Assessing multi-temporal land cover changes in the Mata Nacional da Peneda Geres National Park (1995 and 2009), Portugal - a land change modeler approach for landscape spatial patterns modelling and structural evaluation

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Abstract

The present study sought to evaluate land cover evolution between 1995 and 2009, within the Mata Nacional of Peneda Geres (Portugal). This study was based on Landsat TM images classification and GIS procedures, such as Land Change Modeller approach. Landscape diversity and structural changes were analysed by means of Mean Shape Index, Shannon's Diversity Index and Patch analysis, in order compare landscape metrics and to calculate land cover dynamics. The achieved results enable to state that land cover classes presented significant structural changes. The most significant changes occur in the land cover classes of *Pinus pinaster; Quercus robur*; *Acacia dealbata*; and shrub land. The most worrying result was achieved for the *Acacia dealbata*, which presented a strong invasive behaviour. Landscape metric analysis showed a significant stratification increasing and a dramatic reduction of patch surfaces. In spite of spatial changes observed, the achieved biodiversity indexes are very alike for both dates.

Keywords: Landscape ecology, Spatial patterns analysis, Changes prediction, Landsat, Gerês

1. Introduction

Natural or National Parks use to be created as way to preserve wild areas and to give a chance to nature undergo its trend. However, due to centuries of anthropogenic action, nature must be under human surveillance in order to redress previous misuse or to guide ecosystem recovery.
Over the last 50 years, natural areas have suffered significant changes, which are visible from land cover and land use changes. These changes are due to several causes: human exodus from rural areas, which leaded to uncontrolled shrub growing and, this way, to wild fire starting and spread, alien species introduction and spread, climatic changes and unbalanced forestry composition.
The Peneda Geres National Park is a good and living example of previous state. From the last 200 years, rural population used wild land for grazing cattle, to cut shrubs for cattle's beds, to grow timber and to cut wood for fireplaces, during rigorous inter. However, from the last 30 years, human action within the Park decreased drastically, both by changes in Portuguese way of life and restrictive policy imposed by law. This actions combination is now very visible in

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landscape and leaded to changes in ecosystem balance. Due to a strong anthropogenic pass, this area must be under continuous surveillance in order to avoid irreversible ecosystem losses and unbalanced evolution.

This is also visible throughout Europe, at different scales and domains, due to changes in technologies, policy and economical growing up (Verburg et al. 2008).

Land cover and land use dynamic analysis and evolution qualification has to be used as a way to estimate environmental consequences due to landscape changes (López et al. 2001, Flamenco-Sandovala, et al. 2007; Rutherford et al., 2008). Multi temporal spatial pattern analysis and quantitative landscape structural analysis have been successful used to derive research in this domain (O´Neill et al. 1988; Bresee et al. 2001, Tischendorf 2001).

This research was derived using Remote Sensing and Geographic Information Systems methods, in order to assess the landscape dynamics in Gerês National Forest. We evaluated the global landscape composition and structure from 1995 to 2009 and made projections for 2015 based on transition observed from the past to 2009.

Was selected Geres National Park, as it is a protected area of high landscape value and ecological, part of the Peneda-Geