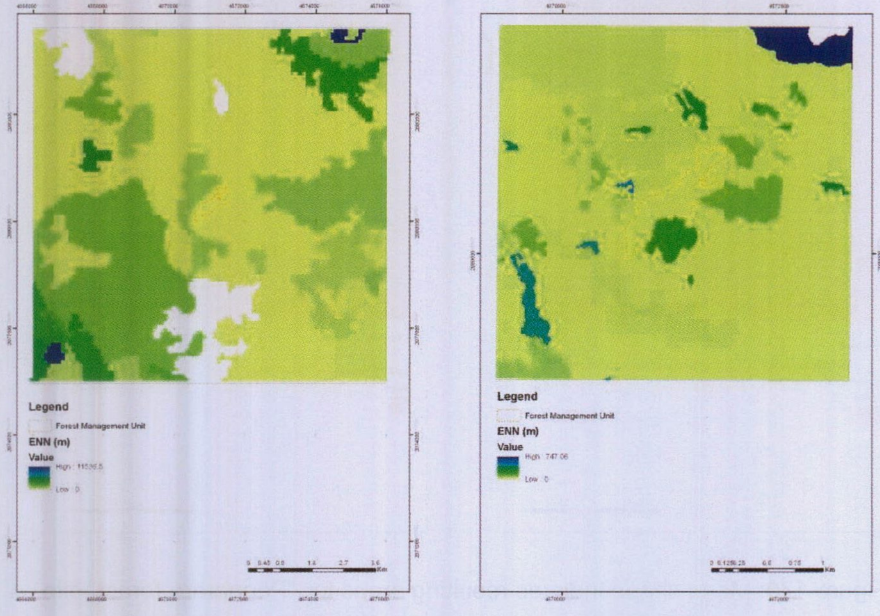


Figure 172: Euclidean nearest neighbor distances maps for “Pennataro forest” site.

2.2.7. Mongiana – Site 4

- **Evaluation of the landscape context and land uses changes: “large” area**

Figure 174 shows CLC data at the three dates (1990, 2000 and 2006) for “large” area.

The landscape of Mongiana “large” area is dominated by broad-leaved forest (class 311) (60.7 %; 6027 hectares at the year 2006) (Table 63 and Figure 173). Mixed forest (class 313) is the second more diffuse land use class (16.15 %; 1601 hectares).

Coniferous forest covers 2.5 % of total area.

Artificial land uses (class 1 of first CLC level) represent only the 0.8 % of total area.

MONGIANA (large area 100 kmq)											
CLC Code	Class	Class Area (CA) (hectares)			Class Area (CA) (%)			Variations (hectares)			Change rate (%)
		1990	2000	2006	1990	2000	2006	(1990÷2000)	(2000÷2006)	(1990÷2006)	(2006÷1990)/ 1990 (%)
112	Continuous urban fabric	45	45	45	0.45	0.45	0.45	0	0	0	0.00
121	Industrial or commercial units		37	37	0.00	0.37	0.37	37	0	37	
133	Construction sites	81	40		0.82	0.40	0.00	-41	-40	-81	-100.00
211	Non-irrigated arable land	1247	1195	1193	12.58	12.05	12.03	-52	-2	-54	-4.33
223	Olive groves	92	30	30	0.93	0.30	0.30	-62	0	-62	-67.39
241	Annual crops associated with permanent crops	89	214	216	0.90	2.16	2.18	125	2	127	142.70
242	Complex cultivation patterns		43	43	0.00	0.43	0.43	43	0	43	
243	Land principally occupied by agriculture, with significant areas of natural vegetation	215	257	251	2.17	2.59	2.53	42	-6	36	16.74
311	Broad-leaved forest	6288	6041	6027	63.41	60.92	60.78	-247	-14	-261	-4.15
312	Coniferous forest	288	253	253	2.90	2.55	2.55	-35	0	-35	-12.15
313	Mixed forest	1545	1601	1601	15.58	16.15	16.15	56	0	56	3.62
322	Moors and heathland	26			0.26	0.00	0.00	-26	0	-26	-100.00
323	Sclerophyllous vegetation		26	26	0.00	0.26	0.26	26	0	26	
324	Transitional woodland-shrub		134	155	0.00	1.35	1.56	134	21	155	
512	Water bodies			39	0.00	0.00	0.39	0	39	39	
	Total	9916	9916	9916	100	100	100				

Table 63: Area values per class and per year and relative changes between dates for Mongiana “large” area. Area of each CLC class is reported in hectares and relative percentage values. In table have been also reported changes in land use classes between dates as variations from 1990 to 2000, from 2000 to 2006 and from 1990 to 2006. Has been also calculated and reported the change rate per class for the time1990-2006.

Broad-leaved forest grows at mean altitudes of about 950 m.a.s.l. (Table 64), on moderate slopes (10-20 %) (Table 65). Mixed forests (class 311) grow on the same slopes of broad-leaved forests at mean altitudes higher (over 1000 m.a.s.l.).

Land use for this area showed several changes (Table 63). Two classes in particular showed a negative change rate of 100 %: class 133 (construction sites) among the artificial classes and class 322 (moors and heathland) among natural and semi-natural classes. Another relevant but positive change there was for annual crops associated with permanent crops (class 241) which showed a change rate of 141 % in 2006 respect to the year 1990.

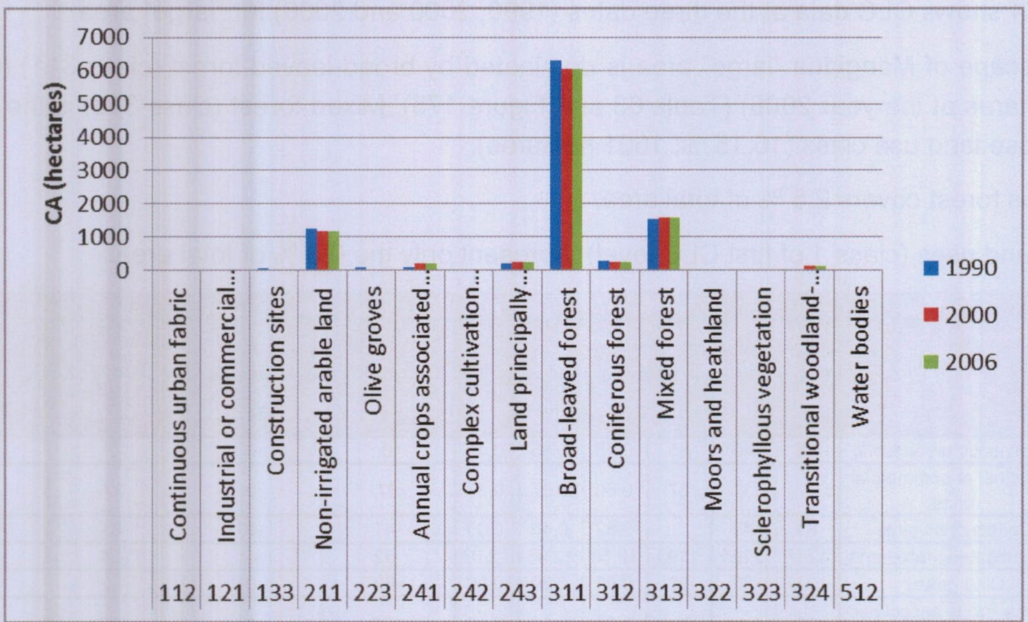


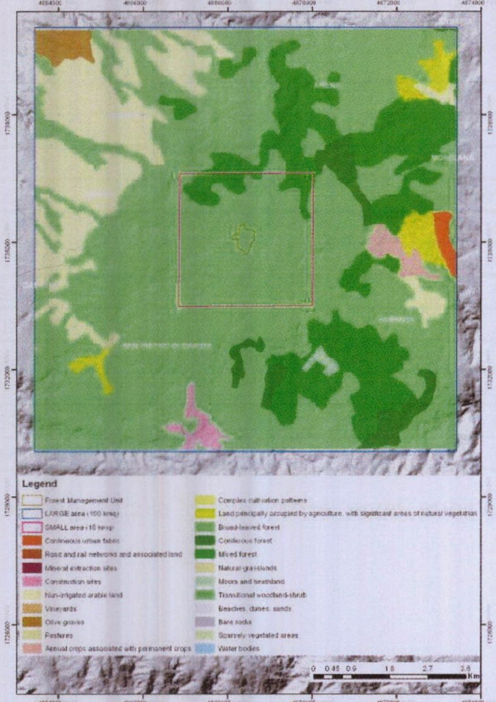
Figure 173: Mongiana "large" (100 kmq) area. Graph of Class Area (CA) metric for each CLC class per year.

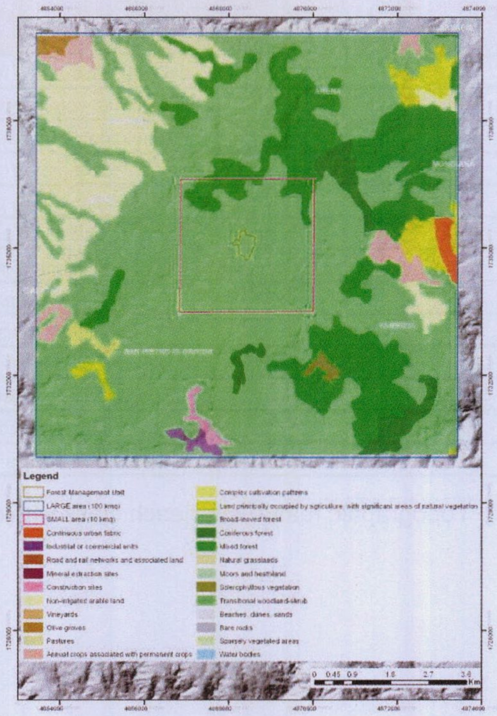
MONGIANA (large area 100 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
112	Continuous urban fabric	1223	929	983	54	958.52	950	974	955
121	Industrial or commercial units	908	823	952	129	878.80	824	828	885
211	Non-irrigated arable land	29562	535	989	454	762.32	800	535	755
223	Olive groves	798	369	587	218	503.21	475	369	504
241	Annual crops associated with permanent crops	5401	475	1061	586	834.95	975	482	941
242	Complex cultivation patterns	1038	762	862	100	796.47	800	762	795
243	Land principally occupied by agriculture, with significant areas of natural vegetation	6404	743	1052	309	938.46	924	743	953
311	Broad-leaved forest	150606	484	1276	792	963.38	1050	484	985
312	Coniferous forest	6276	910	1162	252	1054.48	1125	910	1041
313	Mixed forest	40136	674	1187	513	1012.80	1025	694	1025
323	Sclerophyllous vegetation	656	950	1104	154	1055.22	1075	957	1064
324	Transitional woodland-shrub	3808	810	1012	202	931.84	925	810	927
512	Water bodies	939	845	908	63	852.66	849	870	849

Table64: Topographic features for each class within Mongiana "large" area: altidudes (m.a.s.l).

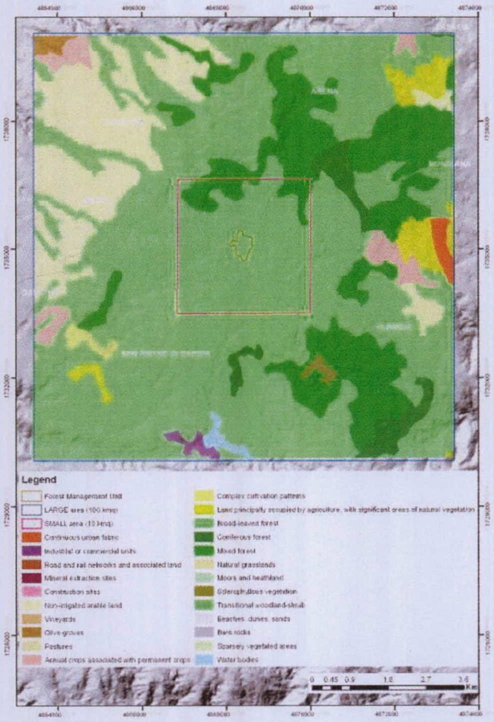
MONGIANA (large area 100 kmq)			
Code	**Class**	**Class of majority presence**	**Slope values**
112	Continuous urban fabric	2	3 - 10 %
121	Industrial or commercial units	5	30 - 50 %
211	Non-irrigated arable land	2	3 - 10 %
223	Olive groves	5	30 - 50 %
241	Annual crops associated with permanent crops	3	10 - 20 %
242	Complex cultivation patterns	3	10 - 20 %
243	Land principally occupied by agriculture, with significant areas of natural vegetation	2	3 - 10 %
311	Broad-leaved forest	3	10 - 20 %
312	Coniferous forest	3	10 - 20 %
313	Mixed forest	3	10 - 20 %
323	Sclerophyllous vegetation	3	10 - 20 %
324	Transitional woodland-shrub	3	10 - 20 %
512	Water bodies	1	< 3%

Table 65: Topographic features for each class within Mongiana “large” area: class of slopes (percentage).





CLC 1990	CLC 2000



CLC 2006

Figure 174: CORINE Land Cover data of Mongiana “large” area.

The cross tabulation analysis between land use maps at the two dates (Table 66 and Table 67) showed as the total area of class 133 has been completely transformed in other land use classes: 36 hectares have been converted in industrial or commercial units (class 121); 13 hectares have been occupied by water bodies (class 512) and 27 hectares have become transitional woodland-shrub (class 324).

Transitions between forest land use classes should be considered carefully since could be false changes.

MONGIANA (large area 100 kmq)																
Cross tabulation (hectares)																
	2006															
1990	112	121	133	211	223	241	242	243	311	312	313	322	323	324	512	Total
112	45	0		0	0	0	0	0	0	0	0		0	0	0	45
121																
133	0	36		0	0	0	0	0	5	0	0		0	27	13	81
211	0	0		1174	0	31	42	0	0	0	0		0	0	0	1247
223	0	0		0	30	62	0	0	0	0	0		0	0	0	92
241	0	0		0	0	89	0	0	0	0	0		0	0	0	89
242																0
243	0	0		4	0	0	1	201	9	0	0		0	0	0	215
311	0	1		15	0	34	0	50	6013	0	115		0	34	26	6288
312	0	0		0	0	0	0	0	0	253	0		0	35	0	288
313	0	0		0	0	0	0	0	0	0	1486		0	59	0	1545
322	0	0		0	0	0	0	0	0	0	0		26	0	0	26
323																
324																
512																
Total	45	37		1193	30	216	43	251	6027	253	1601		26	155	39	9916

Tabella 66: contingency matrix of Mongiana large area (100 kmq) (hectares values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

MONGIANA (large area 100 kmq)																
Cross tabulation (percentage)																
	2006															
1990	112	121	133	211	223	241	242	243	311	312	313	322	323	324	512	Total
112	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	100.0
121																
133	0.0	44.4	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0		0.0	33.3	16.0	100.0
211	0.0	0.0	0.0	94.1	0.0	2.5	3.4	0.0	0.0	0.0	0.0		0.0	0.0	0.0	100.0
223	0.0	0.0	0.0	0.0	32.6	67.4	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	100.0
241	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	100.0
242																
243	0.0	0.0	0.0	1.9	0.0	0.0	0.5	93.5	4.2	0.0	0.0		0.0	0.0	0.0	100.0
311	0.0	0.0	0.0	0.2	0.0	0.5	0.0	0.8	95.6	0.0	1.8		0.0	0.5	0.4	100.0
312	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.8	0.0		0.0	12.2	0.0	100.0
313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.2		0.0	3.8	0.0	100.0
322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		100.0	0.0	0.0	100.0
323																
324																
512																

Tabella 67: contingency matrix of Mongiana large area (100 kmq) (percentage values). It shows how many each class has remained stable between the two considered dates (frequency along the diagonal of the matrix) and quantifies the changes to other classes (frequency offset the diagonal).

Landscape metrics analysis (Figure 175) showed as non-irrigated arable lands (class 211) have the highest number of patches (NP) and its number decreased between years.

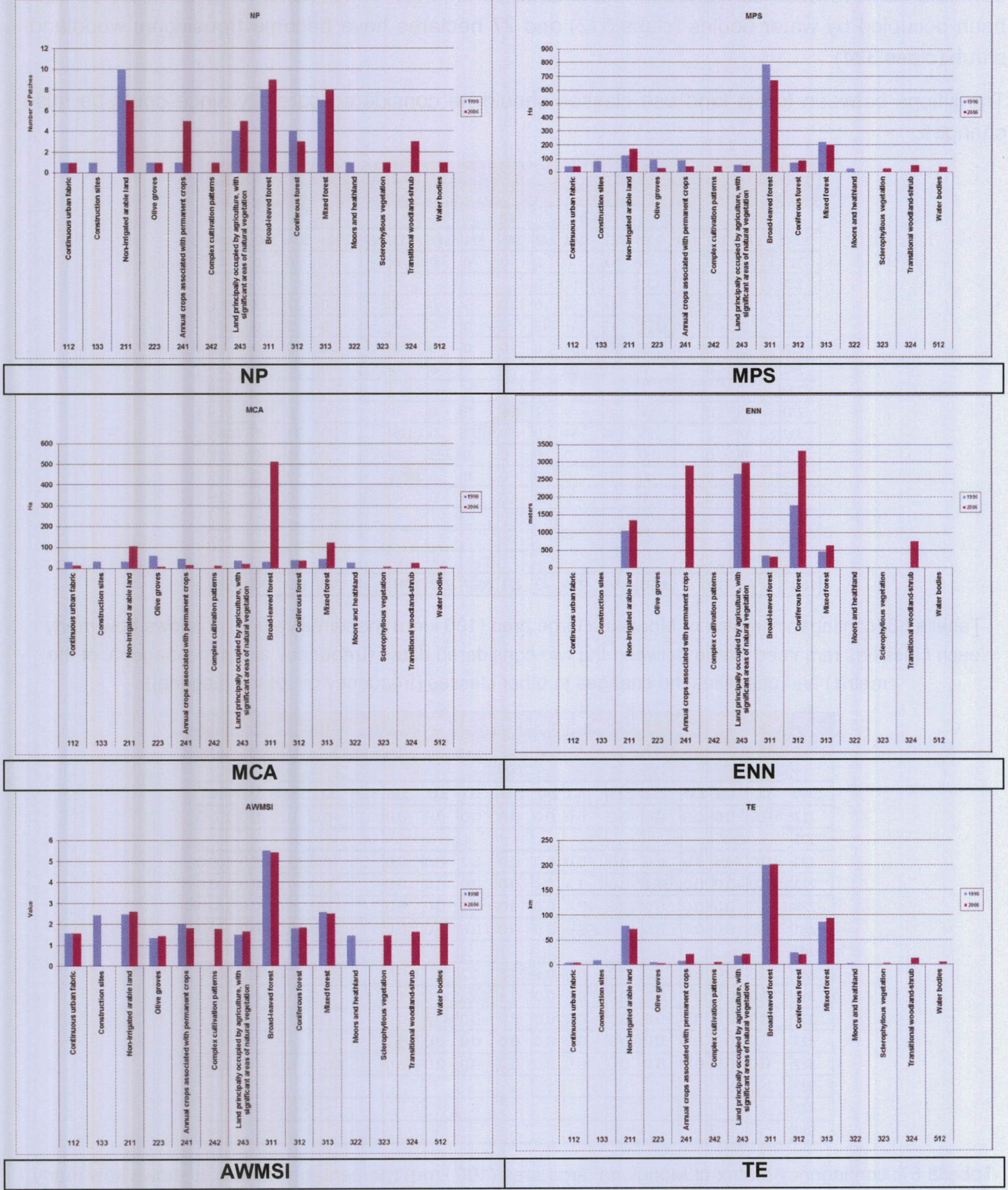


Figure 175: Results of landscape ecology metrics for changes (years 1990-2006) in land use classes for Mongiana "large" area.

Among forest land use classes, broad-leaved class showed the highest NP and the increase of number through the considered time. The opposite trend has been noted for mean path size (MPS) metric for these two land use classes.

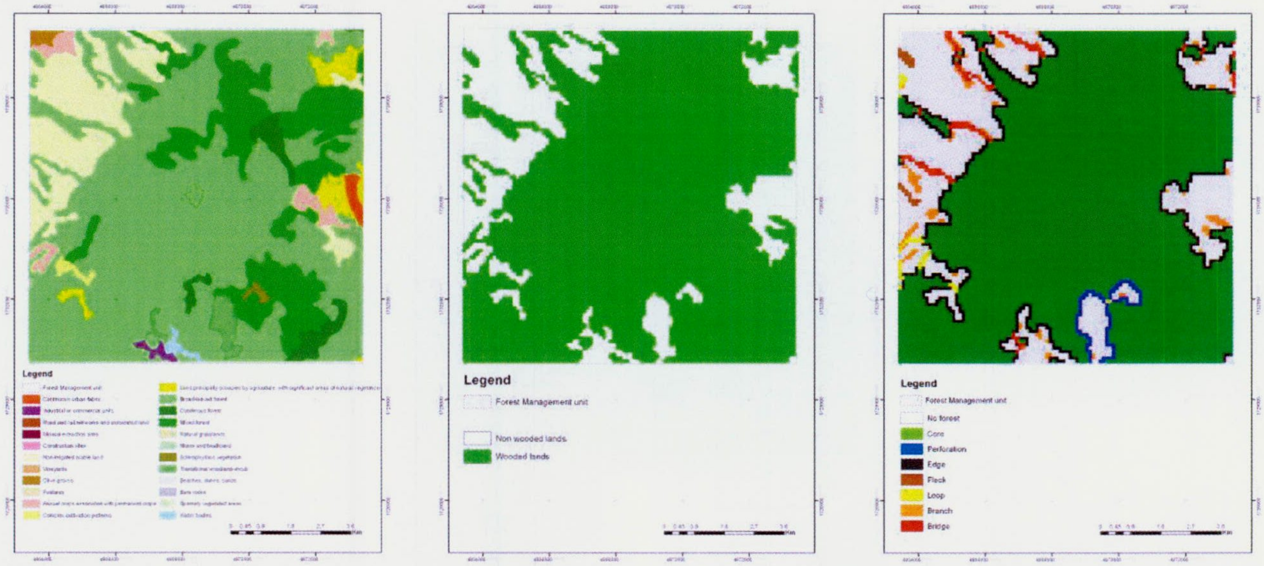
Broad-leaved forests contain the most of forest core area (MCA) and the ENN metric values showed as patches of these forests have low isolation level. More isolated forest are coniferous forest (class 312), and ENN metrics showed the increasing of the isolation through the time.

The higher level of shape complexity (AWMSI) has been identified in broad-leaved forests but this seems to decrease in year 2006. The same forest class showed the highest length of total edge (TE).

- **Forest spatial pattern classification results: "large" area**

Figure 176 shows the input and output of GUIDOS forest spatial pattern classification for Mongiana "large" area based on the CLC data of year 2006.

Large area



CLC map (year 2006) | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 176: Inputs and outputs maps of GUIDOS classification for Mongiana forest/non forest "large" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

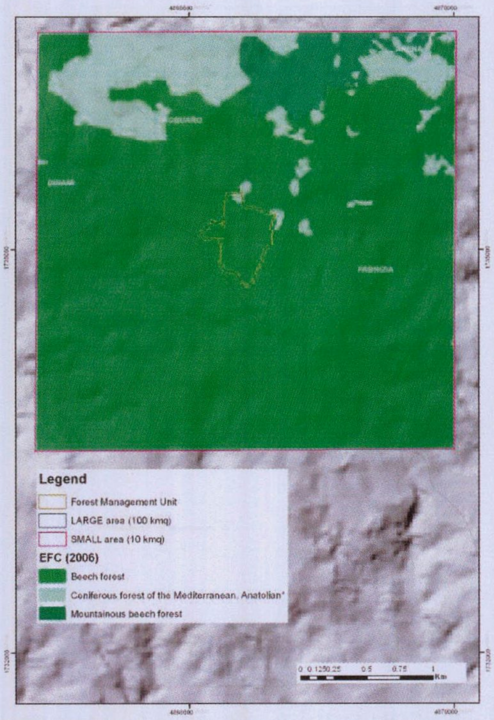
In Table 68, area (in hectares) of each forest spatial pattern class has been reported.

Mongiana (large area 100 kmq)			
Code	Description		AREA (ha)
1	Branch		139
3	Edge		608
5	Perforation		98
9	Islet		31
17	Core		6834
33	Bridge		94
35	Bridge in Edge		34
65	Loop		31
67	Loop in Edge		10
69	Loop in Perforation		2

Table 68: Area (hectares) of GUIDOS forest spatial pattern classes for Mongiana forest/non forest "large" area.

- Evaluation of the landscape context: "small" area

Figure 177 show forest cover data of Mongiana "small" area.



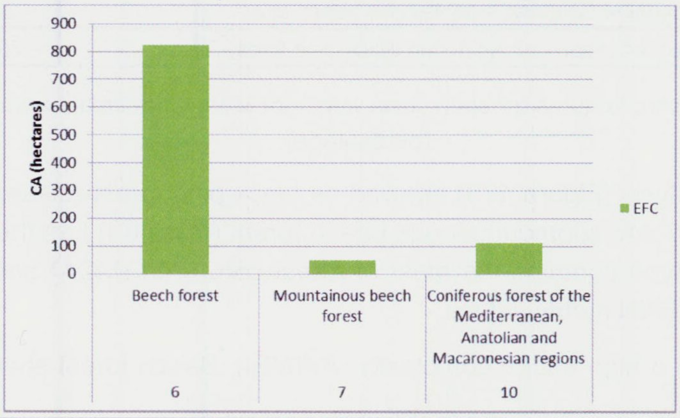
European Forest Categories (2006)

Figure 177: European Forest Categories map (2006) for Mongiana "small" area.

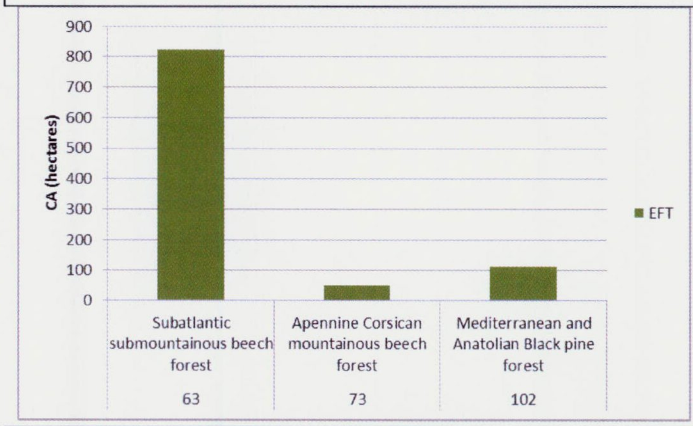
On the basis of map of forest cover at the year 2006, Mongiana "small" area forest covers 988 hectares (Table 69) and the "subatlantic submountainous beech forest" class 73) is the dominant EFT which covers 822 hectares. The second main EFT class is "Mediterranean and Anatolian Black pine forest" (class 102) (113 hectares).

MONGIANA (small area 10 kmq)				
EFC Code	**Class description**	**EFT Code**	**Class description**	**Class Area (CA) (hectares)**
6	Beech forest	63	Subatlantic submountainous beech forest	822.867
			sub total	**822.867**
7	Mountainous beech forest	73	Apennine Corsican mountainous beech forest	52.041
			sub total	**52.041**
10	Coniferous forest of the Mediterranean, Anatolian and Macaronesian regions	102	Mediterranean and Anatolian Black pine forest	113.36
			sub total	**113.36**
			TOTAL	**988.268**

Table 69: Mongiana "small" area. Area (hectares) for EFC and EFT classes. Forest Types date: 2006. NA: not applicable, means the impossibility to reclassification for that level.



EFC level classification



EFT level classification

Figure 178: Mongiana "small" (10 kmq) area. Graphs of Class Area (CA) metric for both EFC level classification and EFT level classification.

Subatlantic submountainous beech forest EFT grows on mean altitudes up to 1100 m.a.s.l. (Table 70) and on moderate slopes (10-20 %) (Table 71). Coniferous forest EFT develops at mean altitude slightly lower (1000 m.a.s.l.) and on very steep slope (> 50 %).

MONGIANA (small area 10 kmq)									
Altitudes (m.a. s.l)									
Code	Class	COUNT	MIN	MAX	RANGE	MEAN	MAJORITY	MINORITY	MEDIAN
63	Subatlantic submountainous beech forest	20603	900	1276	376	1141.57	1150	916	1150
73	Apennine Corsican mountainous beech forest	1299	1098	1179	81	1149.63	1150	1098	1153
102	Mediterranean and Anatolian Black pine forest	2857	894	1187	293	1073.51	1050	894	1070

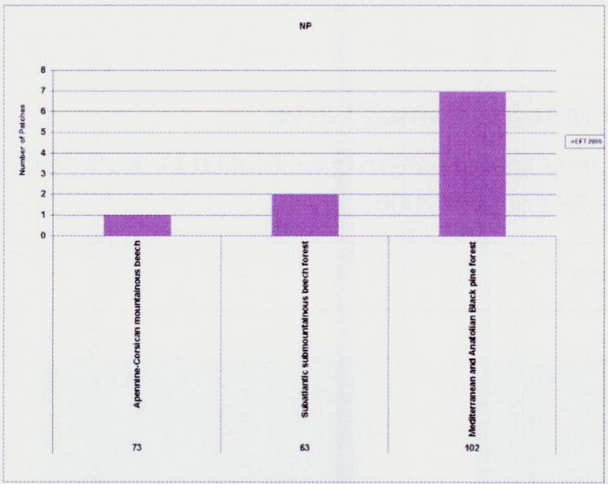
Table 70: Topographic features for each class within for Mongiana "small" area: altidudes (m.a.s.l).

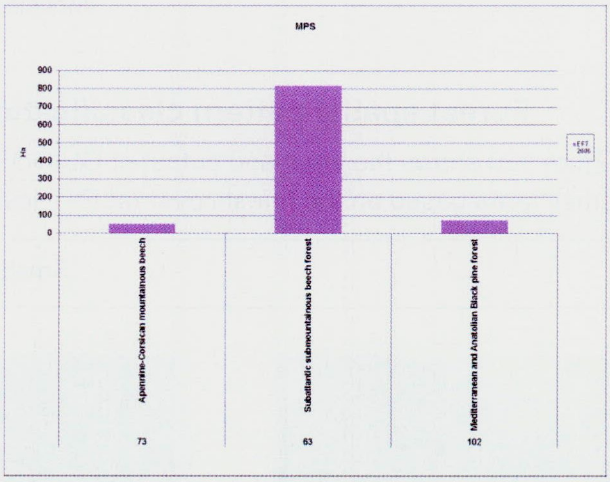
MONGIANA (small area 10 kmq)			
Code	EFT	Class of majority presence	Slope values
63	Subatlantic submountainous beech forest	3	10 - 20 %
73	Apennine Corsican mountainous beech forest	2	3 - 10 %
102	Mediterranean and Anatolian Black pine forest	5	30 - 50 %

Table 71: Topographic features for each class within for Mongiana "small" area: class of slopes (percentage).

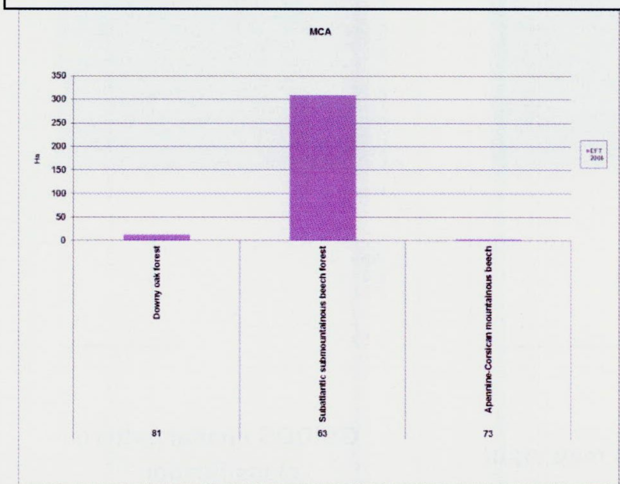
Landscape metrics analysis (Figure 179) showed as black pine forest (class 102) has the highest number of patches (NP) and submountainous beech forest (class 63) has the highest mean patch size. This latter forest type contains the most of forest core area (MCA) and has a low isolation level as showed by the ENN metric values.

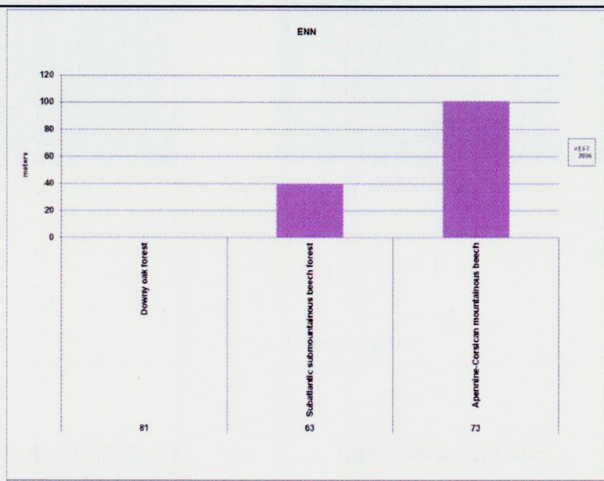
All forest types showed a high shape complexity (AWMSI). Beech forest showed the longest total edge (TE).



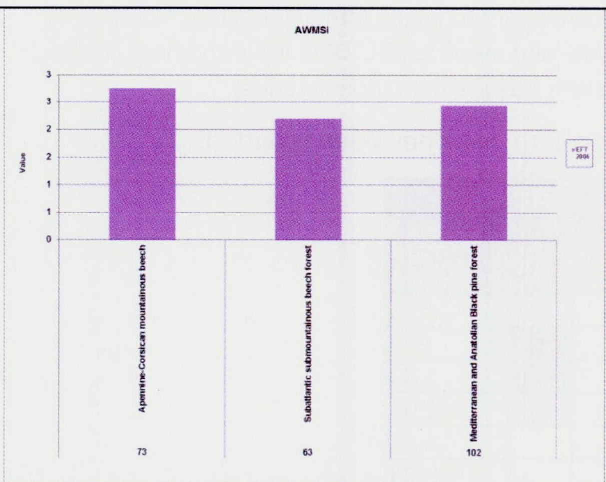


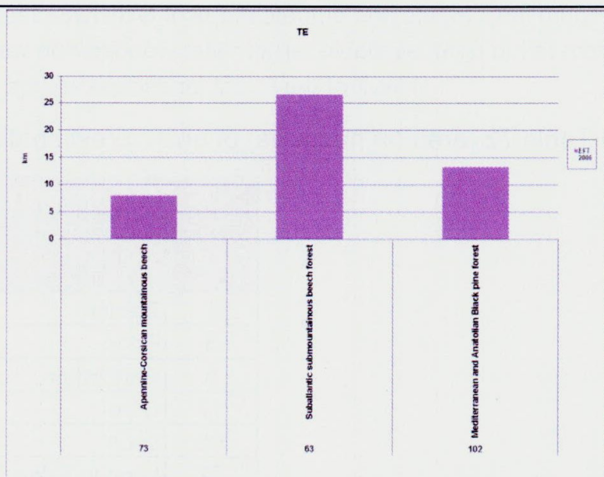
NP	MPS





MCA	ENN





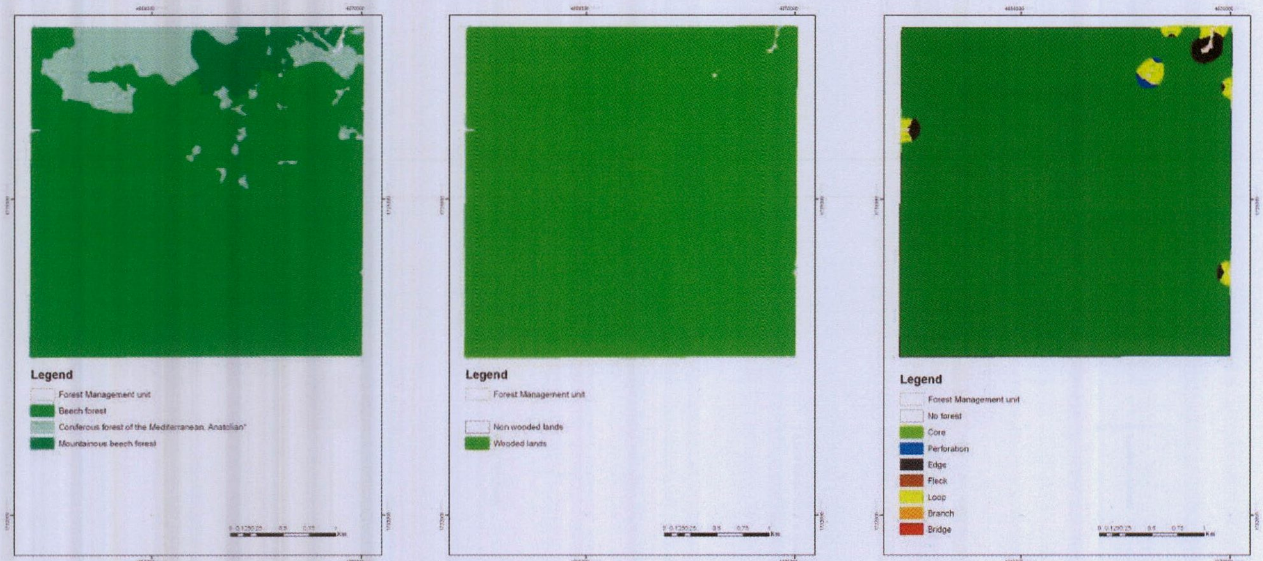
AWMSI	TE

Figure 179: Results of landscape ecology metrics for forest cover (year 2006) within "small" area of for Mongiana site.

- Forest spatial pattern classification results: "small" area

Figure 180 shows the input and output of GUIDOS forest spatial pattern classification for Mongiana "small" area based on the forest cover (at EFT level) data of year 2006.

Small area



Forest cover map | **Forest/non forest map input** | **GUIDOS spatial pattern classification**

Figure 180: Inputs and outputs maps of GUIDOS classification for Mongiana forest/non forest "small" area. From left to right: available target data; wooded/non wooded land maps for GUIDOS inputs (central images); result of the forest landscape spatial pattern classification (right images).

In Table 72, area (in hectares) of each forest spatial pattern class has been reported.

Mongiana (small area 10 kmq)			
Code	**Description**		**AREA (ha)**
1	Branch		0.26
3	Edge		19.9
5	Perforation		1.63
17	Core		952.05
65	Loop		0.17
67	Loop in Edge		9.83
69	Loop in Perforation		4.44

Table 72: Area (hectares) of GUIDOS forest spatial pattern classes for Mongiana forest/non forest "small" area.

Map of landscape metrics

Patch area (ha) (*per patch*) (AREA)

Large area	Small area

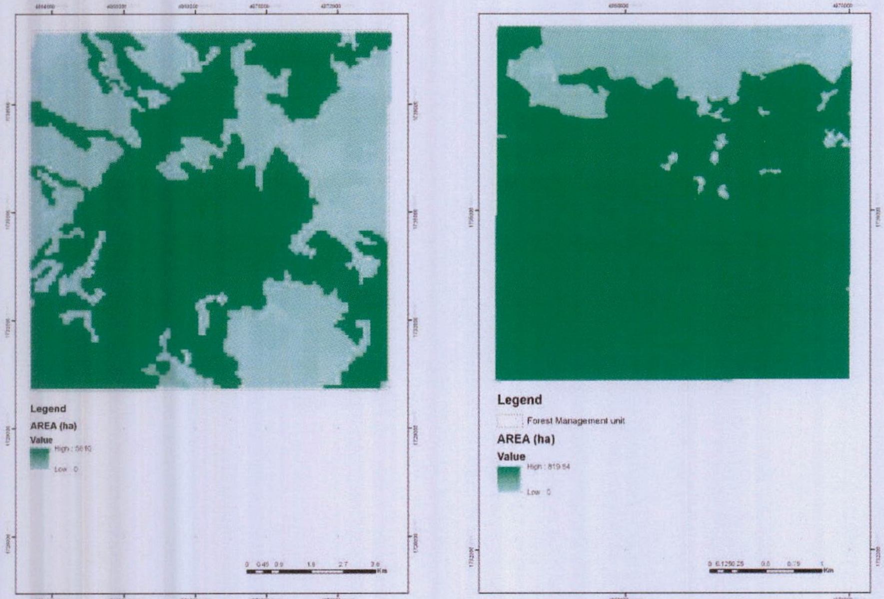


Figure 181: Patch area metrics resulting maps for “Mongiana forest” site.

Class area (ha) (per class) (CA)

Large area	Small area

Figure 182: Class area metrics resulting maps for “Mongiana forest” site.

Class area (ha) (*per class*) (CA)

Large area	Small area

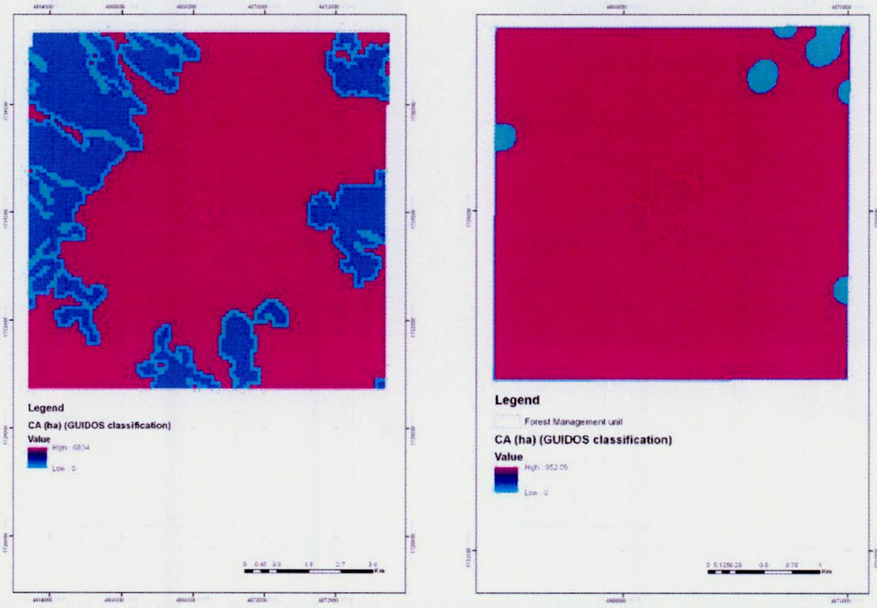


Figure 183: Class area size metrics resulting maps for “Mongiana forest” site (GUIDOS classification).

Mean patch size (ha) (*per class*) (AREA_MN)

Large area	Small area

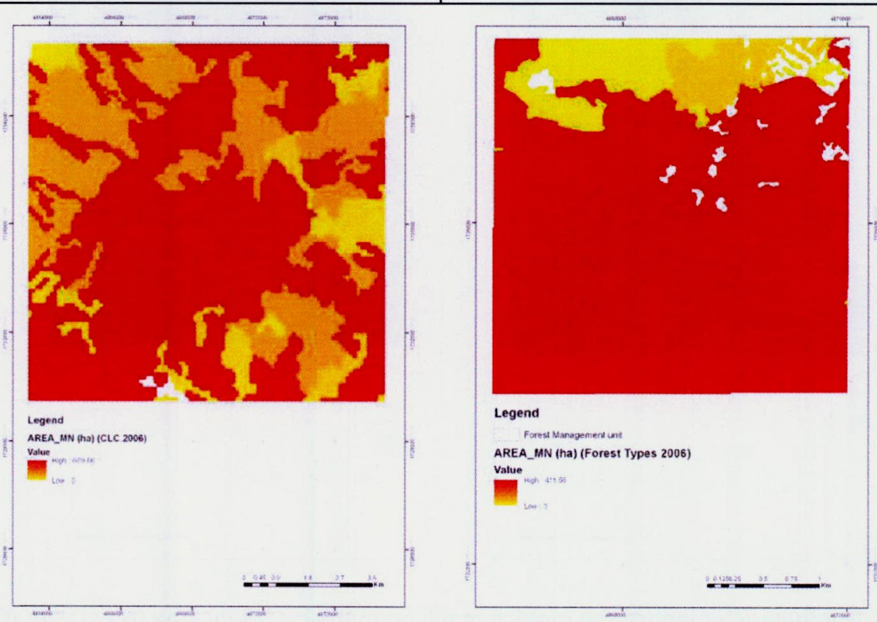
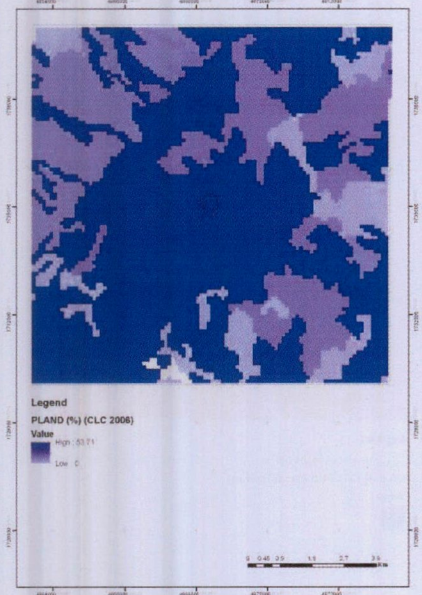


Figure 184: Mean patch size metrics resulting maps for “Mongiana forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area



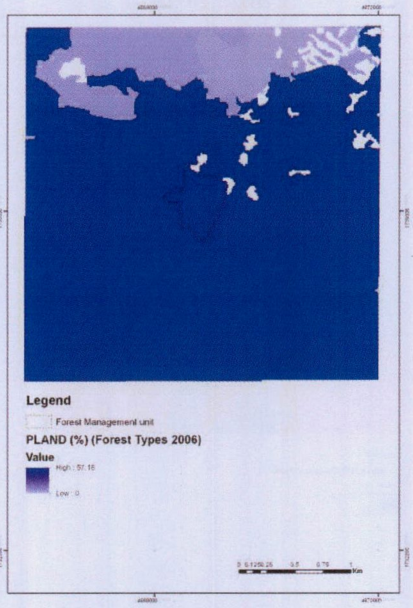


Figure 185: Percentage of landscape metrics resulting maps for “Mongiana forest” site.

Percentage of landscape (%) (*per class*) (PLAND)

Large area	Small area

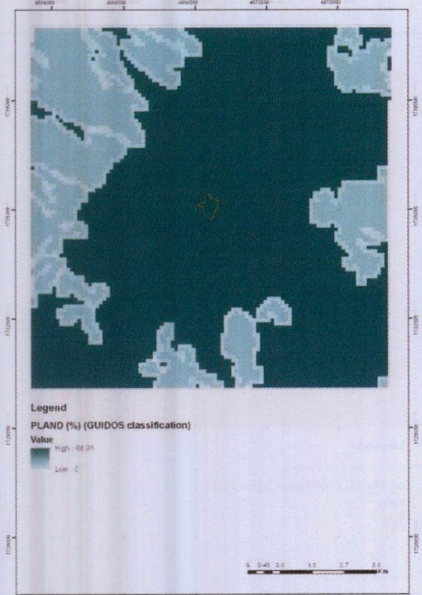


Figure 186: Percentage of landscape metrics resulting maps for “Mongiana forest” site (GUIDOS classification inputs).

Largest patch index (%) (*per class*) (LPI)

Large area	Small area

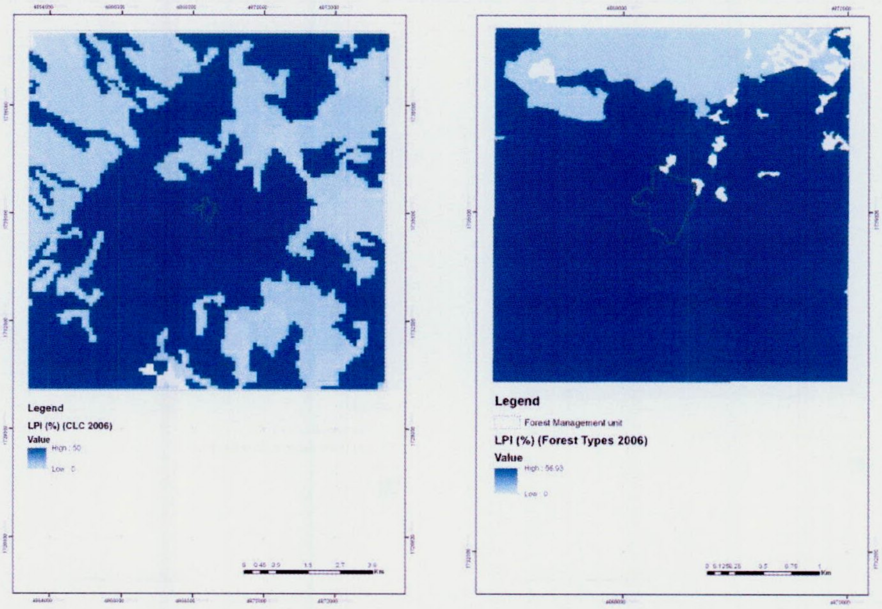


Figure 187: Largest patch index metrics resulting maps for “Mongiana forest” site.

Edge (m) (*per patch*) (PERIM)

Large area	Small area

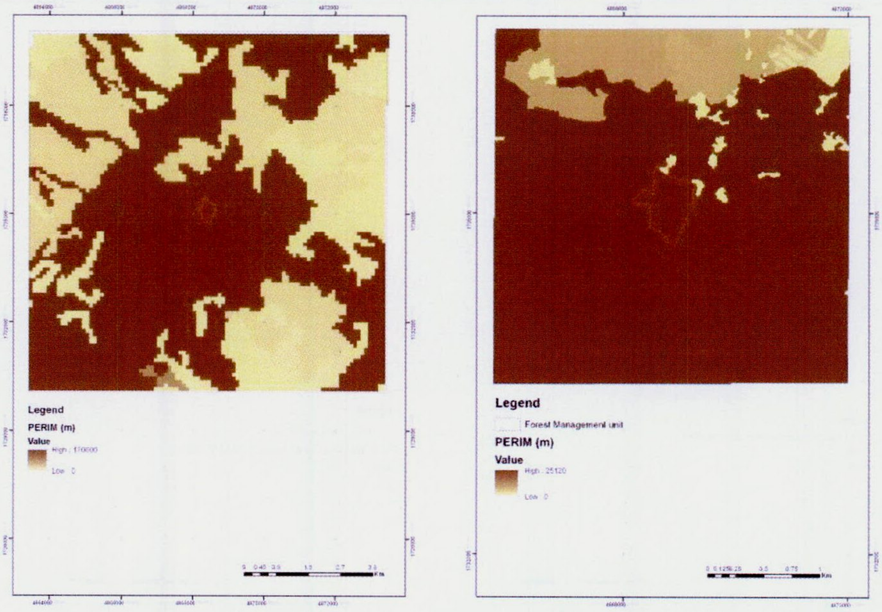


Figure 188: Edge metrics resulting maps for “Mongiana forest” site.

Total core area (ha) (per class) (TCA)

Large area	Small area

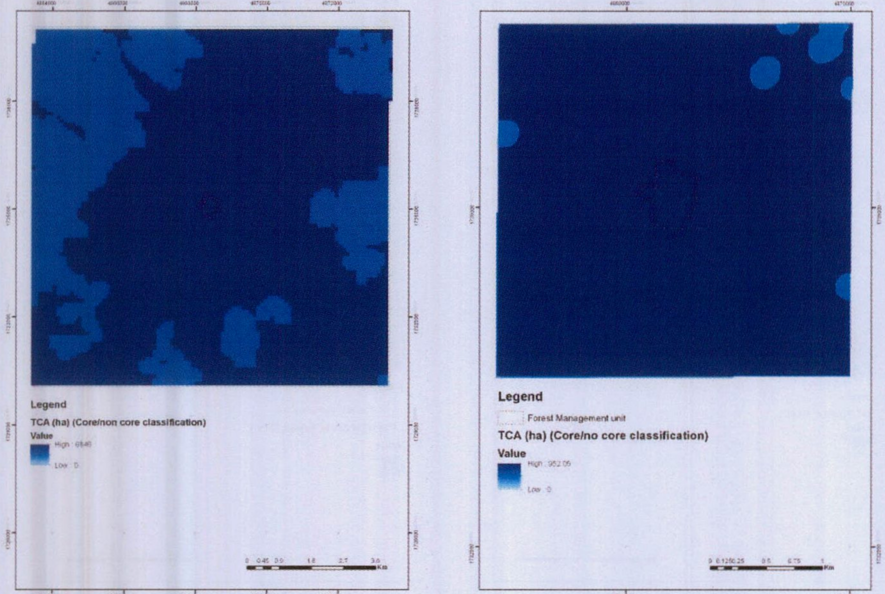


Figure 189: Total core area metrics resulting maps for “Mongiana forest” site.

Core Area Percentage of Landscape (%) (per class) (CPLAND)

Large area	Small area

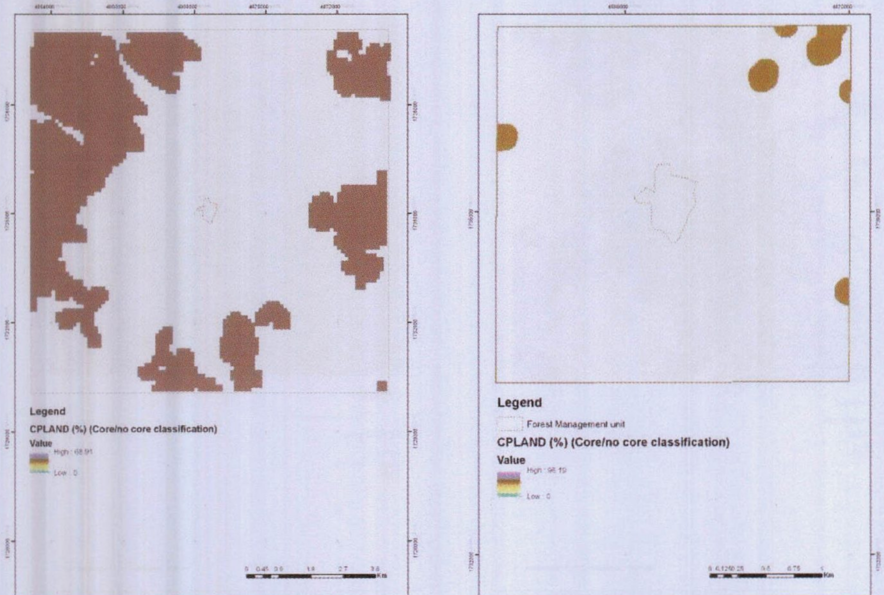


Figure 190: Core Area Percentage of Landscape metrics resulting maps for “Mongiana forest” site.

Number of patches (per patch) (NP)

Large area	Small area

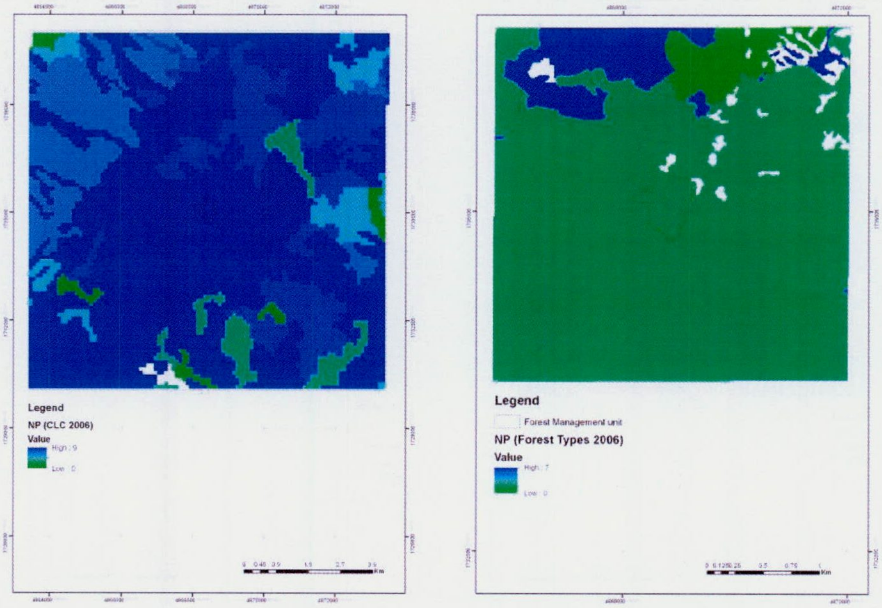


Figure 191: Number of patches in the landscape resulting maps for “Mongiana forest” site.

Patch density (Number per 100 ha) (per class) (PD)

Large area	Small area

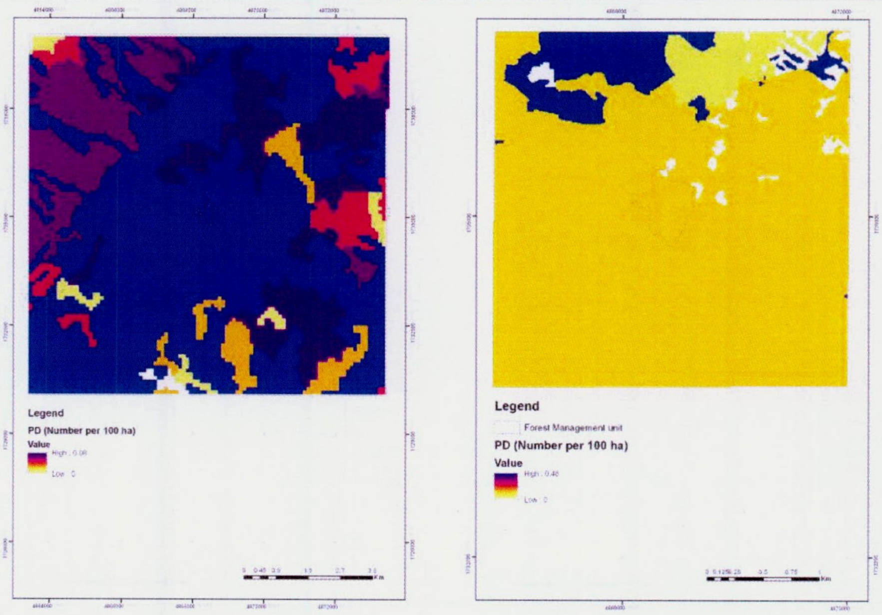


Figure 192: Patch density metrics resulting maps for “Mongiana forest” site.

Shape (per patch) (SHAPE)

Large area	Small area

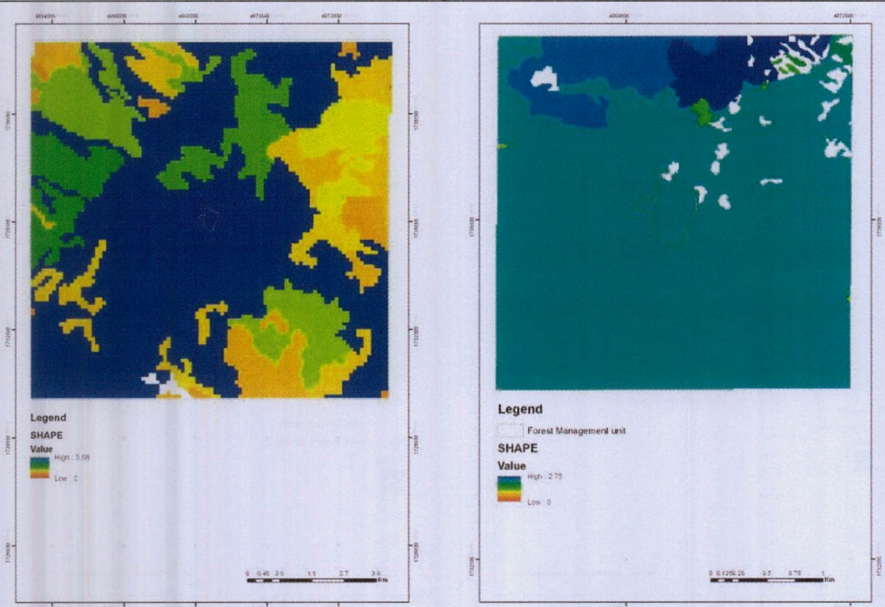


Figure 193: Shape metrics resulting maps for “Mongiana forest” site.

Fractal dimension (per patch) (FRAC)

Large area	Small area

Figure 194: Fractal dimension metrics resulting maps for “Mongiana forest” site.

Mean shape index (per class) (SHAPE_MN)

Large area	Small area

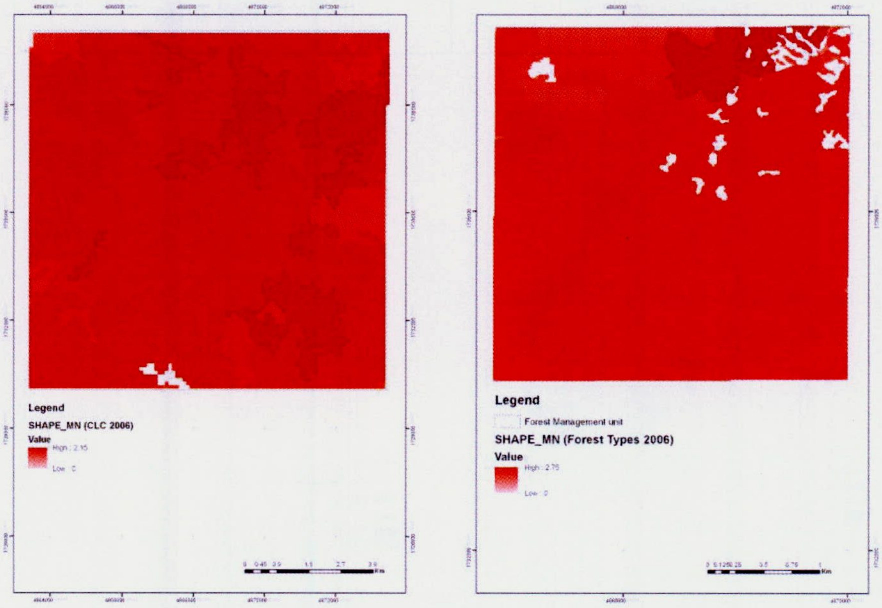


Figure 195: Mean shape indexes resulting maps for “Mongiana forest” site.

Mean fractal index (per class) (FRAC_MN)

Large area	Small area

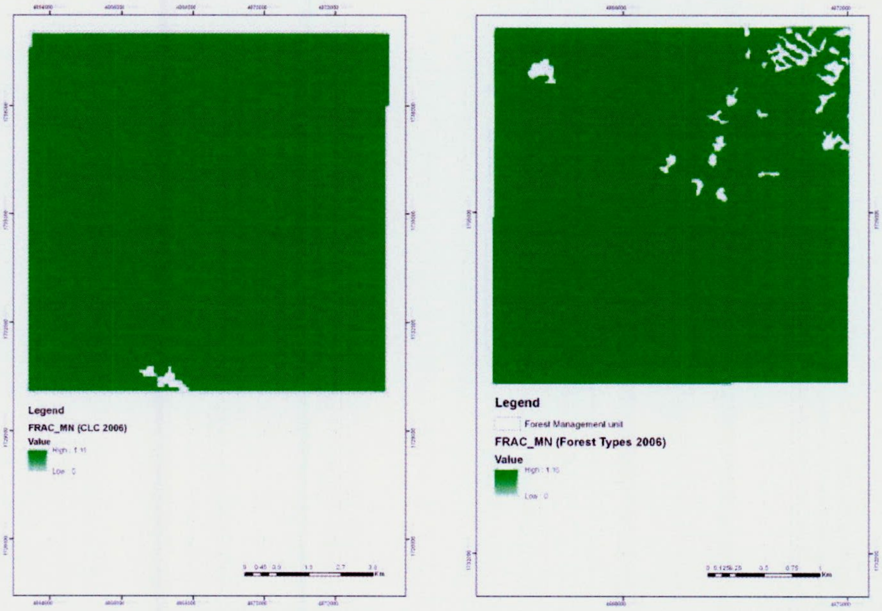


Figure 196: Mean fractal dimensions resulting maps for “Mongiana forest” site.

Euclidean Nearest Neighbor distance

(per patch) (ENN)

Large area	Small area

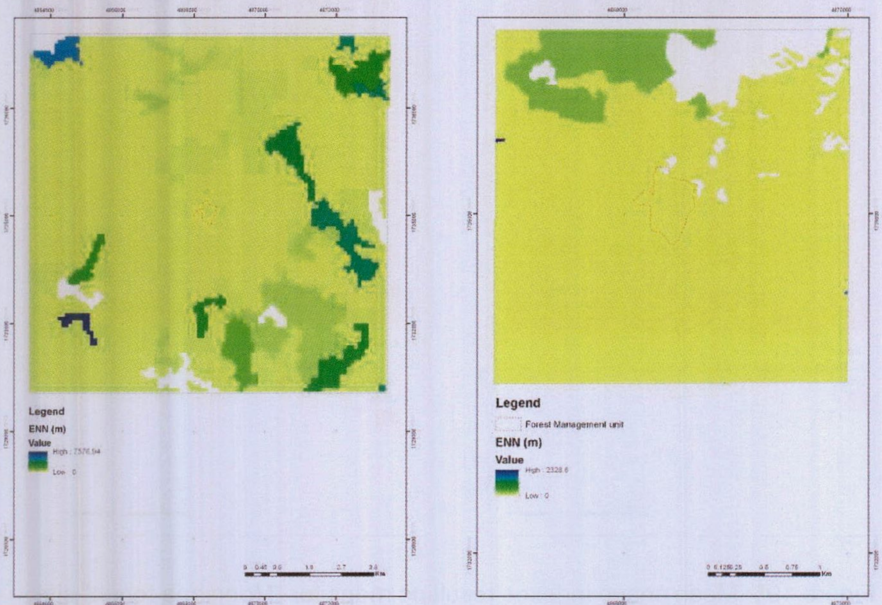


Figure 197: Euclidean nearest neighbor distances maps for “Mongiana forest” site.

2.2.8. General conclusion on landscape analysis

Developed analysis allowed evaluating the landscape context of test sites across the North-South Italian transect. Choosing to spatially define landscapes of equal size allowed their comparison through the transect.

Definition of a "large" and a "small" landscape portion allowed to analyse the landscape context of test site at two different spatial scales: coarse resolution, within "large" area and more fine resolution, within "small" area. In this way, was assured the representativeness of each test site respect to larger landscape contexts.

Within "large" areas from North to the South, *Tarvisio* site has the highest land uses diversity (20 different classes) and *Chiarano-Sparvera* has the lowest land uses diversity (8 different classes. In addiction within the *Chiarano-Sparvera* landscape context there are no artificial land uses classes (class 1 of first CLC level).

In order to quantify the diversity at the landscape level within test sites ("large" and "small" area), Shannon's diversity and Simpson's diversity indexes have been evaluated and compared among test sites.

Figure 198 shows both Shannon's and Simpson's indexes values for all test sites.

For "large" areas the analysis allowed to evaluate the composition of the landscape context within which each forest area appears.

Shannon's diversity index is more sensitive to richness than evenness. Thus, rare types have a disproportionately large influence on the magnitude of the index. Simpson's diversity index is relatively less sensitive to richness and thus place more weight on the common species.

Pennataro test site landscape context (CLC land uses classes) shows the highest diversity index (both SDI and SIDI) (Figure 198) and then, high diversity in the landscape composition.

At level of "small" landscape (forest cover/types), the *Tarvisio* test site has the highest level of composition diversity (Figure 168).

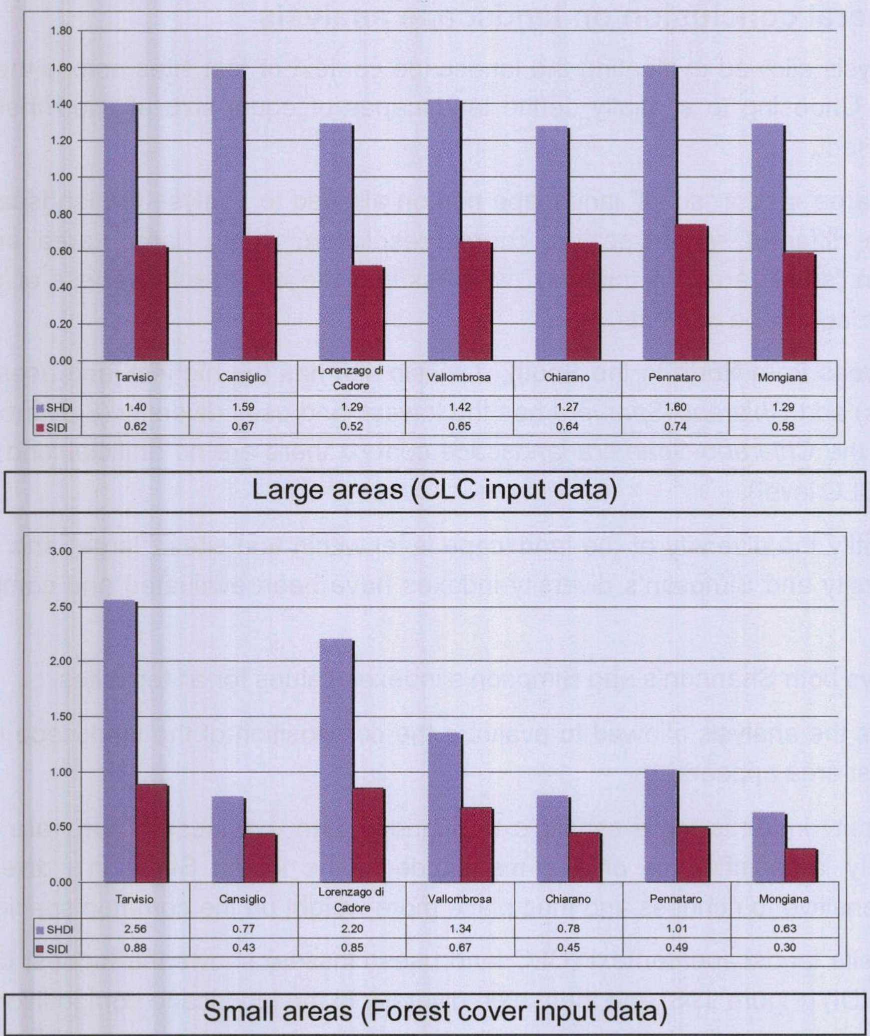


Figure 198: Results of calculated Shannon's and Simpson's diversity indexes for each test site.

Within "large" areas was possible to compare land uses at two dates (year 1990 and year 2006) and evaluate the changes. Through the transect land uses within *Vallombrosa* site showed the greater temporal stability.

The calculated and mapped landscape metrics allowed analysing and comparing the shape, the composition and spatial configuration of the patch (land use classes for "large" area and forest cover classes for "small" area) within considered landscapes.

Through the GUIDOS analysis was possible mapping and analysing the forest landscape spatial pattern for all test sites.

Table 73 shows the forest area and the correspondent core area size identified within each "large" test site at the year 2006.

Large area (100 kmq)		
Test site	Forest area (hectares)	Core area (hectares)
Tarvisio	7405	5771
(%)	74.05	57.71
Cansiglio	7727	6589
(%)	77.27	65.89
Lorenzago di Cadore	6804	5749
(%)	68.04	57.49
Vallombrosa	8552	7419
(%)	85.52	74.19
Chiarano-Sparvera	3478	2205
(%)	34.78	22.05
Pennataro	5173	3668
(%)	51.73	36.68
Mongiana	7881	6834
(%)	78.81	68.34

Table 74: Summarise of forest core size: "large" areas.

Table 75 shows the same forest landscape characteristics for each "small" test site.

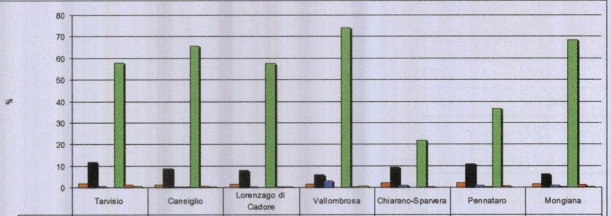
Small area (10 kmq)		
Test site	Forest area (hectares)	Core area (hectares)
Tarvisio	789.53	456.27
(%)	78.95	45.63
Cansiglio	786.75	649.74
(%)	78.68	64.97
Lorenzago di Cadore	854.81	502.56
(%)	85.48	50.26
Vallombrosa	949.85	789.55
(%)	94.99	78.96
Chiarano-Sparvera	294.74	63.48
(%)	29.47	6.35
Pennataro	802.14	552.85
(%)	80.21	55.29
Mongiana	988.28	952.05
(%)	98.83	95.21

Table 75: Summarise of forest core size: "small" areas.

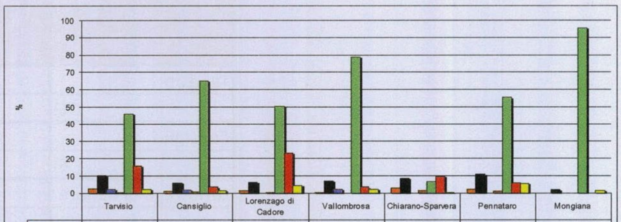
Among "large" areas *Vallombrosa* test site has the highest amount of forest area (85 %) and core area (74 %) respect to other sites. *Chiarano-Sparvera* site has the lowest percentage of forest area (34 %) and core area (22 %) within the considered "large" landscape portion. In this site, forest appears in a landscape matrix composed by other natural and semi-natural habitats.

At more fine spatial scale (within "small" areas) (Table 75), *Mongiana* site presents the highest amount of forest area (98 %) and core area (95 %). While at this spatial scale also *Chiarano-Sparvera* site shows the lowest amount of forest area.

Figure 199 shows the amount of all other forest spatial pattern classes resulting by GUIDOS analysis for all test site (both "large" and "small" areas).



	Tarvisio	Cansiglio	Lorenzago di Cadore	Vallombrosa	Chiarano-Sparvera	Pennataro	Mongiana
Branch	1.99	1.25	1.44	1.4	2.1	2.22	1.39
Edge	11.76	8.55	8.05	5.97	9.28	10.93	6.08
Perforation	0.68	0.34	0.36	2.97	0.82	1	0.98
Islet	0.03	0.35	0	0.1	0	0.24	0.31
Core	57.71	65.89	57.49	74.19	22.05	36.68	68.34
Bridge	1.27	0.56	0.42	0.16	0.4	0.54	1.28
Loop	0.61	0.33	0.28	0.73	0.13	0.12	0.43



	Tarvisio	Cansiglio	Lorenzago di Cadore	Vallombrosa	Chiarano-Sparvera	Pennataro	Mongiana
Branch	2.87	1.18	1.39	0.50	3.25	2.37	0.03
Edge	10.11	5.61	6.15	7.04	8.65	10.90	1.99
Perforation	2.37	1.89	0.17	2.40	0.00	0.00	0.16
Islet	0.55	0.78	0.23	0.00	1.51	0.97	0.00
Core	45.63	64.97	50.26	78.96	6.35	55.29	95.21
Bridge	15.83	3.37	23.11	3.59	9.72	5.71	0.00
Loop	2.12	1.39	4.18	2.49	0.52	5.50	1.44

Large areas	Small areas

Figure 199: Results of GUIDOS forest spatial pattern classification for all test sites.

The forest spatial pattern within "large" landscapes (Figure 198) does not allows to highlight all the classes (except core and edge, all other classes present low rate of cover within the landscape). The forest spatial pattern analysis of "small" landscapes allow to identify the more or less amount of connectivity elements between forest patches (branch, bridge, islet). The forest spatial pattern comparison shows the highest presence of core area within Mongiana "small" area which means a low level of fragmentation of forest habitat. Tarvisio "small" area presents the lowest core area amount and a consequent higher fragmentation level among all test sites.

If this forest spatial pattern were considered from the ecological network point of view, the presence of forest spatial pattern elements as bridges (forest patches connecting forest core areas) could potentially reduce the fragmentation impact on the forest species movement between patches for this site.

At moment, no connectivity index have been quantified. In this first phase of Action ECo have been only identified and quantified composition of forest spatial pattern. Connectivity evaluation will be performed within the second phase of the project and will be connected to habitat suitability characteristics of selected forest species fauna.

2.2.9. Cited references

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2.3. *Performed activity from Sub-action 2 – Activities in Slovenia*

The analyses were performed at two spatial levels (Figure 1), at the forest stand level and at the landscape level. The forest stand level is represented by 3 test sites (test site 8 - Kočevski Rog, test site 9 - Snežnik, test site 10 - Trnovo), each containing 9 sylvicultural treatment plots. Each test site was spatially defined by taking a 200-m buffer arrount the 9 treatment plots. Each site thus measures approximately 70 hectares.

The landscape level has been tested in 3 sample squares measuring 100 km2 each. The squares are centered around the test site's centers of gravity. More detailed analysis will be performed in the next period.

Figure 1: The forests of Slovenia (green) with the layout of the 3 stand-level test sites (small red polygons) and the layout of the 3 bigger landscape-level test areas (squares surrounding the red polygons). Each landscape-level test area measures 10 by 10 kilometers.

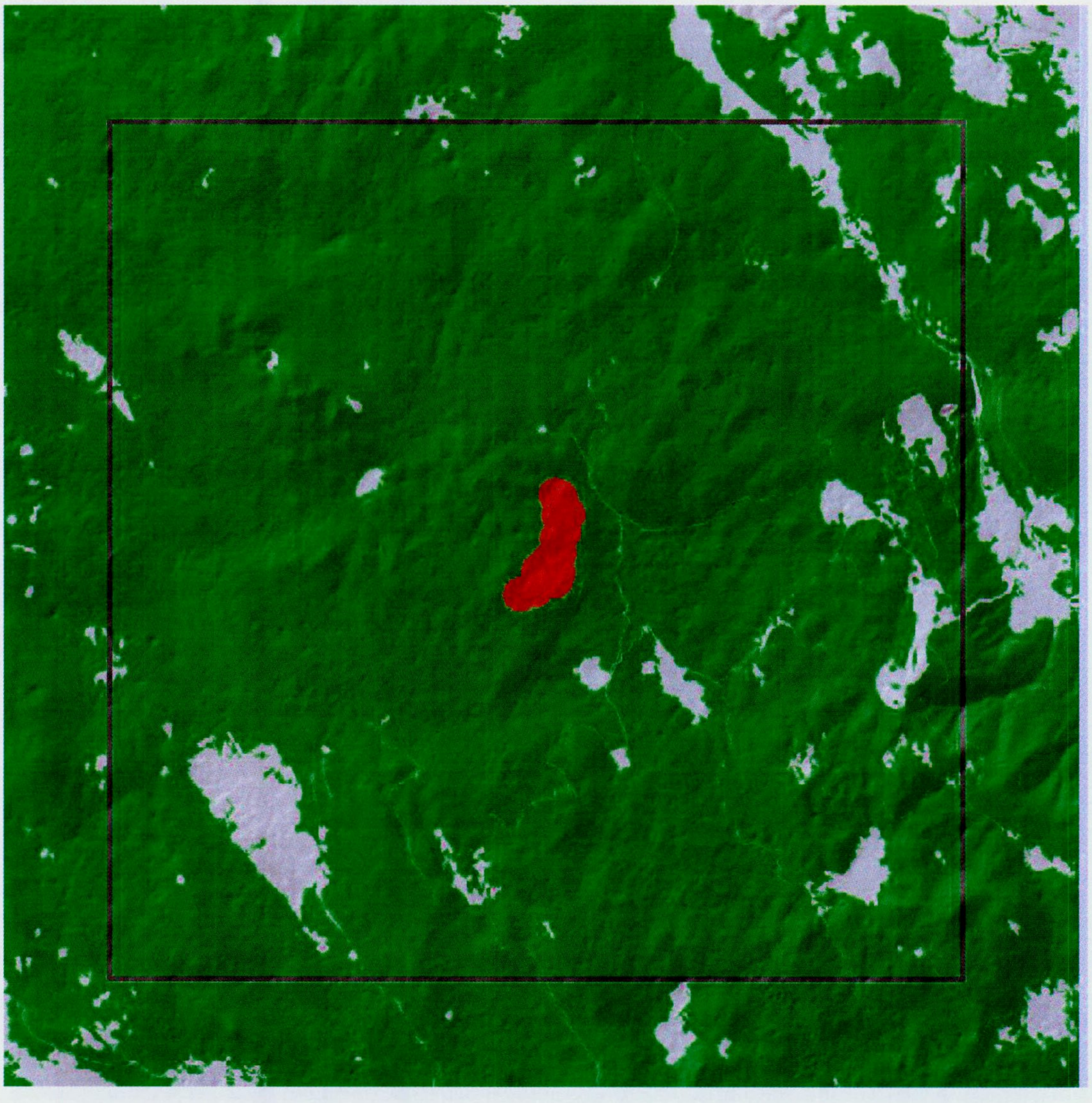

Figure 2: The detailed layout of the landscape-level test area (big square, 10 by 10 km), surrounding the test site 8 – Kočevski Rog (red polygon).

Figure 3: The detailed layout of the landscape-level test area (big square, 10 by 10 km), surrounding the test site 9 – Snežnik (red polygon).

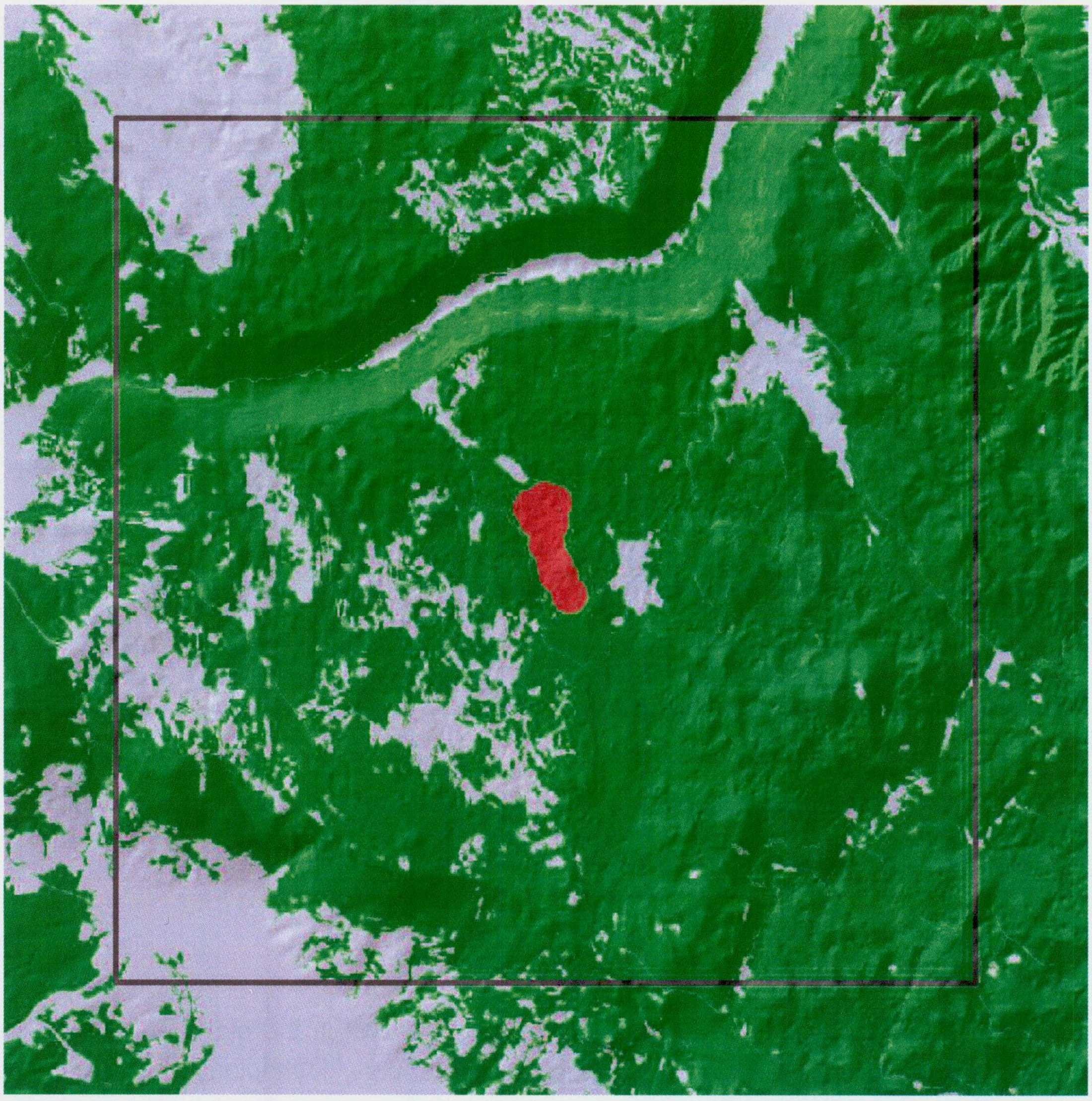

Figure 4: The detailed layout of the landscape-level test area (big square, 10 by 10 km), surrounding the test site 10 – Trnovo (red polygon).

The analyses at the landscape level have been done with monotemporal Agricultural landccover data at map scale 1:5000 (Ministry of Agriculture and Environment), containing the forest border as of 2012. Although the agricultural landcover data are available from the year 2002 on, the early releases contain lots of photointerpretation errors and are thus not really comparable to the recent release. Earlier forest masks (e.g. 1975, taken from the topographical map scaled 1:50.000 are not usable due to much different scale of mapping).

The emphasis of our work is upon the forest stand level, where effects of sylvicultural treatments are being felt. The analyses at the forest stand level are being done using high-resolution multitemporal aerial lidar data (acquired December 2011 and, tentatively, December 2013). Aerial lidar data were acquired for the pre-treatment forest stands on all three Slovenian test areas (Trnovo, Snežnik, Rog) in December 2011. Post-treatment lidar data will be acquired tentatively in fall 2013.

After the second lidar data acquisition the results of processing the pre-treatment lidar data will be compared to the post-treatment lidar data in order to detect 3-D changes in forest stand structure due to the sylvicultural treatments. After acquisition of post-treatment lidar data changes of forest stand structure will be evaluated through change detection and analysis of several lidar based change criteria/indicators, as follows:

1. Criterion: Continuity of forest canopy cover
    - Indicator: Spatial pattern of gaps in the forest stand canopy
    - Related to MCPFE indicators:
        - 3.1 Increment and fellings
        - 4.2 Regeneration
        - 4.7 Landscape pattern
    - Rationale: Discontinuities (gaps) in forest canopy reaching to the ground are the centers of forest rejuvenation. Their areal percentage and spatial juxtaposition is an important indicator of forest stand developmental and ecological status.
2. Criterion: Amount of forest canopy cover
    - Indicator: Forest canopy cover pattern
    - Related to MCPFE indicators:
        - 3.1 Increment and fellings
        - 4.2 Regeneration
        - 4.7 Landscape pattern
    - Rationale: Canopy cover regulates the light conditions in the stand and thus also the increment, rejuvenation, species composition etc. Lidar technology enables computing continuous gradients of this indicator over large areas, enabling more informed sylvicultural treatments. This is an alternative indicator to the Spatial pattern of gaps in the forest stand canopy.
3. Criterion: Forest stand productivity potential
    - Indicator: Volume of photosyntheticaly active forest canopy
    - Related to MCPFE indicators:
        - 3.1 Increment and fellings
        - 4.7 Landscape pattern
    - Rationale: The amount of the photosyntheticaly active part of the forest stand canopy is a proxy for the stand productivity. As the canopy is a 3-D structure it can be gleaned from the lidar point cloud. The rectangular 3-D pixels (voxels) are classified into 'filled' (by lidar returns) and 'empty' voxels. The upper 65% of filled voxels in each column are considered the photosyntheticaly active part of the canopy, according to (Lefsky et al.,

1999, Lidar remote sensing of the canopy structure ..., Remote Sening of Environment, 70: 339-361).

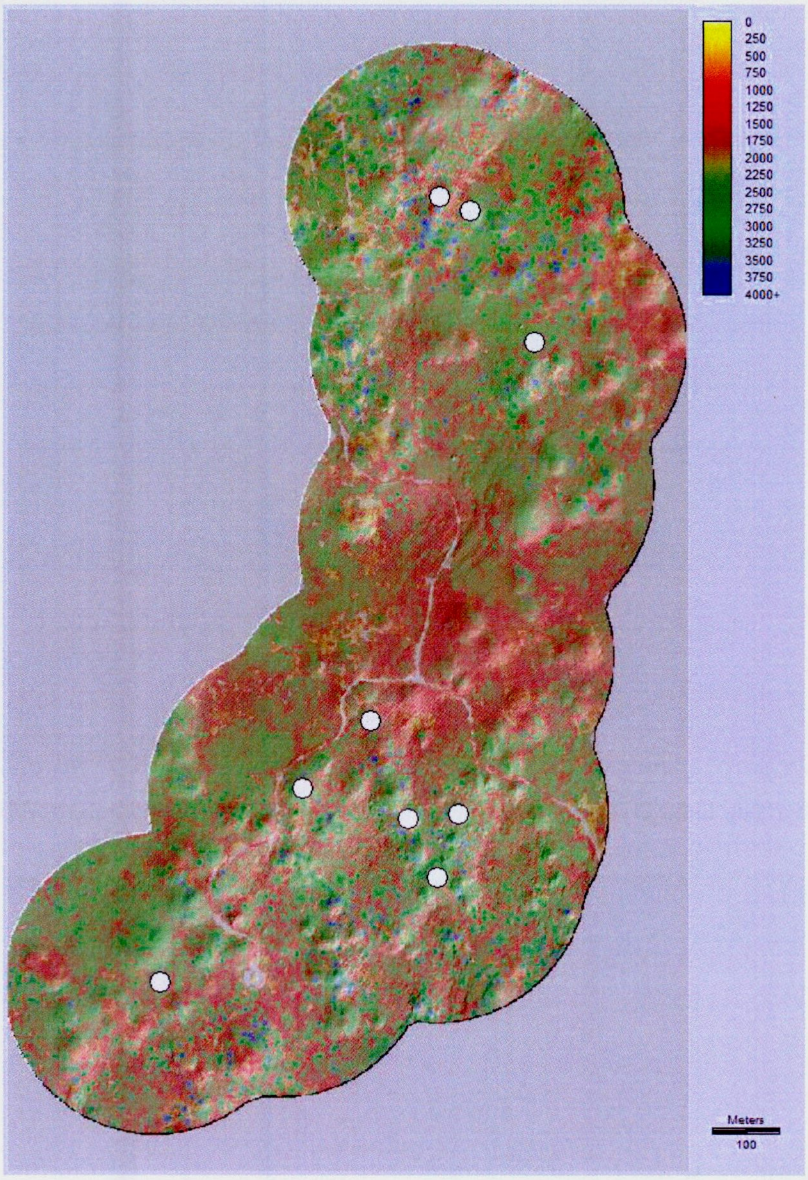

Figure 5: Test site Kočevski rog. Lidar DTM draped by lidar vegetation height in centimeters. White dots represent the treatment plots.

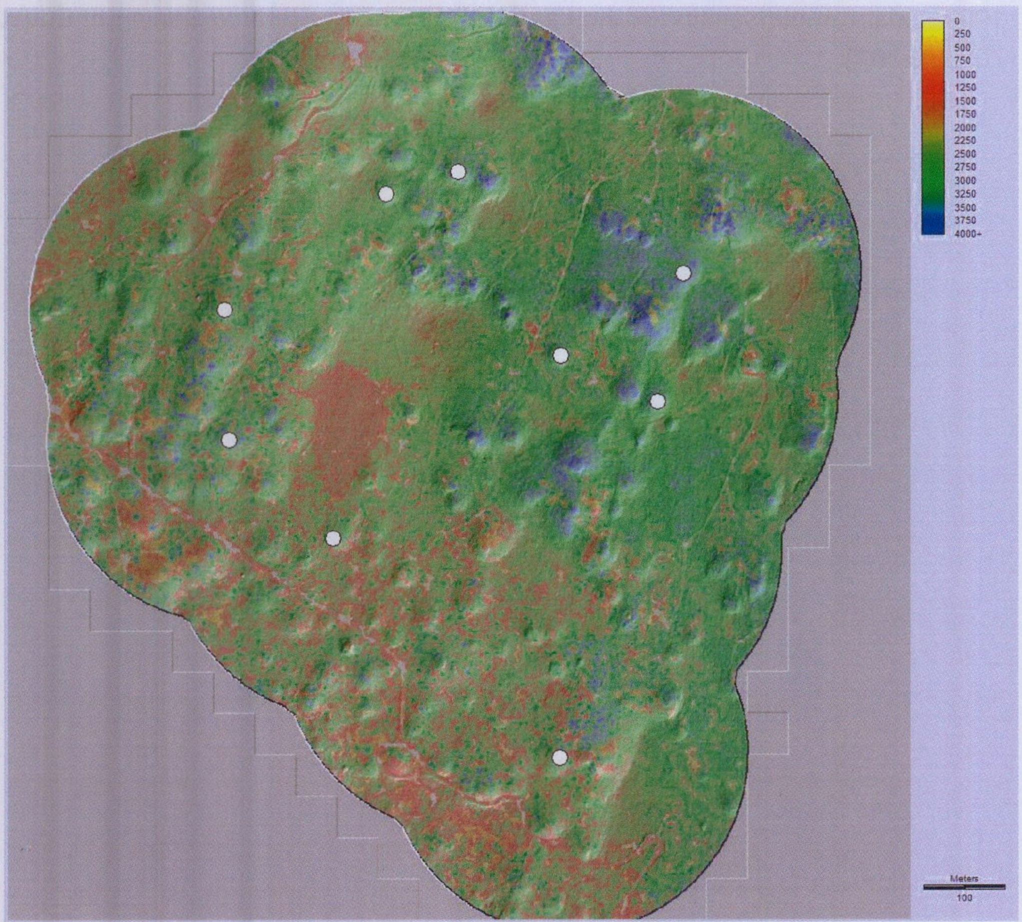

Figure 6: Test site Snežnik. Lidar DTM draped by lidar vegetation height in centimeters. White dots represent the treatment plots.

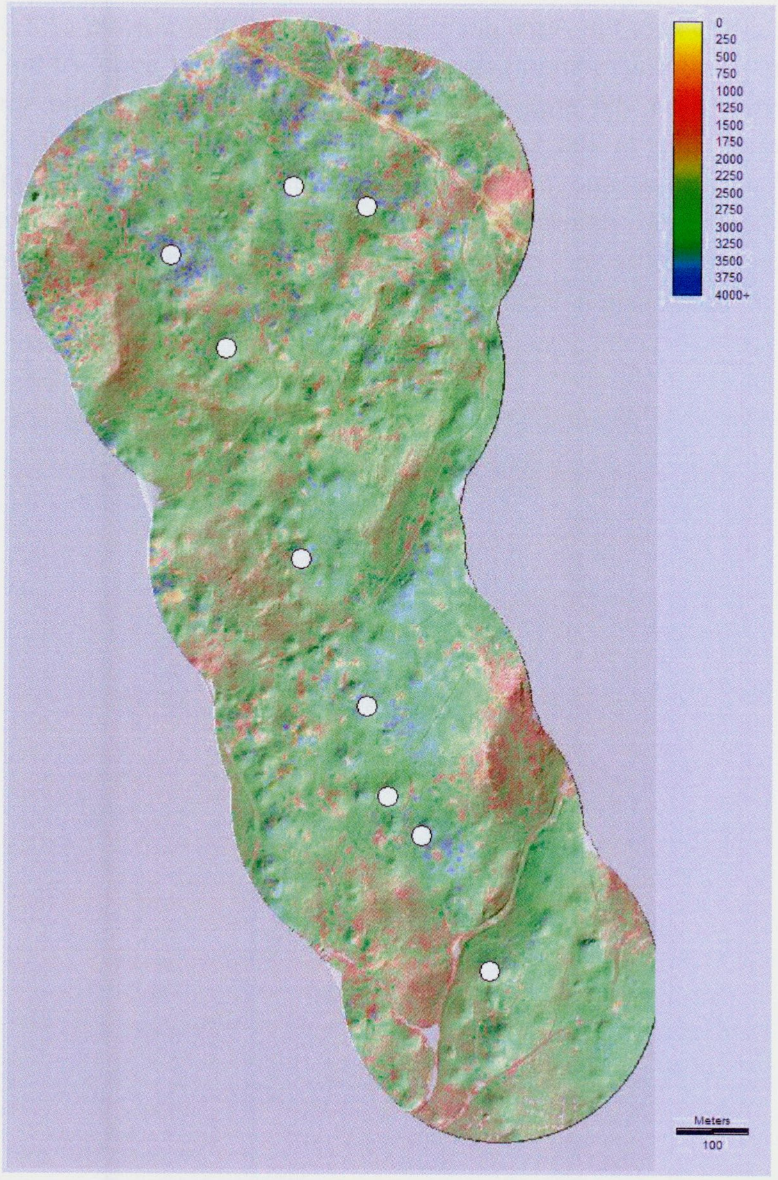

Figure 7: Test site Trnovo. Lidar DTM draped by lidar vegetation height in centimeters. White dots represent the treatment plots.

2.4.1. Analyses at the landscape level

At the landscape level several forest core area metrics were evaluated. The forest core area is the internal area of large forest patches, that is sufficiently far from the forest edge, so that nonforest disturbances are not felt. The cores of the forest patches are at least 300 m inside of the forest edge, according to Hladnik (Hladnik D., 2005, Spatial structure of disturbed landscapes in Slovenia, Ecological Engineering 24 (2005) 17–27). Hladnik has proposed this distance in accordance with Forman (Forman, R.T.T., 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, p. 632), who examined how the number of different bird species depended on the size of forest remnants.

The basis of the analyses was the Agricultural land use map at the scale of 1:5.000, as of 2012 (Ministry of Agriculture and Environment), containing also the forest edge. At the landscape level, the forest mask, derived from the agricultural land use map, contains some superfluous details, i.e., apparent clearings due to the presence of forest roads. In Slovenia these are legally considered to be forest area, and may be considered forest also ecologically, at this scale. Therefore these superfluous details have been filtered out using morphological closing. Morphological closing consists of morphological dilation of the forest area, followed by morphological erosion, both using a circle with a radius of 15 m as the structuring element (**Figure 8**).

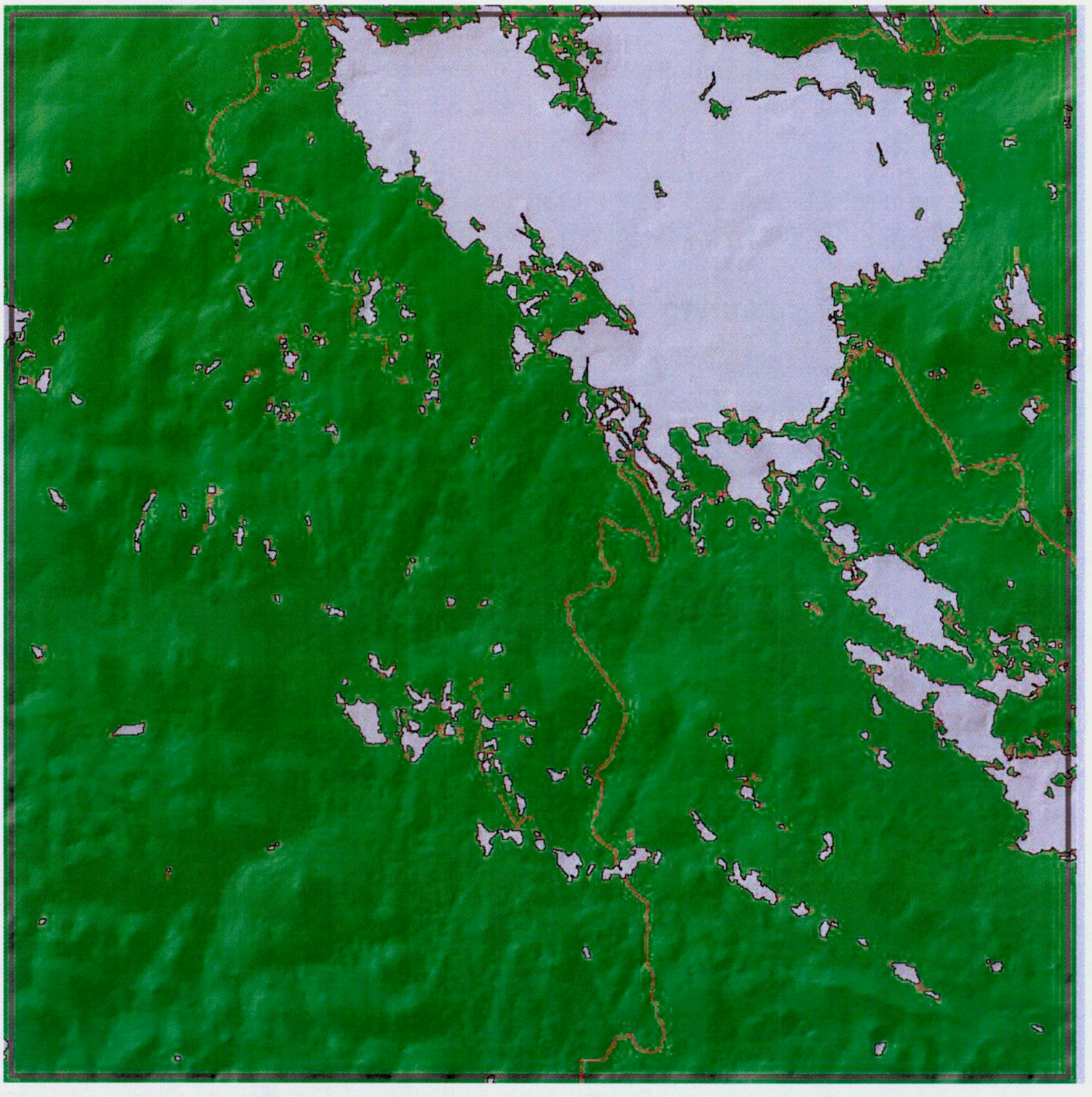

Figure 8: Results of filtering out the superfluous forest edge details using morphological filtering (closing) of the forest mask (raster resolution 10 m). The map shows the effect of morphological closing on the example of the Snežnik test area (10 x 10 km), where the red line represents filtered out forest edge details and the black line represents the post-filtering forest edge. Note the removal of the forest roads and of the very small forest clearings.

The filtered forest mask was used for all landscape-scale analyses. For each test area at the landscape level the following metrics were evaluated from the forest mask using procedures in Idrisi rater GIS software:

- Percent of forest cover relative to the landscape area.
- Percent of core area relative to the forest area.
- Number of core areas (McGarigal and Marks, Fragstats, 1994, Oregon University, Corvallis). This metric has been calculated for the entire area of the country in order to mitigate the spurious border effects at the edges of the 10 by 10 km test areas. I.e., all

disjunct core areas were identified within Slovenia, and subsequently they were counted within each test area.

- Core area percent of the landscape (McGarigal and Marks, Fragstats, 1994, Oregon University, Corvallis). The sum of the core areas within each test area, divided by the total area of each test area.
- Total core area (McGarigal and Marks, Fragstats, 1994, Oregon University, Corvallis). The sum of the core areas within each test area.

2.4.2. Airborne lidar scanning

The pre-treatment lidar data acquisition for the three Slovenian test areas was done by the FLYCOM Company, Slovenia, on December 8, 2011, between 12 AM and 3 PM. The laser scanner Riegl LMS Q560 was mounted onto a helicopter. The lidar data acquisition was done in clear weather with a flying height of 200 m above the terrain and at a ground speed of 60 km/h. The pulse frequency was selected at 180 kHz. Scanning angle was ±30° from nadir, beam divergence 0.5 mrad and the footprint was 10 cm. The resulting average point cloud density over the three test areas is >300/m^2 (combined for the first, last, intermediate and only returns). The average cloud density for the first and only returns (i.e., those used for DTM generation) is 110/m^2.

Post-treatment lidar data will be acquired tentatively in the fall 2013 at approximately the same scanning parameters, in order to maximize harmonization/comparability between the two datasets.

Airborne laser scanning (ALS), also termed airborne lidar (Light Detection And Ranging), is one of many laser remote sensing techniques. By measuring the round trip time of an emitted laser pulse from the sensor to a reflecting surface and back again, the distance from the sensor to the surface is determined using the known speed of light. For measuring the topography of the earth surface from an aircraft, typically an airplane, the position and attitude of the platform have to be known. These parameters are determined with GPS and IMU. Through periodical deflection of the emitting direction across the flight path by an oscillating or rotating mirror and by the forward motion of the aircraft, a dense cloud of points is sampled on the earth's surface in the form of a swath.

Because of its immediate generation of 3D data, high spatial resolution and accuracy, ALS data is becoming popular for the reconstruction of digital terrain models as well as for the 3-D forest structure reconstruction. Since the lidar signal has the ability to pass through gaps in foliage and reflect from different parts of trees it is also used for measuring tree height and estimating other forest stand parameters.

2.4.3. High resolution digital terrain model

Raster grid digital terrain models (DTMs) with a horizontal resolution of 1 m have been computed for all three Slovenian test areas.

Typically, the 3-D lidar point cloud data contain point elevations above sea. An accurate high-resolution DTM is thus needed as a precondition for many lidar based forest stand analyses, because we first need to know the relative height of each point above bare ground. This height is computed as the difference between the point elevation and the local DTM elevation.

To generate the DTM from aerial lidar data in the tree Slovenian test areas, which are densely covered by forest canopy and also contain some steep terrain, we used the REIN algorithm (Kobler et al., 2007, Repetitive interpolation: A robust algorithm for DTM generation from Aerial Laser Scanner Data in forested terrain, Remote Sensing of Environment 108 (2007) 9–23). REIN is especially applicable in steep, forested areas where other filtering algorithms typically have problems distinguishing between ground returns and off-ground points reflected in the vegetation.

Before describing the REIN filtering method, used to generate DTM in the ECO-SI action, let us first take a short overview of existing lidar filtering methods, used for generating DTMs (Kobler et al. 2007). The first group of methods, the morphological filtering, uses a structure element, describing admissible height differences depending on horizontal distance. The smaller the distance between a ground point and its neighboring points, the less height difference is accepted between them. This structure element is placed at each point so off-terrain points are identified as those above the admissible height difference. The second group of filters works progressively, where more and more points are classified as ground points. It uses the lowest points in large grid cells as the first ground points and a triangulation of the ground points identified so far as reference surface. For each triangle one additional ground point is determined by investigating the offsets of the unclassified points in each triangle with the reference surface. The offsets are the angles between the triangle face and the edges from the triangle vertices to the new point. If a point is found with offsets below threshold values, it is classified as a ground point and the algorithm proceeds with the next triangle. In this way the triangulation is progressively densified. The third group of algorithms is based on a surface model through the entire point set that iteratively approaches the ground surface. A first surface model is used to calculate residuals from this surface model to the points. If the measured points lie above it, they have less influence on the shape of the surface in the next iteration, and vice versa. Finally, the fourth group of filters works on segments by classifying the segments based on neighborhood height differences. The REIN algorithm, used in ECo-SI, takes a different approach - the random sampling makes REIN unique among the methods of filtering airborne laser data. While other filters behave deterministically, always generating a filter error in special situations, in REIN, because of its random aspects, these errors do not occur in each sample, and typically cancel out in the final computation of DTM elevations.

REIN algorithm (Kobler et al. 2007) is intended to generate a DTM in steep relief covered by heterogeneous forests, which leads to a high variation in the penetration rate and therefore high variation in the number of ground returns per unit area. In flat terrain with sparse forest cover, allowing high penetration rates and a high density of ground returns, the existing filtering algorithms are accurate and efficient. However, filtering results get less accurate in steep relief under dense forest cover. REIN mitigates this deficiency by using a two-stage approach that can be summarized as follows:

1. In the initial filtering stage (**Figure 9**a) negative outliers and most, but not necessarily all, off-ground returns (positive outliers) are removed. To achieve the latter the morphological filter is used.

2. In the final filtering and DTM generation stage (**Figure** 9b,c) the DTM is produced from the initially filtered point cloud. For this task, the REIN is able to deal with a partially filtered point cloud in steep relief. It makes use of multiple ground elevation estimates at individual DTM points in a vector grid, interpolated from surrounding ground returns. These elevation estimates are generated from multiple independent samples taken from the initially filtered point cloud. TINs are used for computing the elevation of the DTM points.

The initial filtering stage (**Figure** 9a) is necessary because there are two preconditions for the REIN algorithm to generate DTMs with no or only a few filter errors. The first precondition is that many, but not necessarily all, off-ground returns are removed from the point cloud before applying REIN. The second precondition is that no negative outliers remain in the point cloud before moving on into the second, final filtering stage. The initial filtering stage has two steps.

The first step is to remove the extreme negative outliers from the point cloud. For each point in the point cloud, we compute its vertical displacement D to the average elevation of its k neighboring points (neighborhood being considered in the X-Y plane). We then rank all the points according to D and discard P percent of points having the largest negative D values. P should be small, but at the same time it must be large enough to ensure no significant negative outliers are retained, even at the cost of removing some non-outliers.

During the second step of the initial filtering stage we remove most off-ground points, using a filter based on the slope between neighboring points. Starting from the lowest point, for each point its k nearest neighbors are investigated, and if the slope between a point pair is larger than a threshold the higher of the two point is removed. The slope threshold is set to a slightly higher value than the steepest slope expected in the area of interest. This prevents accidentally filtering out the ground points in steep areas; however more off-ground points remain in the point set as a consequence and have to be dealt with in the final filtering and DTM generation stage.

The input for the final filtering (**Figure** 9b) and DTM generation stage is thus a filtered point cloud (FPC) containing mostly ground points scattered within the error band, with some positive and no negative outliers. The error band is the buffer zone along the surface of the true bare ground, caused by the lidar point errors due to the lidar range measurement errors, scanning angle error, direct geo-referencing error and grass and low herbal vegetation. Another component affecting this error band is caused by relief details with extent below the lidar sampling distance which therefore cannot be recovered. Because the steep relief imposes a high threshold used in the slope filter, some positive outliers, i.e., vegetation points remain in the initially filtered point cloud. These outliers would introduce errors into the DTM, if it were generated directly from FPC. Instead of this, a DTM is fitted to the ground points within the error band using the REIN algorithm.

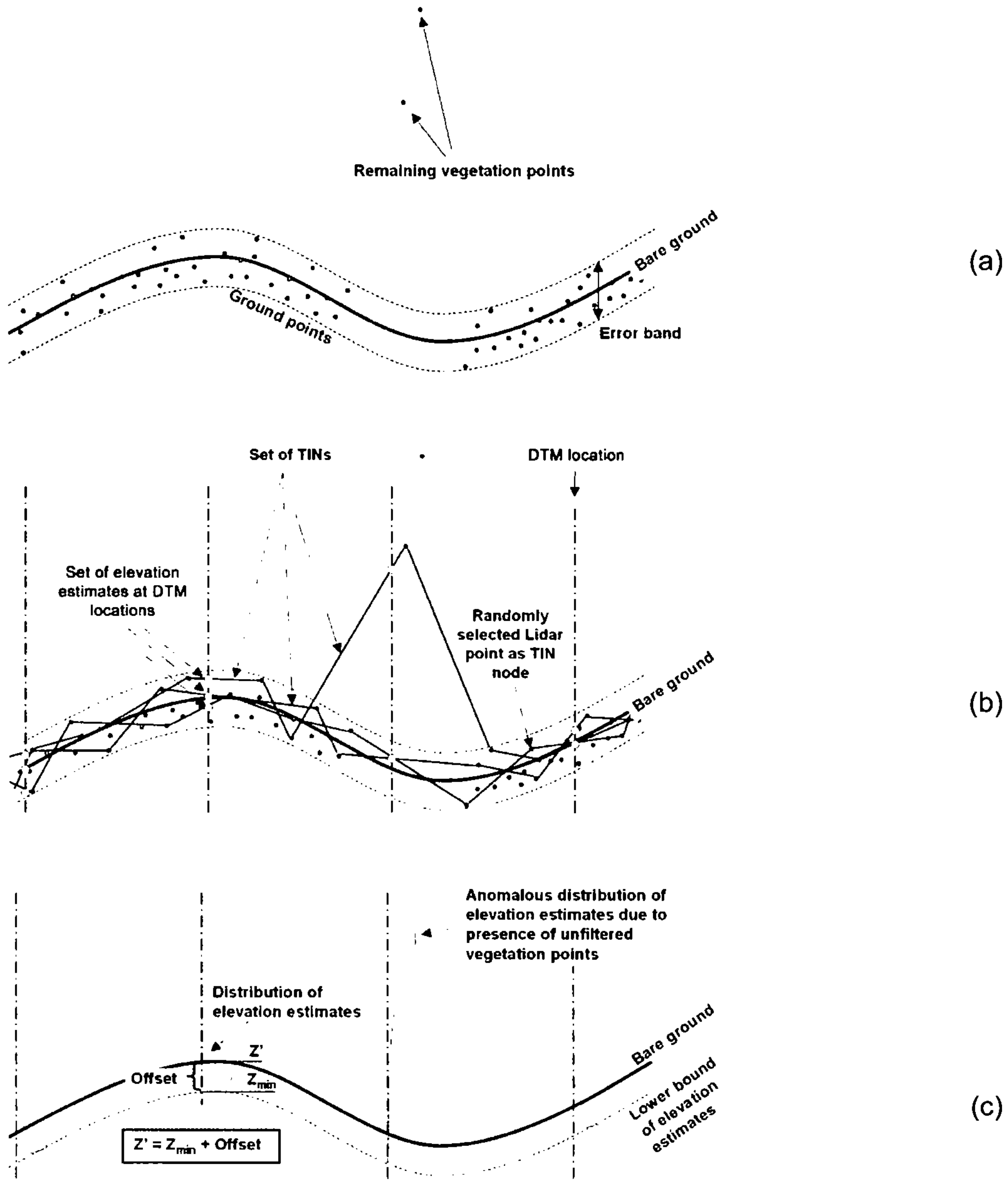

Figure 9 (from Kobler et al. 2007): Illustration of the REIN algorithm used in the final stage of the filtering. (a) The result of the initial filtering stage (using, e.g., a slope threshold filter) are ground points with few remaining unfiltered vegetation points and no negative outliers. Note the redundancy of ground points within the error band. The scattering within the error band is caused by measurement errors, grass and low herbal vegetation. (b) Repeated random selections of lidar points are used to build a set of TINs, out of which sets of elevation estimates are interpolated at the locations of DTM grid points. Note that also the remaining unfiltered vegetation points may become TIN nodes. (c) DTM elevations are approximated by adding global mean offset to the lower bounds of elevation distributions, which are unaffected by the unfiltered vegetation points.

The basic idea of the REIN algorithm (illustrated in the above figure) is to make use of the redundancy in the initially filtered point cloud in order to mitigate the effect of the residual off-ground points in the FPC. The true elevations at those locations in the X-Y plane, that we want to include into the DTM (termed DTM locations), can be approximated from repeated independent estimates of the relief. Each estimate is based on an independent random sample (termed FPCs) taken from the FPC. During each iteration the points of each FPCs are used as nodes to build a triangulated irregular network (TIN). Elevations at DTM locations are interpolated from each triangulated irregular network. After repeating the interpolation a number of times we get a distribution of elevation estimates at each DTM location. The true elevations can be estimated, based on two observations:

1. The lower bounds of the distributions are almost insensitive to positive outliers. On the other hand, the negative outliers have no effect, assuming they were removed previously. This means that, within comparable forest and relief circumstances, the lower bounds have a more or less constant vertical offset to the true bare-ground surface. Comparable forest circumstances mean a limited variation in laser penetration rates throughout the area of interest, enabling a more or less consistent efficiency of vegetation point removal in the initial filtering stage. Comparable relief circumstances mean there is a limited variation in relief coarseness.
2. The majority of the distribution bounds match the error band, assuming that (a) the sampling rates to collect FPCs were not too low and (b) relatively few positive outliers remained in the FPC. The assumption (a) implies that only rarely elevation interpolations would smooth out the relief curvature between sampled points, while the assumption (b) implies that only a few distributions have anomalous upper bounds (**Figure 9**c). Further assuming that the width of the error band is constant within comparable forest and relief circumstances, we can estimate the global mean offset between the lower distribution bounds and the true relief elevations (gmo). The gmo equals the average of differences dij = zij – zj,min over all DTM locations, where zij is the i-th elevation estimate at the j-th DTM location and zj,min is the lowest elevation estimate at the j-th DTM location.

After computing gmo and all the zj,min, the estimate of the true elevation zj at the j-th DTM location is:

$$z_j = z_{j,min} + gmo$$

Note that simply drawing a random sample out of the available ground points during each iteration of REIN would yield TINs that are overly detailed in areas of high point density and too generalized in areas of low point density. Such irregularities are caused by variable penetration rates in a heterogeneous forests and by irregularly spaced scan-lines. It is therefore important that each sample of points used as TIN nodes should be spatially as unbiased as possible. This is ensured by a selection procedure, where a set of random locations in X-Y plane is generated within the bounds of the filtered point cloud and then the nearest point found for each random location is chosen. Thus the sparse lidar ground returns under very dense forest canopy have higher chance of being selected than the more frequent ground returns in less dense forest stands, enabling REIN to give more consistent results irrespective of canopy cover.

The operation of REIN is guided by two parameters – samplesize (the number of points in each FPCs) and numsamples (the number of iterations).

2.4.4. Continuity of forest canopy cover

The criterion "Continuity of forest canopy cover" corresponds to the change indicator "Spatial pattern of gaps in the forest stand canopy". The change of the indicator will be analysed after the acquisition of the post-treatment lidar data. This indicator is related to the MCPFE indicators 3.1 Increment and fellings, 4.2 Regeneration and 4.7 Landscape pattern. The discontinuities (gaps) in forest canopy reaching to the ground are the centers of forest rejuvenation. Their areal percentage and spatial juxtaposition is an important indicator of forest stand developmental and ecological status.

The indicator is gleaned from the lidar based high-resolution digital canopy model (DCM). DCM contains the vegetation heights, estimated from lidar point cloud with known relative heights above bare ground (that is why we first need a DTM). DCM vegetation heights were computed in a rectangular grid with the horizontal resolution of 1 m x 1 m. All types of lidar returns were taken into account. For each return its height above the bare ground was computed using bilinear interpolation from the neighbouring DTM grid points. The highest lidar return within each grid cell was considered as the vegetation height for this grid cell.

DCMs have been computed for all three Slovenian test areas. The gaps in forest stand canopy have been identified from DCM as those areas where vegetation heights do not exceed 1 m, i.e. discontinuities or gaps in the forest canopy cover. In addition, the depth of the internal forest environment was computed as proximity to the nearest gap in forest stand canopy.

2.4.5. Amount of forest canopy cover

The criterion "Amount of forest canopy cover" corresponds to the indicator "Forest canopy cover pattern". The change of the indicator will be analysed after the acquisition of the post-treatment lidar data. This indicator is related to the MCPFE indicators 3.1 Increment and fellings, 4.2 Regeneration and 4.7 Landscape pattern. Canopy cover regulates the light conditions in the stand and thus also increment, rejuvenation, species composition etc. Lidar technology enables computing continuous gradients of this indicator over large areas, enabling more informed sylvicultural treatments. This is an alternative indicator to the Spatial pattern of gaps in the forest stand canopy.

The indicator is gleaned from the lidar based digital forest canopy cover map. Canopy cover (CC) is given as a numerical value between 0 and 1, computed for each cell in the 1 by 1 m grid as the ratio of ground-to-vegetation frequencies of different return types:

$$CC = 1 - [(N_{first,ground} + N_{intermediate,ground} + N_{last,ground} + N_{only,ground}) / N_{all}]$$

where:

CC ... canopy cover

$N_{first,ground}$, $N_{intermediate,ground}$, $N_{last,ground}$, $N_{only,ground}$... *frequencies of those first, intermediate, last and only returns in the cell, respectively, that are 1 m or less above bare ground*

N_{all} ... *total frequency of all first, intermediate, last and only returns in the cell*

CC maps have been computed for all three Slovenian test areas.

2.4.6. Forest stand productivity potential

The criterion "Forest stand productivity potential" corresponds to the indicator "Volume of photosyntheticaly active forest canopy". This indicator is related to the MCPFE indicators 3.1 Increment and fellings and 4.7 Landscape pattern. The amount of the photosyntheticaly active part of the forest stand canopy is a proxy for the stand productivity. As the canopy is a 3-D structure it can be gleaned from the lidar point cloud. The rectangular 3-D pixels (voxels) are classified into 'filled' (by lidar returns) and 'empty' voxels. The upper 65% of filled voxels (i.e., containing at least one return) in each column are considered the photosynthetically active part of the canopy, according to (Lefsky et al. 1999, Lidar remote sensing of the canopy structure ..., Remote Sening of Environment, 70: 339-361).

The procedure of 3-D detection of photosynthetically active part of the forest stand canopy has been conceptually tested in a pilot case study in the Trnovo test site on a pre-treatment spruce plot that was to be 50% thinned. The change of the indicator will be analysed for all three Slovenian test areas after the acquisition of the post-treatment lidar data.

2.4. *Results from Sub-action 2 – Activities in Slovenia*

2.4.1. Kočevski Rog – Site 8

In Kočevski Rog test area (Figure 10, Table 1) the forest covers a total area of 9537,8 ha, representing 95,4% of the total landscape. The forest core area covers 6793,7 ha, representing 71,2% of the forest area and 67,9% of the total landscape. The total core area is distributed among 7 disjunct patches, 4 of which are 10 ha or larger (Figure 11). The tentatively monotemporal results of the lidar based analysis at the forest stand level are presented in Figure 12, Figure 13, Figure 14 and Figure 15.

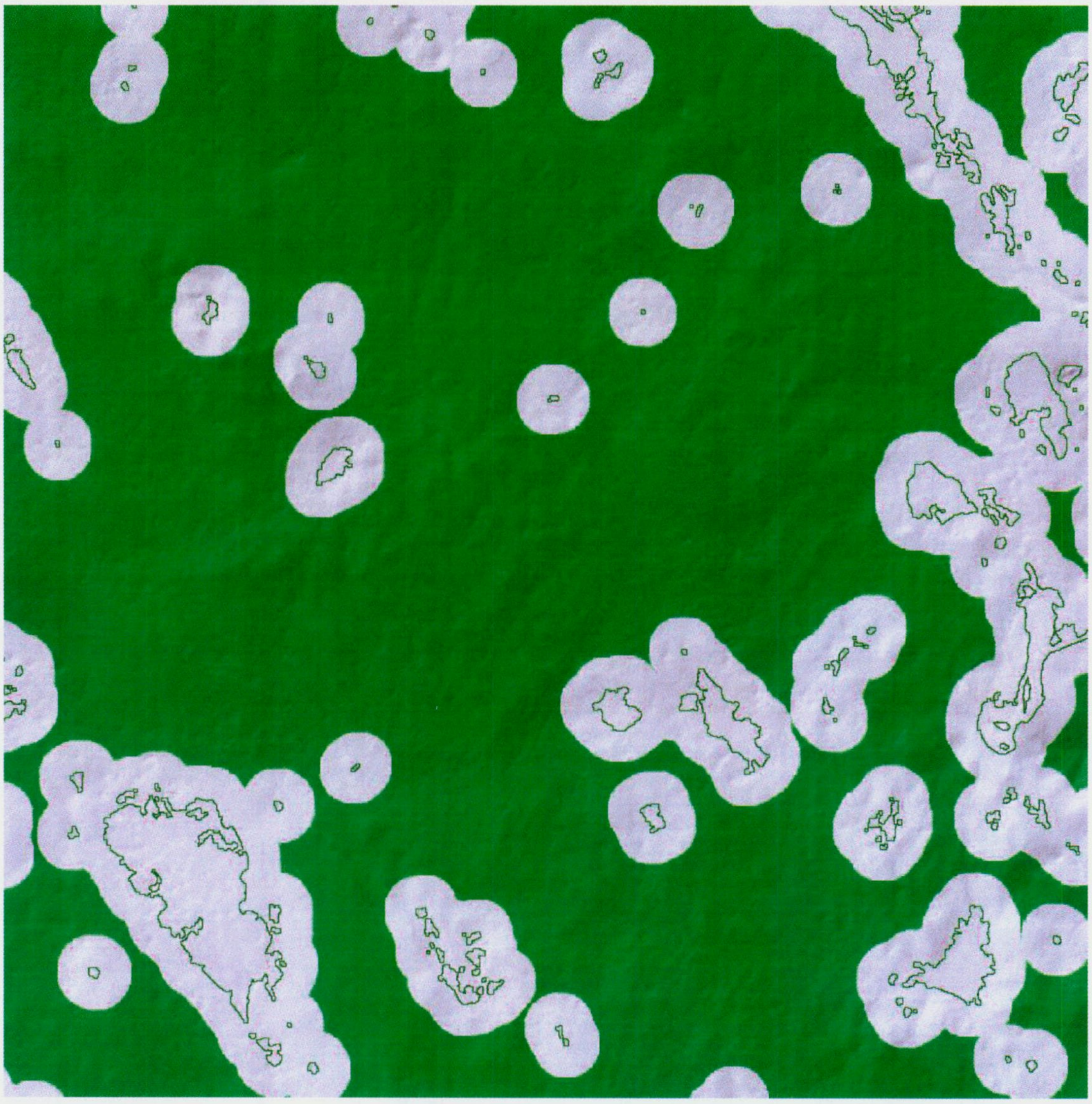

Figure 10: The core area of forest (green) in the Kočevski Rog test area. The green line delineates forest edge. The forest core area is the internal area of large forest patches, that is sufficiently far from the forest edge (in our case 300 m), so that nonforest disturbances are not felt.

Figure 11: Color-coded disjunct core area patches in the Kočevski Rog test area. Note that »disjunct« is meant in the spatial context of the entire Slovenia.

Table 1: Statistics of the core areas in the Kočevska test area

Core area ID	Frequency of pixels	Area (ha)	Percent of landscape
Non-CA	320632	3206,3	32,1%
1	668293	6682,9	66,8%
2	8063	80,6	0,8%
3	1513	15,1	0,2%
4	1493	14,9	0,1%
5	2	0,0	0,0%
6	2	0,0	0,0%
7	2	0,0	0,0%
Total CA	679368	6793,7	67,9%
Grand total	1000000	10000,0	100,0%

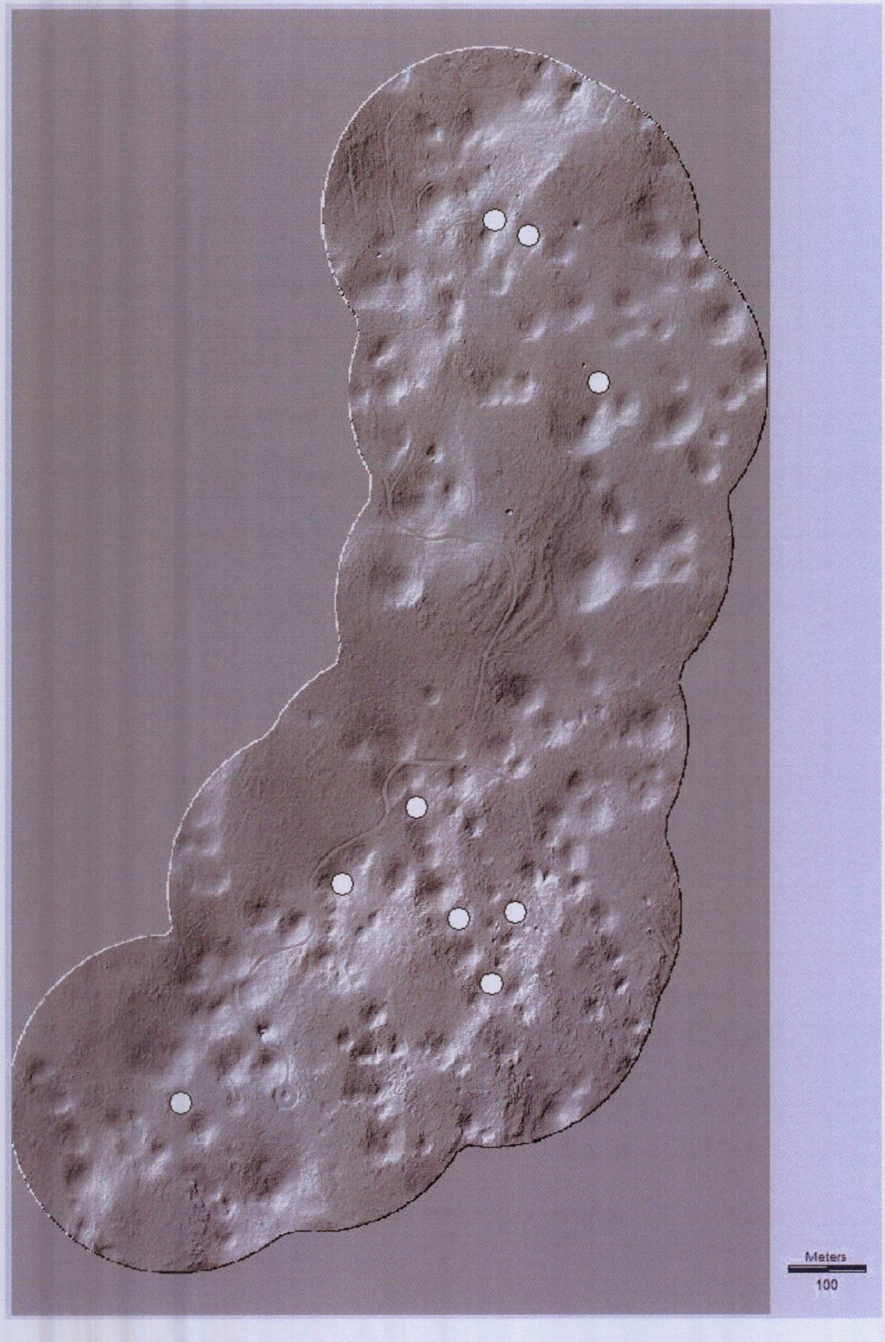

Figure 12: Kočevski Rog test site. The shaded image of the high resolution (1 meter) lidar digital terrain model. White dots indicate the locations of the nine treatment plots within this test area. An accurate high-resolution DTM is needed as a precondition for many lidar based forest stand analyses, because we first need to know the relative height of each point above bare ground. This relative height is computed as the difference between the point elevation and the local DTM elevation.

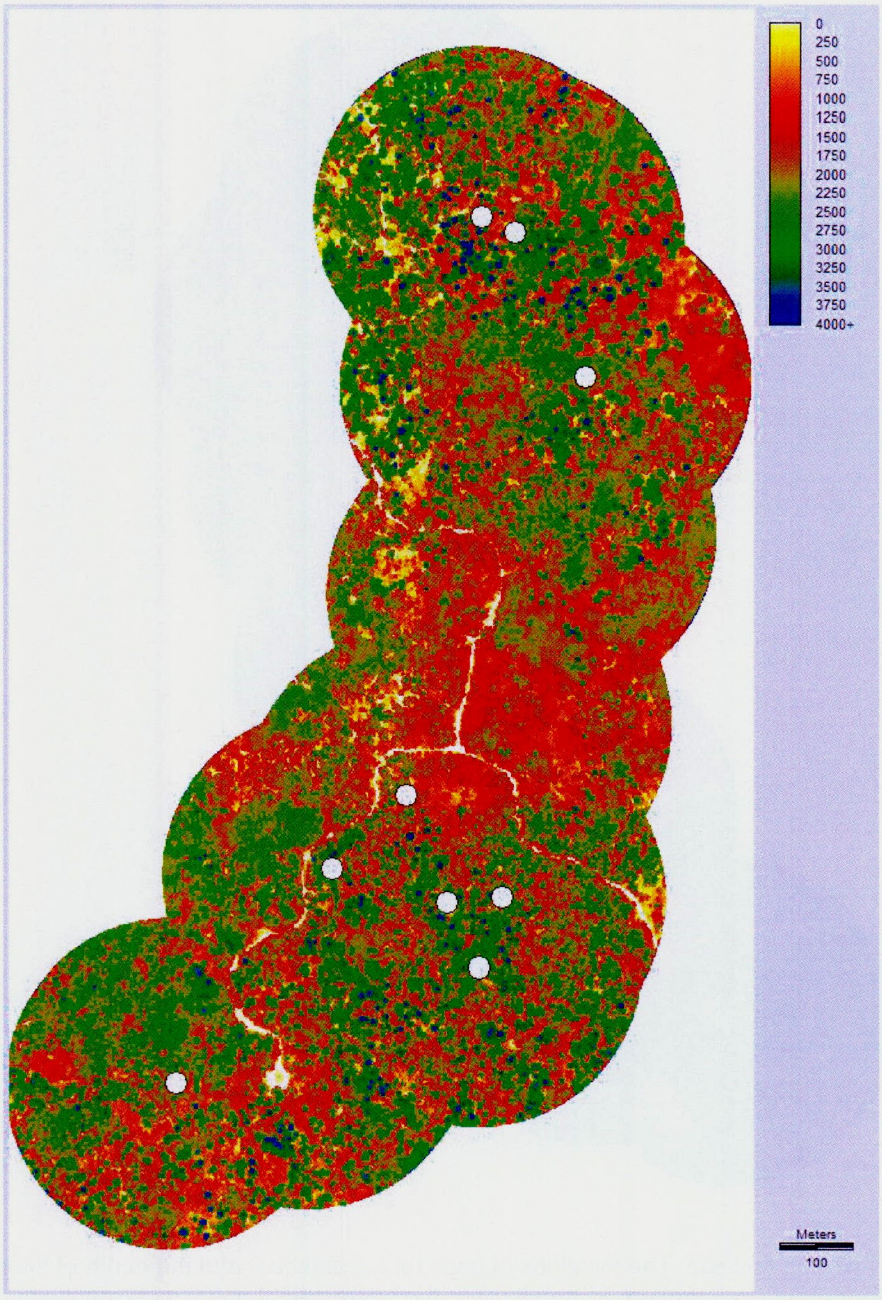

Figure 13: Kočevski Rog test site. The digital canopy model (i.e., forest vegetation heights), heights given in centimeters, horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. DCM will be the basis for computing the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

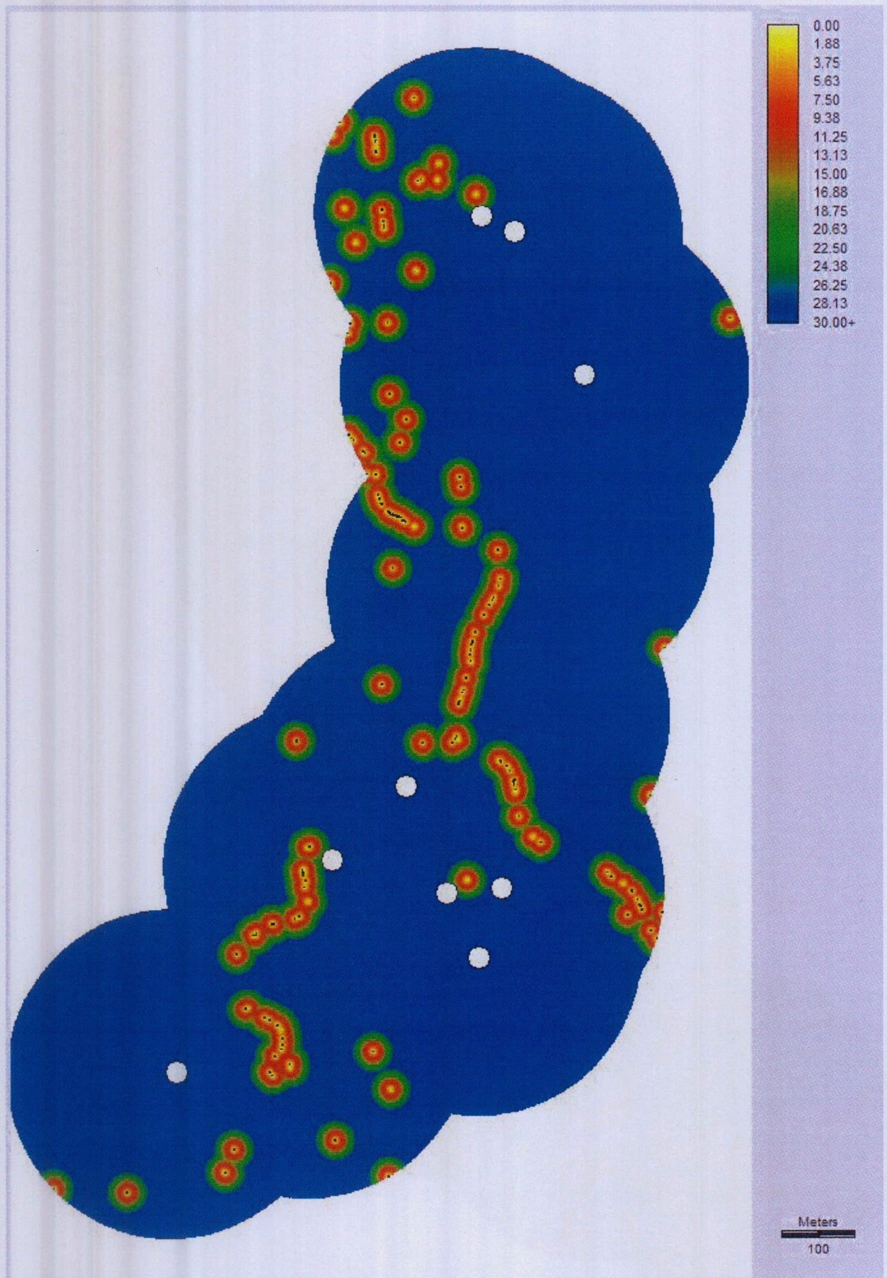

Figure 14: Kočevski Rog test site. The locations of gaps (black patches) and the depth of the internal forest environment. Depth is given in meters as proximity to the nearest light gap (i.e., discontinuity in the forest canopy cover). White dots indicate the locations of the nine treatment plots within this test area. The pattern of the gaps will also be considered in order to compute the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

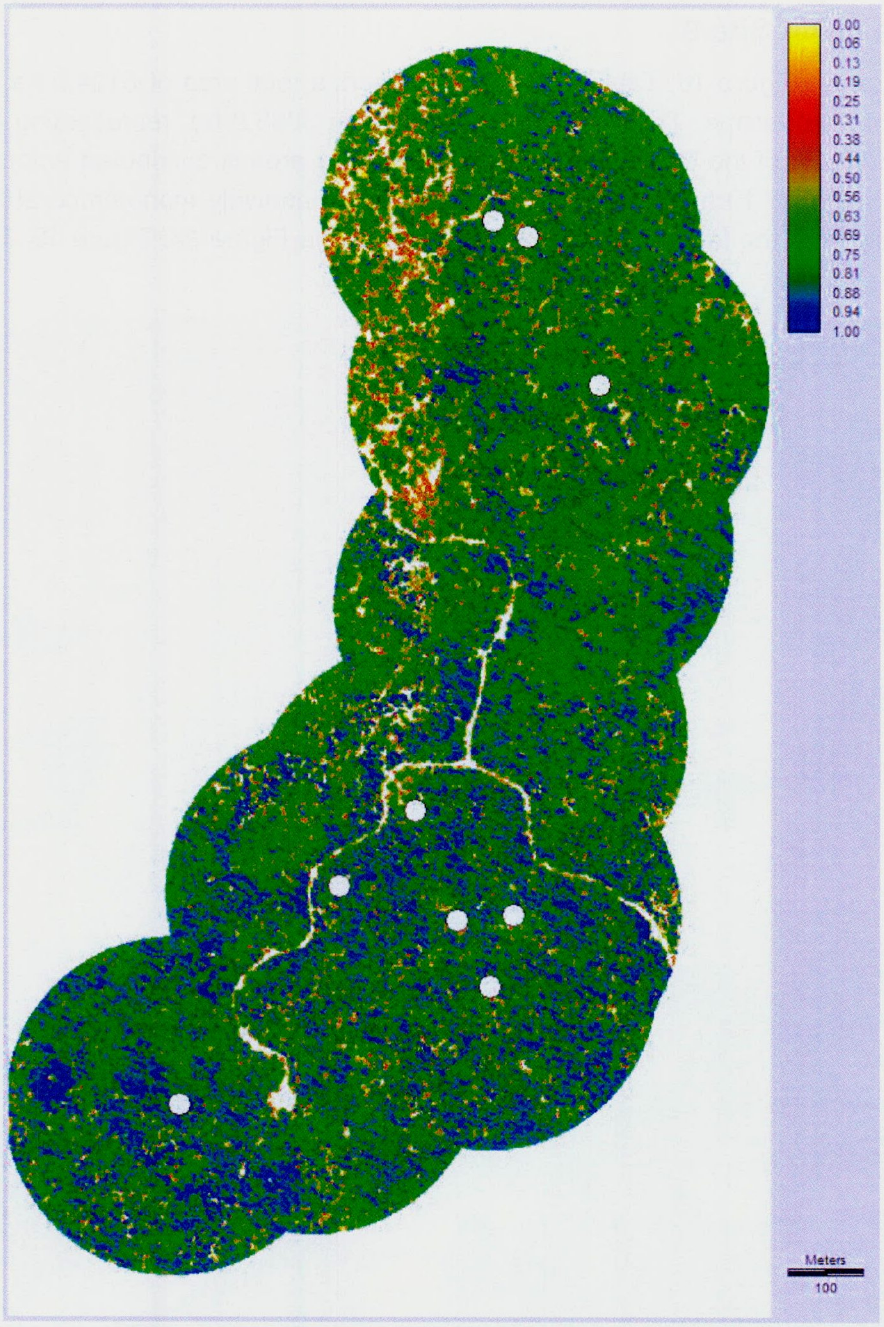

Figure 15: Kočevski Rog test site. The amount of forest canopy cover (i.e., 0.0 meaning no forest canopy cover and 1.0 meaning 100% cover), horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. The amount of forest canopy cover will be the basis for computing the change of the indicator "Forest canopy cover pattern".

2.4.2. Snežnik – Site 9

In Snežnik test area (Figure 16, Table 2) the forest covers a total area of 8104,9 ha, representing 81,0% of the total landscape. The forest core area covers 3868,9 ha, representing 47,7% of the forest area and 38,7% of the total landscape. The total core area is distributed among 12 disjunct patches, 5 of which are 10 ha or larger (Figure 17). The tentatively monotemporal results of the lidar based analysis at the forest stand level are presented in Figure 18, Figure 19, Figure 20 and Figure 21.

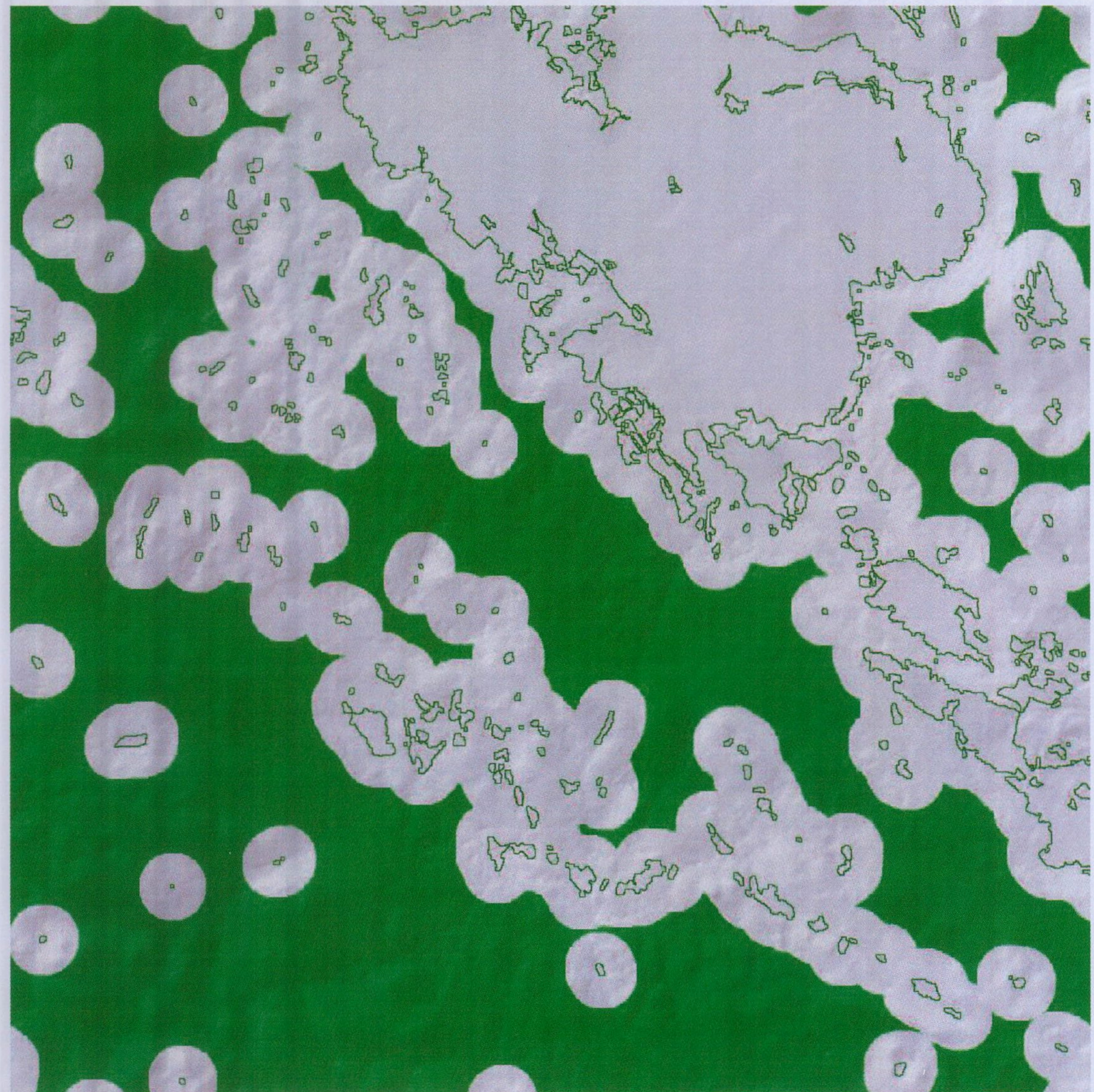

Figure 16: The core area of forest (green) in the Snežnik test area. The green line delineates forest edge. The forest core area is the internal area of large forest patches, that is sufficiently far from the forest edge (in our case 300 m), so that nonforest disturbances are not felt.

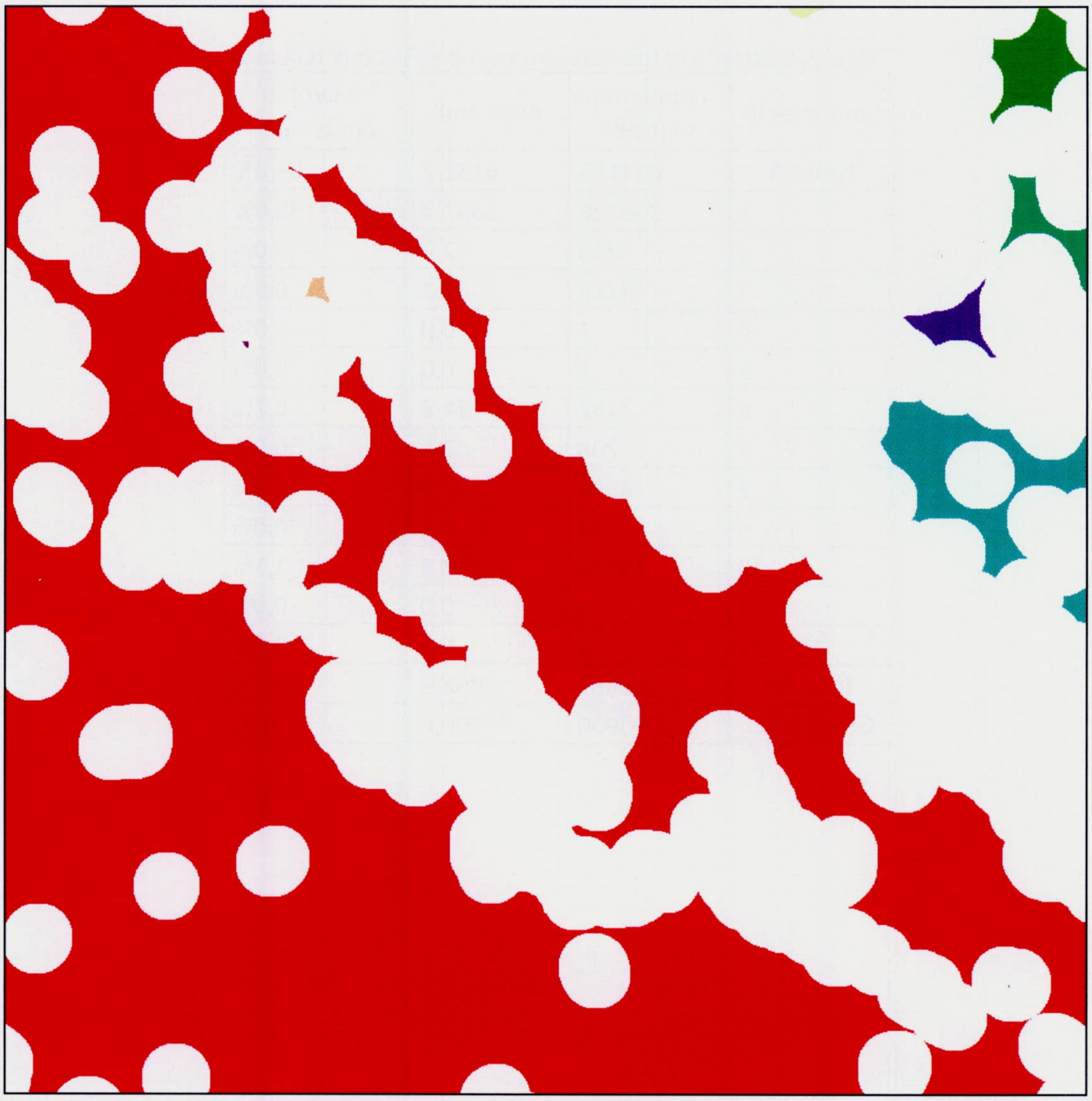

Figure 17: Color-coded disjunct core area patches in the Snežnik test area. Note that »disjunct« is meant in the spatial context of the entire Slovenia.

Table 2: Statistics of the core areas in the Snežnik test area

Core area ID	Frequency of pixels	Area (ha)	Percent of landscape
Non-CA	613115	6131,2	61,3%
1	366226	3662,3	36,6%
2	218	2,2	0,0%
3	4718	47,2	0,5%
4	1	0,0	0,0%
5	2	0,0	0,0%
6	2482	24,8	0,2%
7	288	2,9	0,0%
8	2090	20,9	0,2%
9	24	0,2	0,0%
10	10834	108,3	1,1%
11	1	0,0	0,0%
12	1	0,0	0,0%
Total CA	386885	3868,9	38,7%
Grand total	1000000	10000,0	100,0%

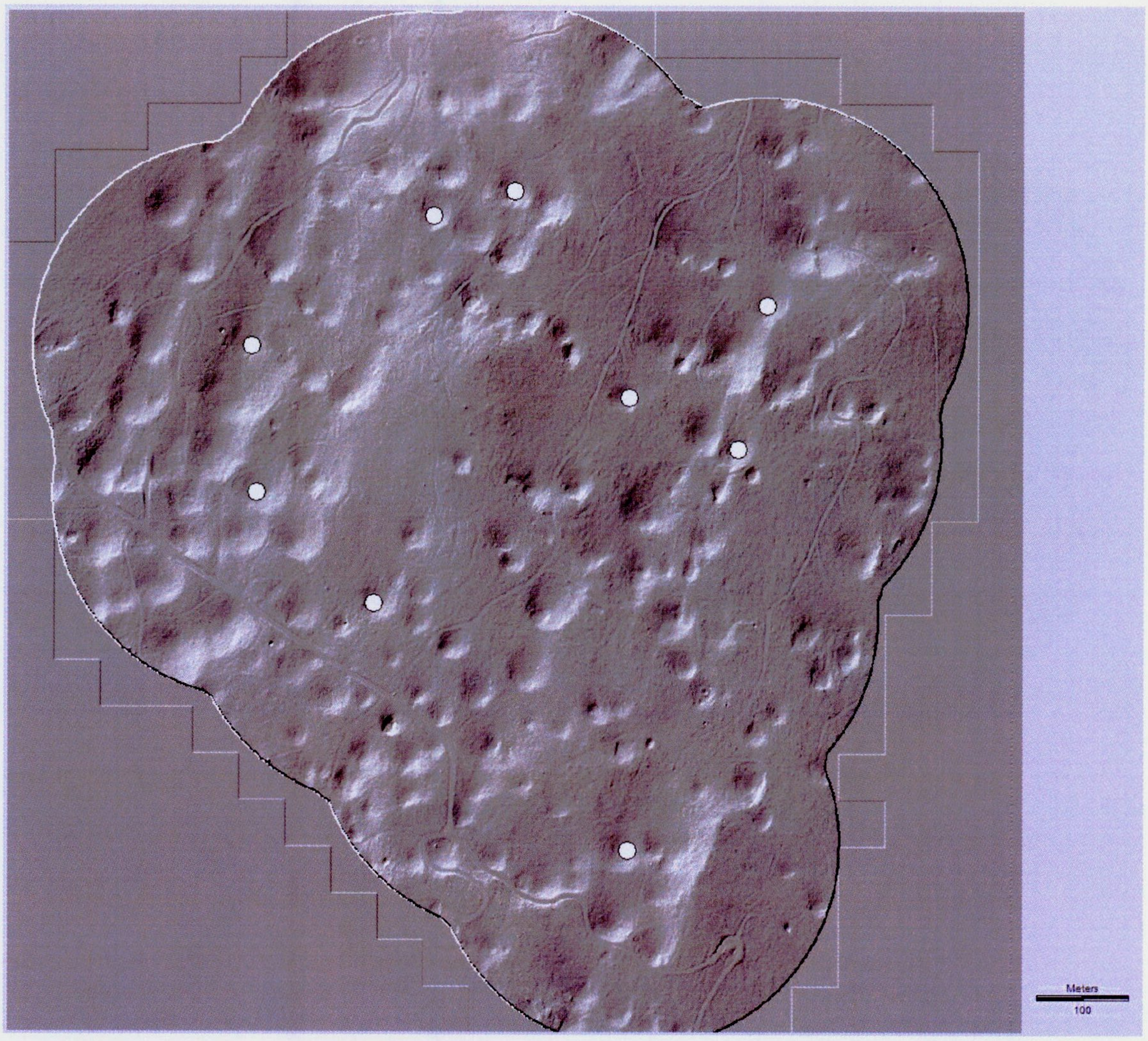

Figure 18: Snežnik test site. The shaded image of the high resolution (1 meter) lidar digital terrain model. White dots indicate the locations of the nine treatment plots within this test area. An accurate high-resolution DTM is needed as a precondition for many lidar based forest stand analyses, because we first need to know the relative height of each point above bare ground. This relative height is computed as the difference between the point elevation and the local DTM elevation.

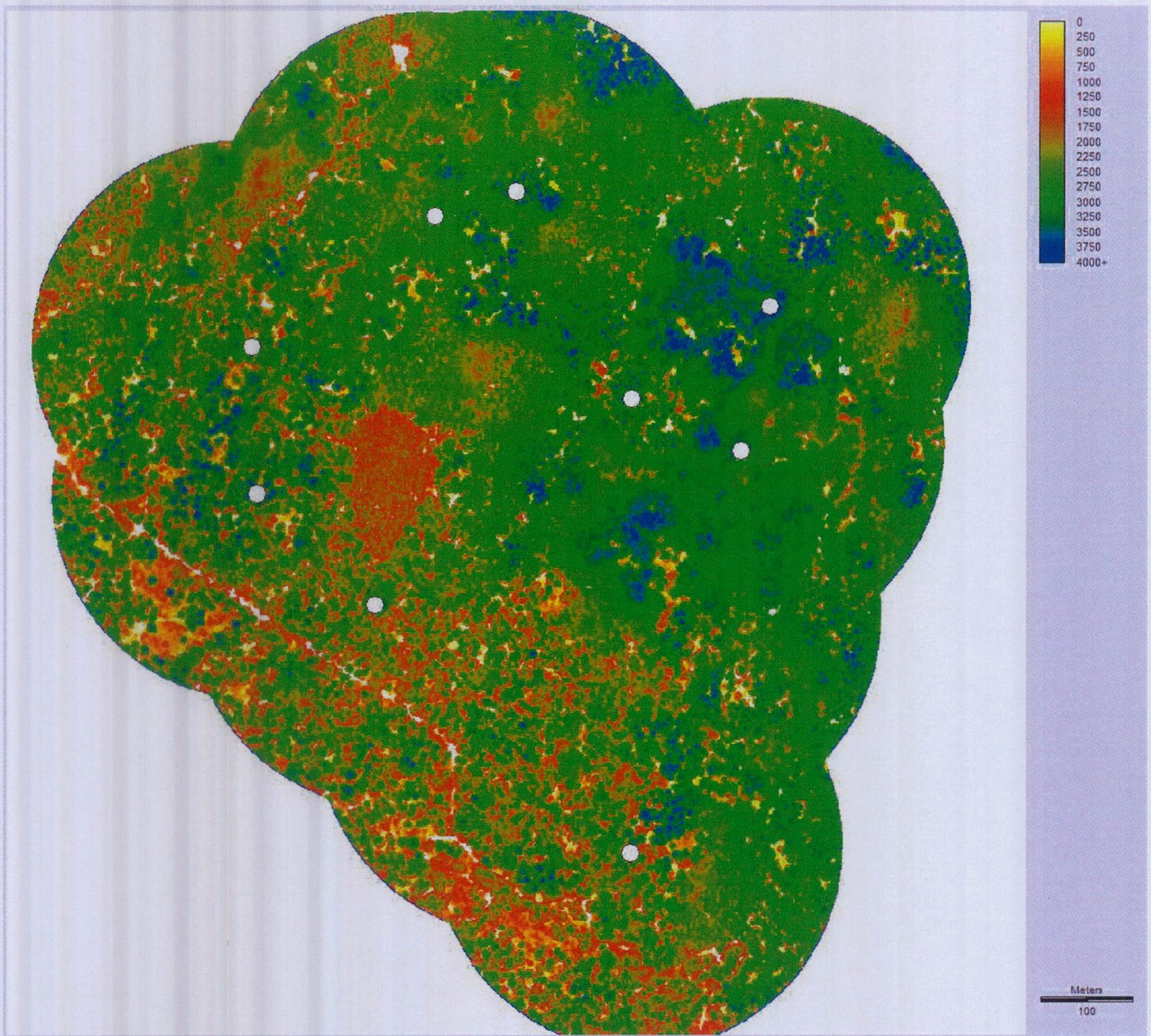

Figure 19: Snežnik test site. The digital canopy model (i.e., forest vegetation heights), heights given in centimeters, horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. DCM will be the basis for computing the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

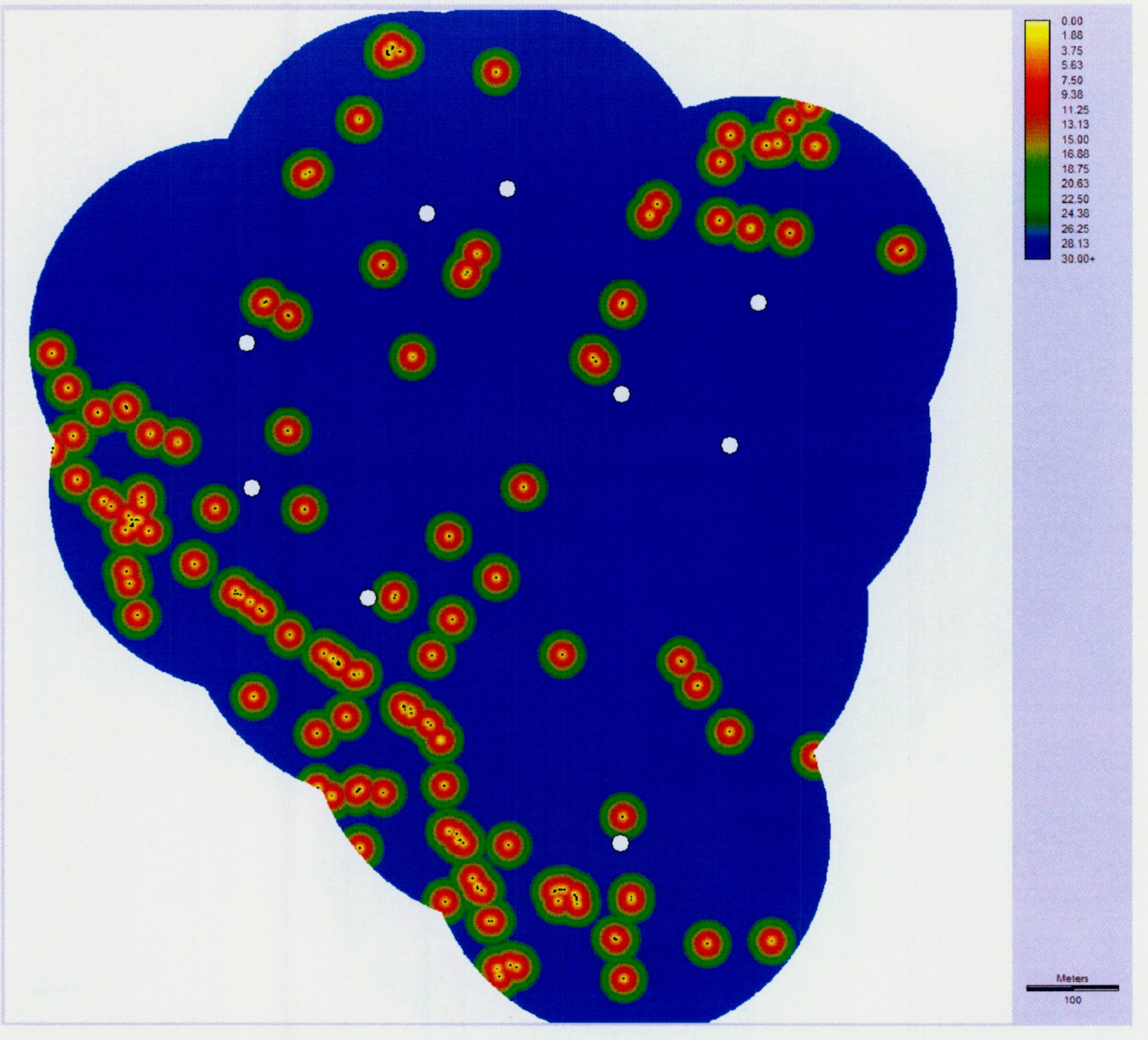

Figure 20: Snežnik test site. The locations of gaps (black patches) and the depth of the internal forest environment. Depth is given in meters as proximity to the nearest gaps (i.e., discontinuity in the forest canopy cover). White dots indicate the locations of the nine treatment plots within this test area. The pattern of the gaps will also be considered in order to compute the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

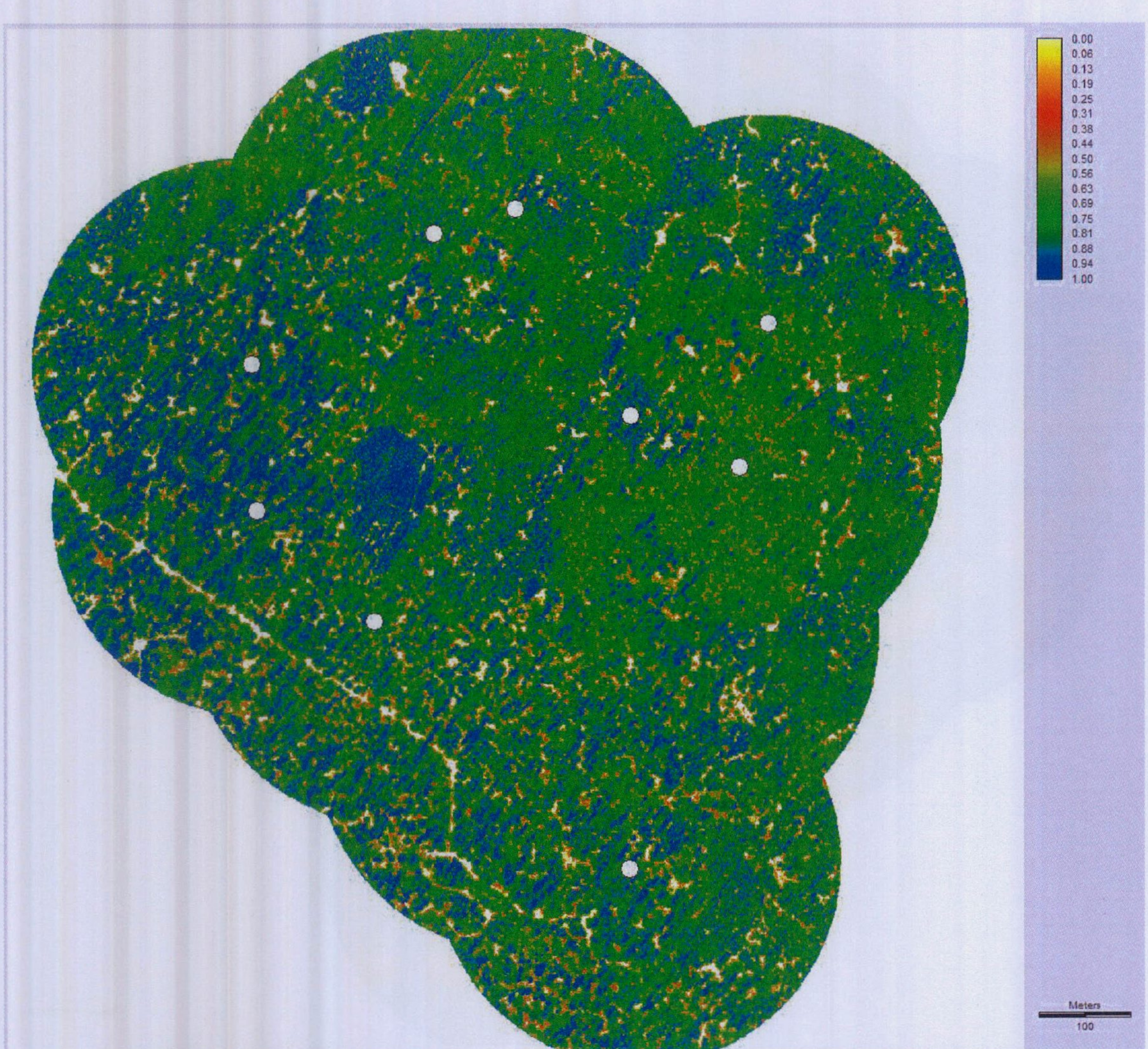

Figure 21: Snežnik test site. The amount of forest canopy cover (i.e., 0.0 meaning no forest canopy cover and 1.0 meaning 100% cover), horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. The amount of forest canopy cover will be the basis for computing the change of the indicator "Forest canopy cover pattern".

2.4.3. Trnovo – Site 10

In Trnovo test area (Figure 22, Table 3) the forest covers a total area of 8459,9 ha, representing 84,6% of the total landscape. The forest core area covers 3387,9 ha, representing 40,0% of the forest area and 33,9% of the total landscape. The total core area is distributed among 23 disjunct patches, 9 of which are 10 ha or larger (Figure 23). The tentatively monotemporal results of the lidar based analysis at the forest stand level are presented in Figure 24, Figure 25, Figure 26 and Figure 27.

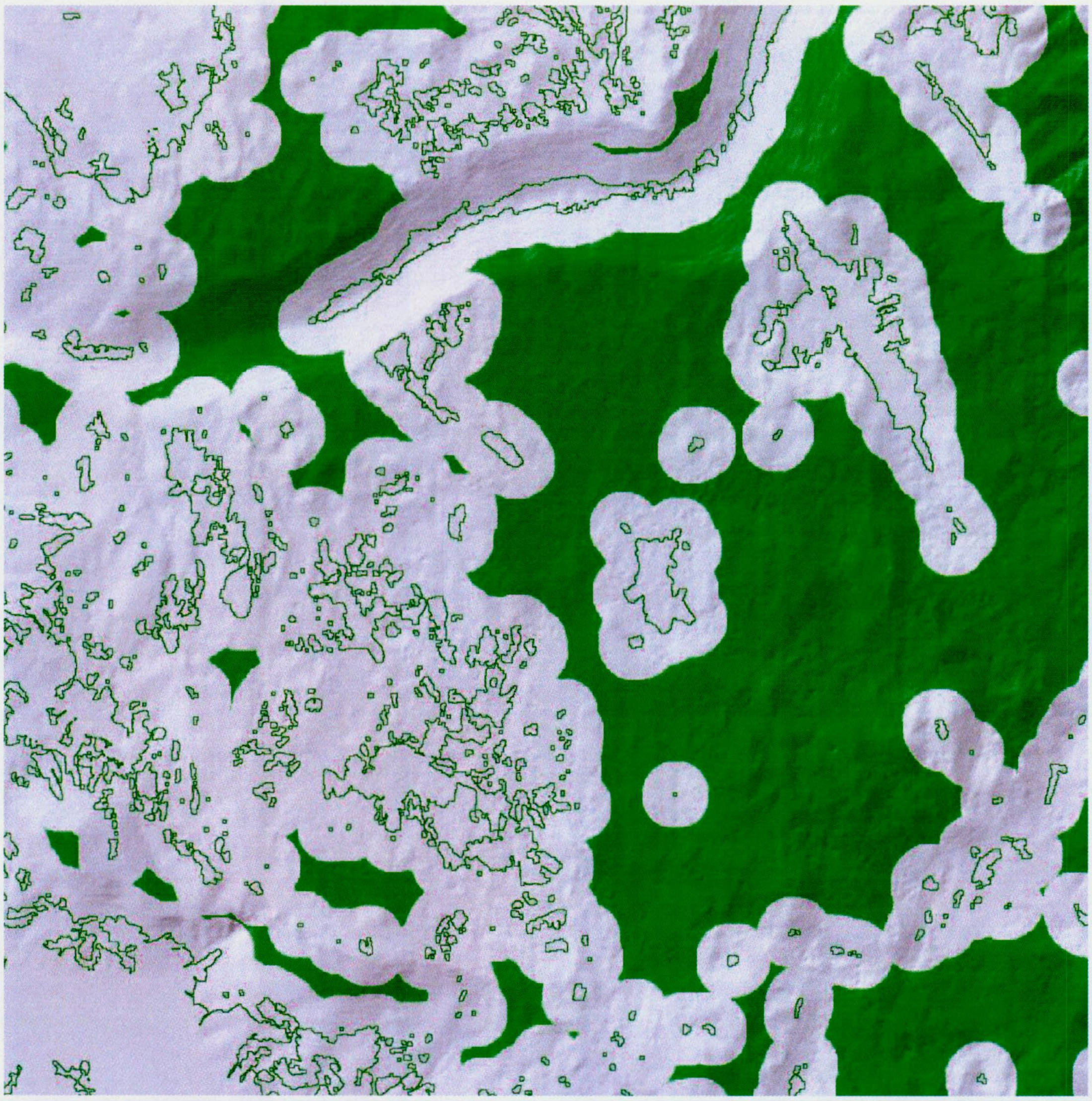

Figure 22: The core area of forest (green) in the Trnovo test area. The green line delineates forest edge. The forest core area is the internal area of large forest patches, that is sufficiently far from the forest edge (in our case 300 m), so that nonforest disturbances are not felt.

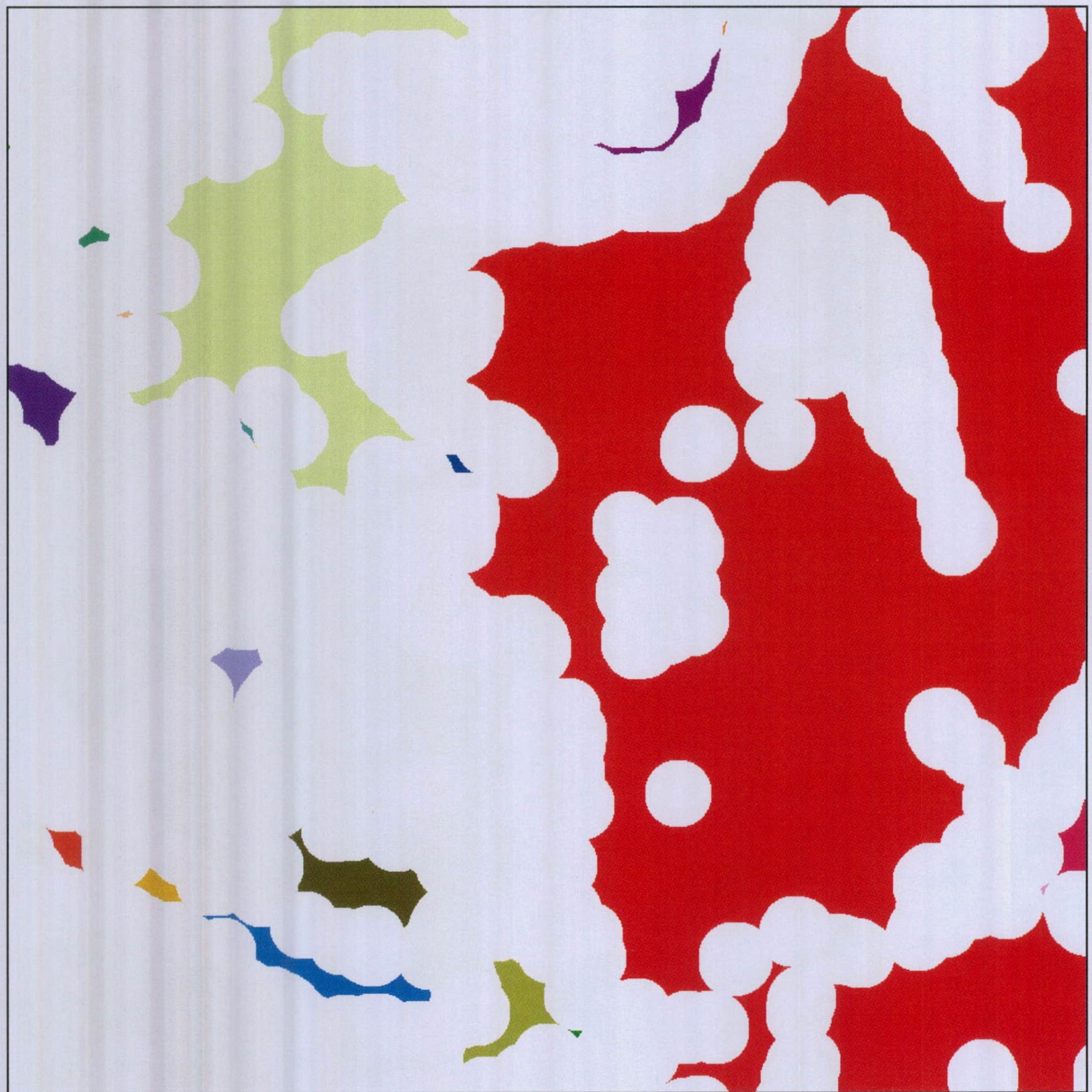

Figure 23: Color-coded disjunct core area patches in the Trnovo test area. Note that »disjunct« is meant in the spatial context of the entire Slovenia.

Table 3: Statistics of the core areas in the Trnovo test area

Core area ID	Frequency of pixels	Area (ha)	Percent of landscape
Non-CA	661214	6612,1	66,1%
1	280029	2800,3	28,0%
2	40407	404,1	4,0%
3	8	0,1	0,0%
4	22	0,2	0,0%
5	1465	14,7	0,1%
6	286	2,9	0,0%
7	51	0,5	0,0%
8	2548	25,5	0,3%
9	1	0,0	0,0%
10	80	0,8	0,0%
11	3	0,0	0,0%
12	197	2,0	0,0%
13	1022	10,2	0,1%
14	4	0,0	0,0%
15	1125	11,3	0,1%
16	728	7,3	0,1%
17	4417	44,2	0,4%
18	647	6,5	0,1%
19	31	0,3	0,0%
20	2942	29,4	0,3%
21	2726	27,3	0,3%
22	46	0,5	0,0%
23	1	0,0	0,0%
Total CA	338786	3387,9	33,9%
Grand total	1000000	10000	100,0%

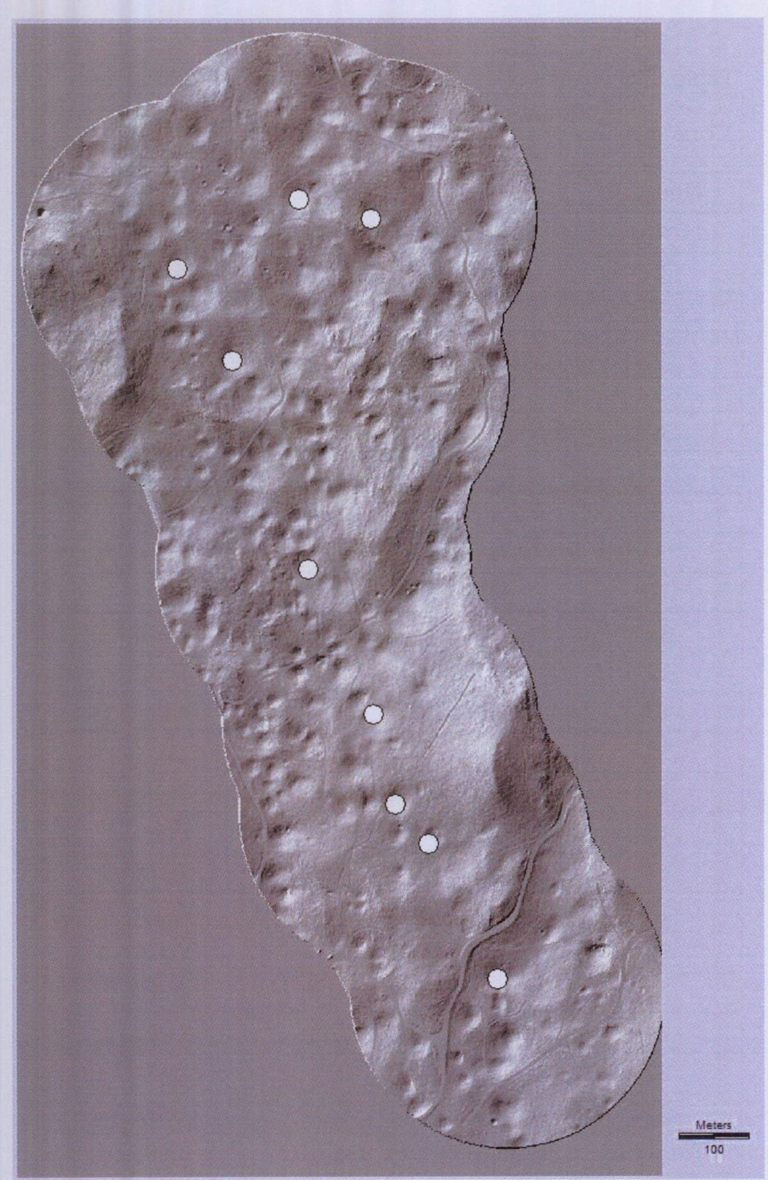

Figure 24: Trnovo test site. The shaded image of the high resolution (1 meter) lidar digital terrain model. White dots indicate the locations of the nine treatment plots within this test area. An accurate high-resolution DTM is needed as a precondition for many lidar based forest stand analyses, because we first need to know the relative height of each point above bare ground. This height is computed as the difference between the point elevation and the local DTM elevation.

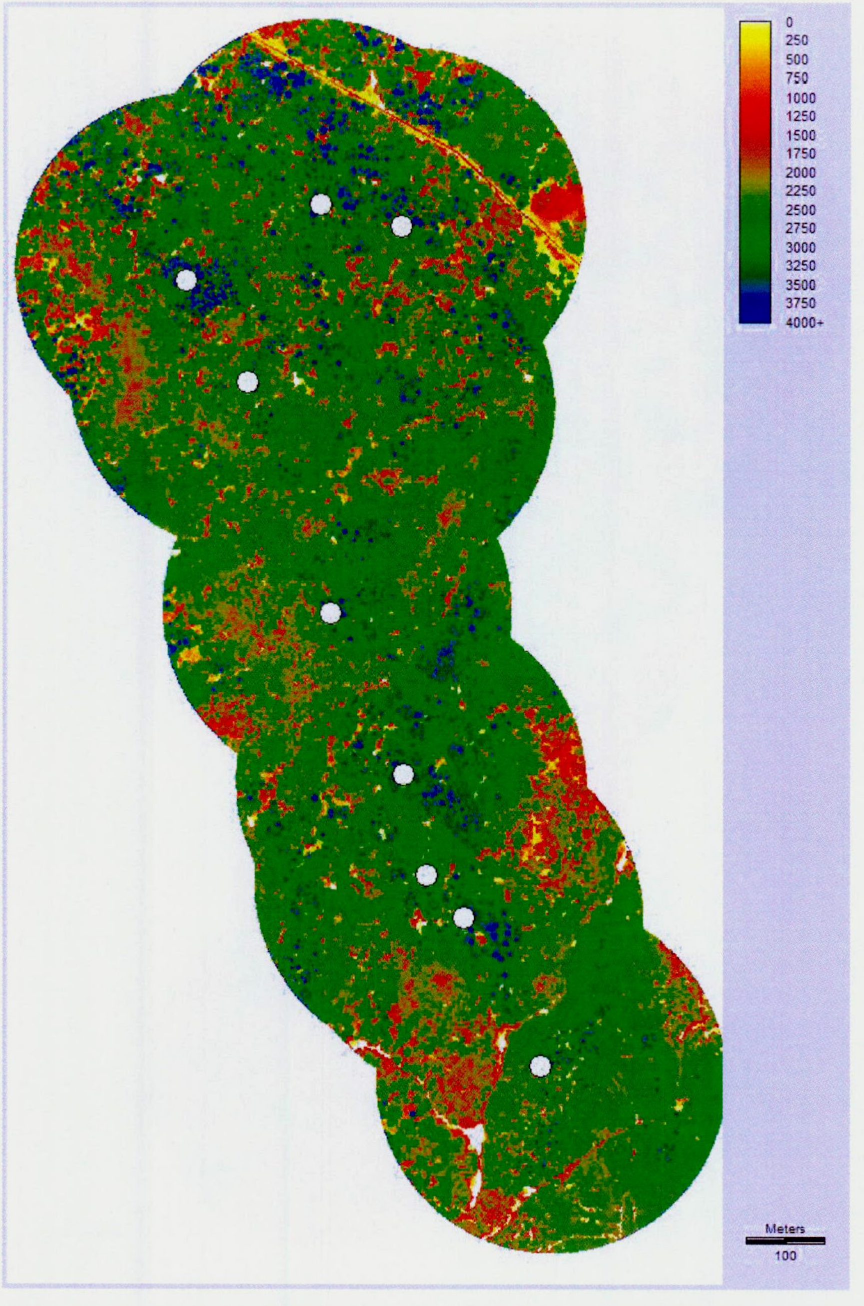

Figure 25: Trnovo test site. The digital canopy model (i.e., forest vegetation heights), heights given in centimeters, horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. DCM will be the basis for computing the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

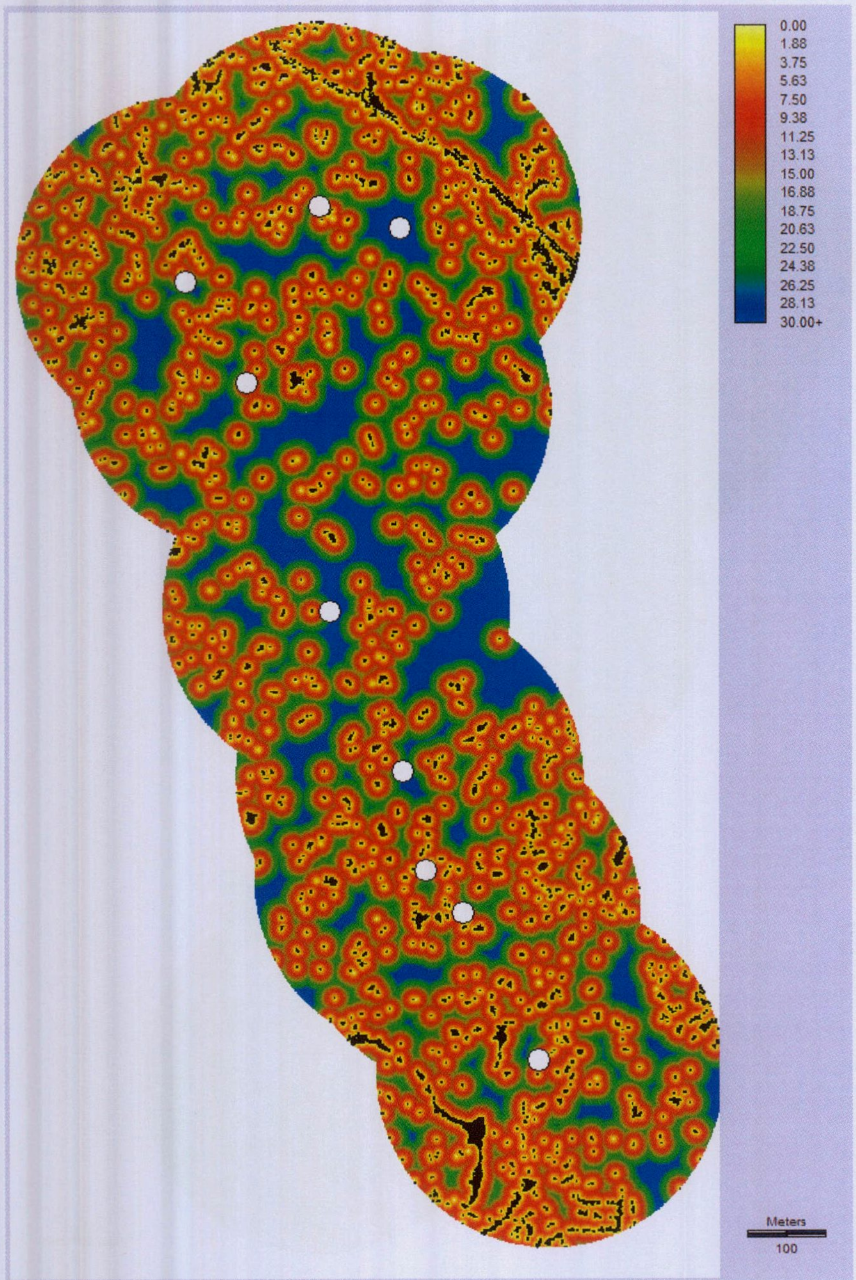

Figure 26: Trnovo test site. The locations of gaps (black patches) and the depth of the internal forest environment. Depth is given in meters as proximity to the nearest gaps (i.e., discontinuity in the forest canopy cover). White dots indicate the locations of the nine treatment plots within this test area. The pattern of the gaps will also be considered in order to compute the change of the indicator "Spatial pattern of gaps in the forest stand canopy".

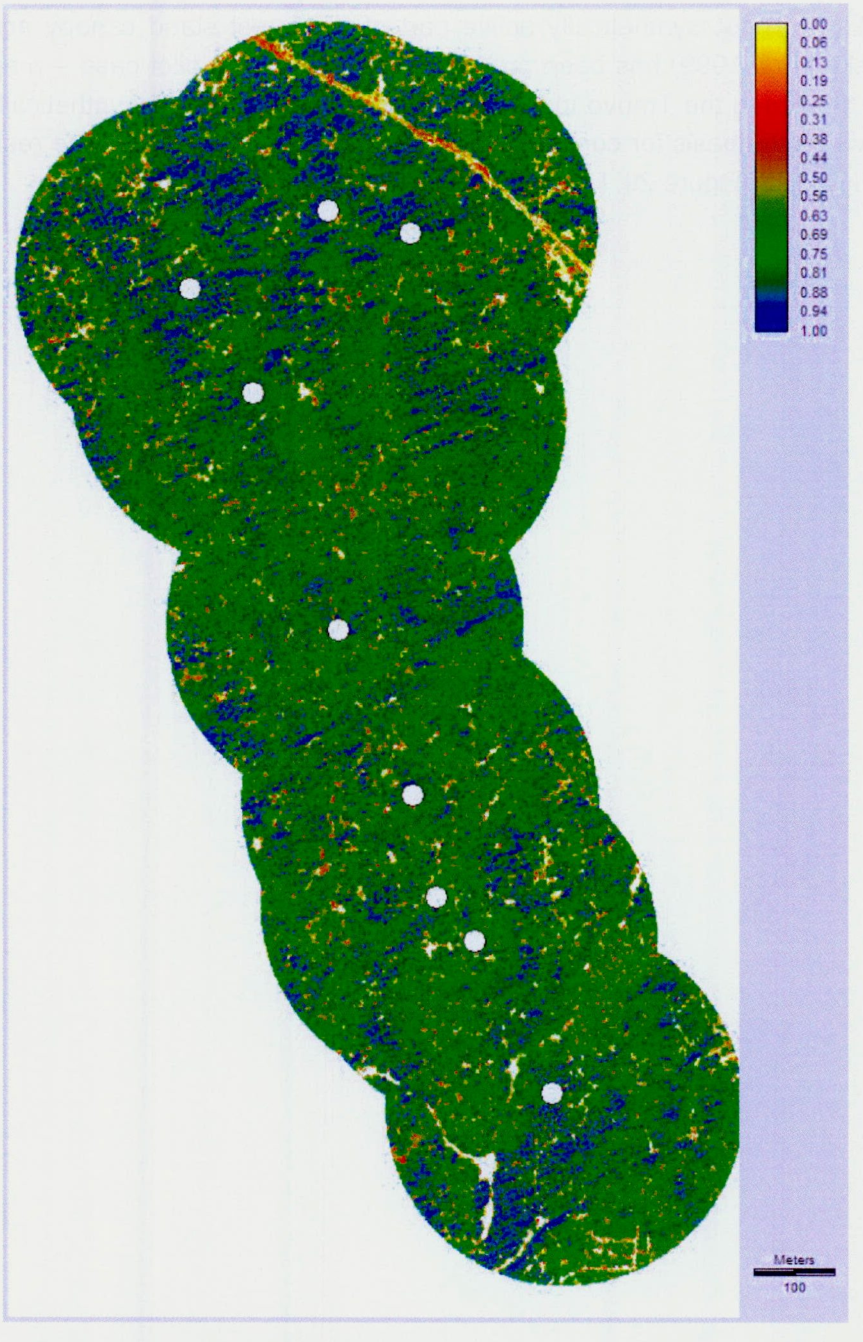

Figure 27: Trnovo test site. The amount of forest canopy cover (i.e., 0.0 meaning no forest canopy cover and 1.0 meaning 100% cover), horizontal resolution 1 m. White dots indicate the locations of the nine treatment plots within this test area. The amount of forest canopy cover will be the basis for computing the change of the indicator "Forest canopy cover pattern".

The 3-D detection of photosynthetically active part of the forest stand canopy according to the method of (Lefsky et al. 1999) has been pre-treatment tested on a pilot case – a spruce plot that was to be 50% thinned in the Trnovo test area. The amount of the photosynthetically active forest stand canopy will be the basis for computing the change of the indicator "". The results of the test are illustrated Figure 28, Figure 29, Figure 30, Figure 31 and Figure 32.

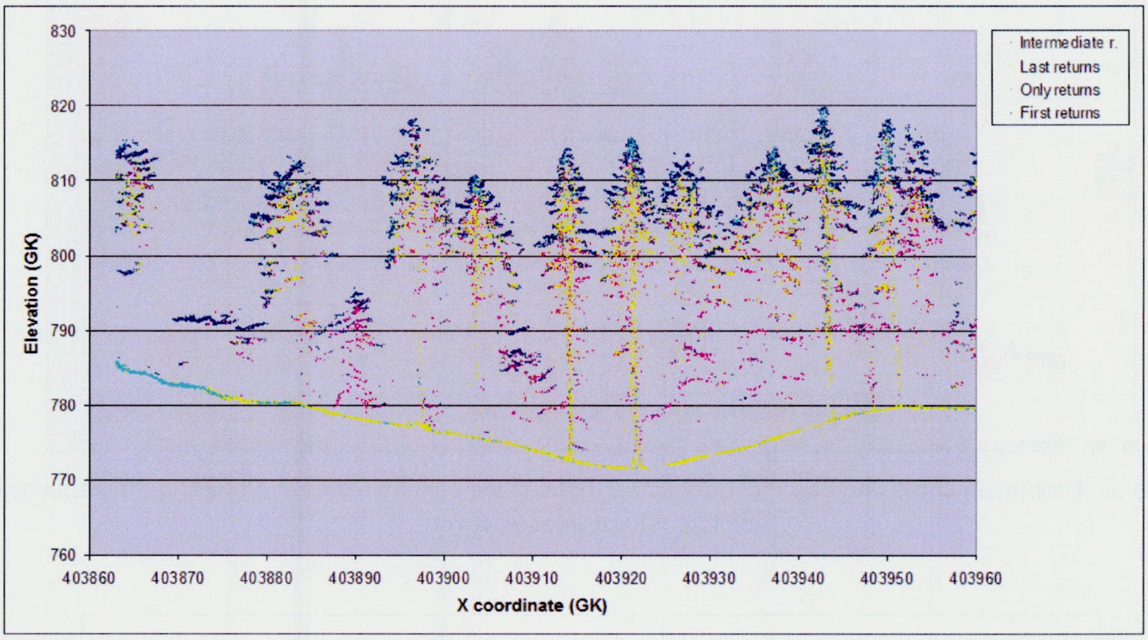

Figure 28: Estimation of the photosynthetically active forest stand canopy - step 1. Extraction of relevant lidar returns within a 100 m long and 1 m wide transect through the spruce forest stand.

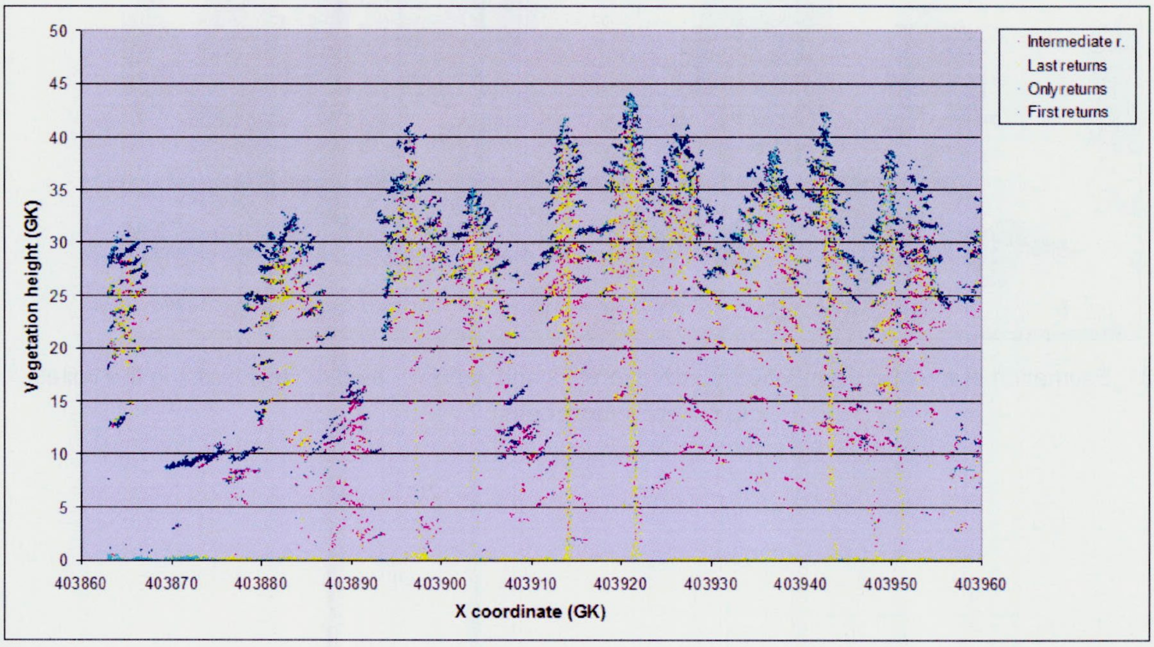

Figure 29: Estimation of the photosynthetically active forest stand canopy - step 2. Normalization of elevations above sea level to heights above bare ground, using the DTM.

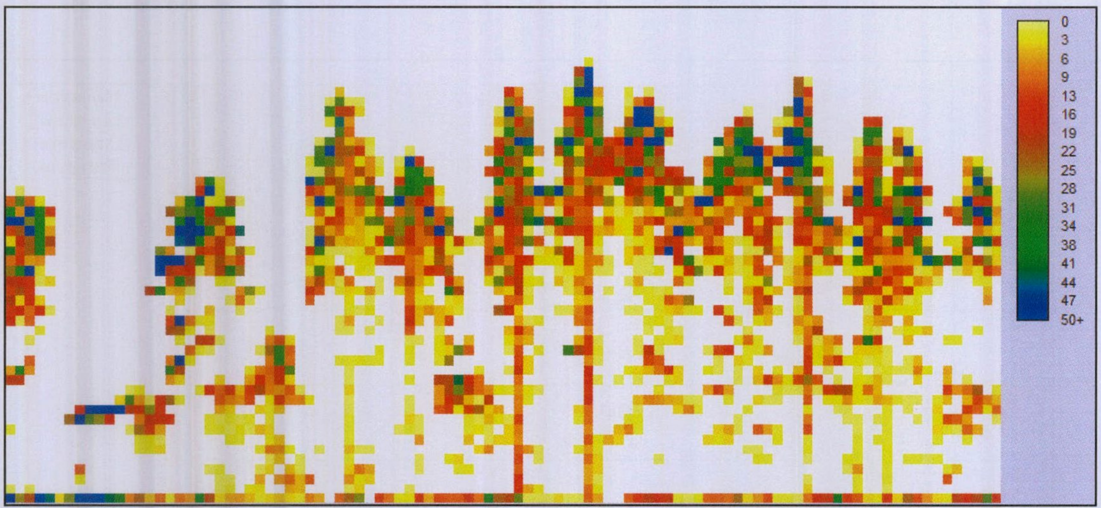

Figure 30: Estimation of the photosynthetically active forest stand canopy – step 3. Detecting the frequencies of lidar returns in each voxel.

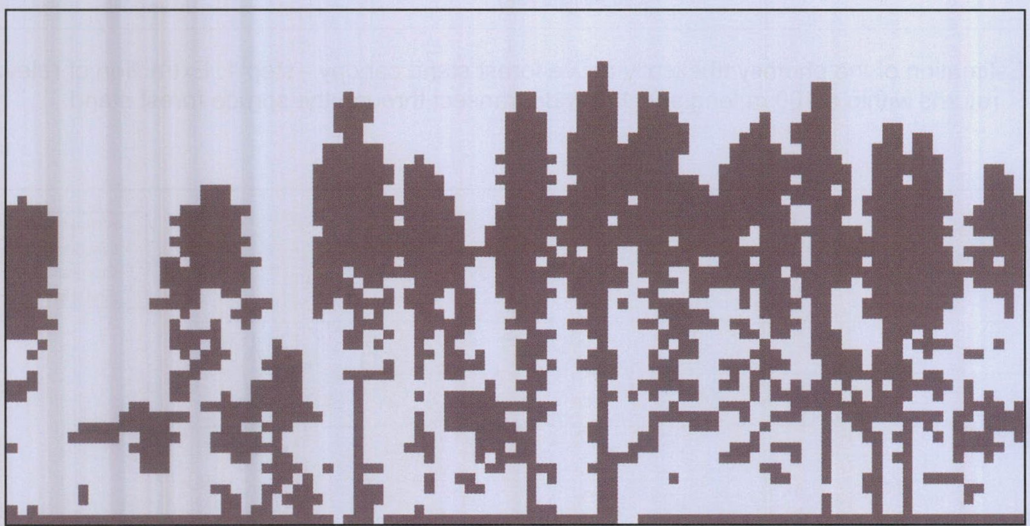

Figure 31: Estimation of the photosynthetically active forest stand canopy - step 4. Reclassifying the voxels into full and empty ones.

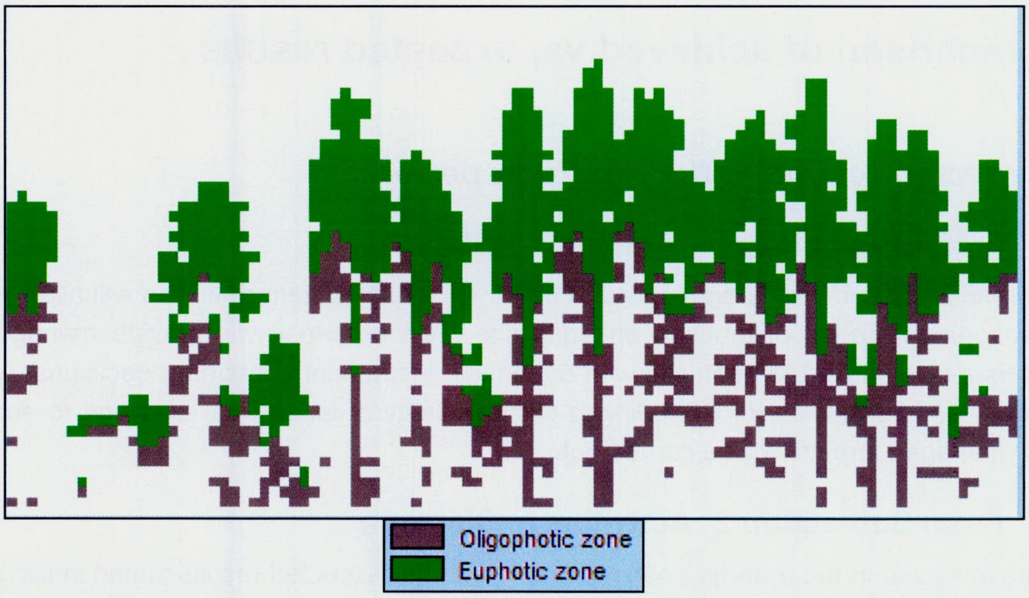

Figure 32: Estimation of the photosynthetically active forest stand canopy – step 5. Counting the upper 65% of the full voxels in each column and classifying them as the photosinthetically active zone, i.e., the euphotic zone (according to Lefsky et al. 1999).

3. Comparison of achieved vs. expected results

3.1. *Expected results in the reporting period*

3.1.1. From Sub-action 1 – Activities in Italy

Expected results concerns different aspects. First of all spatial pattern definition will allow a better forest management option distribution on each site. Furthermore it will provide managers and stakeholders directly linked to each site with a planning instrument supporting decisions. At last a description of good practices for SFM, linked to biodiversity at landscape level and to ecological function of managed forests, will be carried out.

3.1.2. From Sub-action 2- Activities in Slovenia

The results achieved in the reporting period comply with the expected results stated in the project. The lidar data were processed into digital terrain model, enabling the estimation of relative heights of cloud points above the bare ground. Based on these the digital canopy model and other products were computed, enabling us to glean the pre-treatment forest stand structure. The pre-treatment high-resolution estimation of the stand structure will be the basis for change detection after the second lidar data acquisition. As these changes will be mainly due to sylvicultural treatments, impacts of treatments upon stand structure will be gleaned. The forest core area metrics at the landscape scale have also been evaluated at the landscape scale.

3.2. *Evaluation of performance during the reporting period*

3.2.1. From Sub-action 1 – Activities in Italy

The Action ECo activities of the first reporting period have been developed in parallel with other Action activities and the expected results have been achieved.

At the end of first phase (February 2013) all seven sites have been analysed and landscape ecology metrics have been mapped for both "large" and "small" area.

The landscape context evaluation in the pre-treatment has been performed.

The spatial definition of landscape of investigation was a crucial point in this first phase of Action activities.

The small size of foreseen forest treatments (about 3 ha for each type) inside plots of about 30 ha size makes it difficult to identify forest spatial pattern for these sites. For this reason, according with other project units and in particular with that engaged of zoological aspects (since landscape extent depends on fauna indicator species choices), it was decided to extend the impact analysis caused by the different forest treatments at a bigger area all around the 30 ha size plot.

Starting from centroid of each plot, two square frames of different size (a big frame of 100 km^2 includes a smaller frame of 10 km^2) including the surrounding landscape have been drawn for all test sites.

The spatial pattern analysis have been developed within both "small" (10 km^2 square surrounding of 30 ha plot subjected to the forest treatments) and "large" area (100 km^2) (surrounding forest areas and/or other natural or semi-natural ecosystems).

The spatial pattern analysis provided quantitative metrics on the spatial structures diversity of forest areas within the "small" area and on the interaction with other land cover patches within "large" area.

The identical size for all test areas "small" (10 km^2) and "large" (100 km^2) allowed to compare the quantitative results on forest and/or no forest spatial pattern diversity of different areas with an objective method.

The forest landscape spatial pattern has been also classified by GUIDOS Software. The GUIDOS results allowed classifying the forest landscape spatial pattern in several classes which can be assimilated at potential ecological network elements. This landscape classification is more significant if related to zoological aspects and comparison between forest spatial pattern maps pre and post-treatments will allow to identified changes and their impact on ecological aspects.

In this first phase of the Action activities no landscape connectivity metrics have been calculated. Maps of metrics delivered in this phase provided a general description of landscapes in test areas in quantitative way. Landscape connectivity metrics generally attempt to reflect the degree to which patches are isolated or connected across landscapes and are strictly correlated to ecological aspects. For this reason, this aspect will be analysed in the second phase according to zoological parameters related to habitat suitability.

3.2.2. From Sub-action 2 – Activities in Slovenia

The performance of actions pursues the time schedule set in the project paper. No delays have been detected. All three test sites (70 hectares each) in Slovenia have been scanned by lidar and a number of lidar-based maps of pre-treatment forest stand structure have been computed. The landscape level analysis (core area metrics) has been performed for all three test areas (10000 hectares each).

3.3. Overall future estimation of planned Action's objectives

3.3.1. From Sub-action 1 – Activities in Italy

In the second phase of Action activities forest treatments characteristics implemented in each study area will be extended in simulated landscapes at different times. Depending on forest treatment, different resulting landscape structures will be predicted at different years.

Application of spatially-explicit forest landscape models will allow to simulate forest change over time with (or without) the disturbance process (traditional and innovative harvests).

Landscape ecology quantitative metrics will be recalculated in each simulated landscape and results will be analysed and compared with results achieved in the pre-treatments landscape investigations.

The layers obtained from spatial analysis will evaluated with a Multi-Criteria (MCE) approach in order to analyse the effect of different management options on landscape.

The simulation of forest treatments impacts at landscape level and the projection of these impacts in the future will allow overcoming the obstacle of project duration. Changes in biodiversity at landscape level could not be notice in this brief period. Moreover, the application of landscape simulation models will allow to add and model together different parameters connected to both ecological and non-ecological factors.

MCE results will be compared to analyse how the different forest practices can influence the landscape and faunal biodiversity levels in order to identify best forest management actions of SFM in each site.

3.3.2. From Sub-action 2 – Activities in Slovenia

Until the end of the project the focus at the forest stand level will be (1) the lidar-based change detection of the proposed forest stand structure indicators due to sylvicultural treatments and (2) the identification, analysis and evaluation of treatment impacts, based on these lidar indicators.

At the landscape scale we will identify the best practices in terms of sylviculture (within forests) and land use (within the broader forested and seminatural landscape), linking landscape change detection based on historical maps and archives of past forest management practices.

4. Indicators of progress

4.1. Planned indicators

4.1.1. From Sub-action 1 – Activities in Italy

Spatial analysis performed in Action ECo will provide a series of indices (known as metrics) aimed to describing spatial patterns of "small" and "large" areas.

The potential ecological network between forest habitats will be analysing by GUIDOS software realised by European Commission.

The GUIDOS results provide a forest spatial pattern classification composed by seven main classes described in Table 76.

GUIDOS classes	
Core	interior forest area minus a fixed edge size
Edge	external perimeter of core patch
Perforation	perimeter of perforation in core patch
Bridge	connectors between cores
Loop	connectors between cores when same core
Branches	pixels that do not belong to any of the previously defined categories. They emanate from boundaries as edge or perforation
Islet/fleck	isolated non-core forest patches

Table 76: Description of GUIDOS classes.

Two main groups of metrics will be computed considering as classes: forest types classes (small area), forest and other land cover classes (large areas) and forest spatial pattern classes resulting by GUIDOS classification.

- landscape composition metrics (e.g. he number and amount of different habitat types or land cover classes);
- landscape configuration metrics (describing the spatial arrangement of classes within the landscape). This metrics are strictly correlated to ecological aspects like those zoological.

Each metric will be mapped for both "small" and "large" areas.

Landscape composition metrics calculated and mapped in the first reporting period and that will be calculated in the simulated landscapes are listed in Table 77.

Metric type	Metric name	Scale	Acronym	Metric (units)	Maps (Y/N)*
Area metrics	Patch area	Patch	AREA	Hectares	Y
	Class area	Class	CA	Hectares	Y
	Percentage of landscape	Class	PLAND	Percent	Y
	Largest patch index	Class	LPI	Percent	Y
	Area mean	Class	AREA_MN	Hectares	Y
Edge metrics	Perimeter	Patch	PERIM	Meters	Y
Nearest neighbor metrics	Euclidean Nearest-Neighbor Distance	Patch	ENN	Meters	Y
Core area metrics	Total core area (ha)	Class	TCA	Hectares	Y
	Core area percentage of landscape	Class	CPLAND	Percent	Y
Shape metrics	Shape mean	Class	SHAPE_MN	None	Y
	Fractal dimension	Class	FRAC_MN	None	Y
	Shape index	Patch	SHAPE	None	Y
	Fractal dimension	Patch	FRACT	None	Y
Patch density, patch size and variability metric	Number of patches	Class	NP	None	Y
	Patch density	Class	PD	Number per 100 hectares	Y
Diversity metrics	Shannon's diversity	Landscape	SHDI	None	N
	Simpson's diversity	Landscape	SIDI	None	N

* If the landscape metric map has been produced.

Table 77: List of landscape composition metrics.

4.1.2. From Sub-action 2 – Activities in Slovenia

All test sites in Slovenia have been scanned by lidar and a number of lidar-based maps of pre-treatment forest stand structure have been computed. The test phase at a landscape scale has been finished. The method of landscape analysis has also been designed and will be applied in 2013 and partly in 2014.

4.2. Additional indicators

4.2.1. From Sub-action 1 – Activities in Italy

No additional indicators are defined at the moment.

4.2.2. From Sub-action 2 – Activities in Slovenia

No additional indicators are defined at the moment.

5. Envisaged progress until next report

5.1. *From Sub-action 1 – Activities in Italy*

By December 2013 second phase of Action Eco will be completed and analysis on simulated post-treatments landscapes conditions will be performed for 50 % of test sites

In the next report by February 2014 quantitative results of second phase will be provided and quantitative metrics will be discussed for each test areas in order to analyse the landscape composition in the simulated forest landscapes.

A timetable of planning Action ECo activities is reported in Table 78.

Action objective	Test area	Objective	Predicted deadline
Forest Landscape simulation	Tarvisio	Modelling	July 2013
	Cansiglio	Modelling	
	Lorenzago di Cadore	Modelling	
	Vallombrosa	Modelling	
Reporting on quantitative results for test sites	Tarvisio	Discussion of quantitative results	February 2014
	Cansiglio	Discussion of quantitative results	
	Lorenzago di Cadore	Discussion of quantitative results	
	Vallombrosa	Discussion of quantitative results	

Table 78: Timetable of Action ECo activities for the next reporting period.

5.2. *From Sub-action 2 – Activities in Slovenia*

At the forest stand level the main activity in the next reporting period will be acquisition and (partial) processing of pots-treatment lidar data. The second data acquisition will be done in comparable phonological vegetation stage in order to optimize the capture of forest stand structure change. This will be followed until the end of the project by lidar-based change detection of the proposed forest stand structure indicators (Spatial pattern of gaps in the forest stand canopy, Forest canopy cover pattern, Volume of photosyntheticaly active forest canopy) due to sylvicultural treatments and to identification, analysis and evaluation of treatment impacts.

At the landscape scale further metrics of spatial pattern will be analysed, including landscape fragmentation / connectivity. Using historical maps and archives of past forest management practices we will analyse impacts of management practices and identify best practices in terms of sylviculture (within forests) and land use (within the broader forested and seminatural landscape).

After analysing the preliminary results at the landscape scale, we will analyse the historical spatial data and compare them with the current state, and also analyse the present fragmentation processes. We will select the sets of cadastral maps within the three regions, sample land use data from those maps, and correlate these data with selected sociological data sets (population records, prevalent economic activities, etc.).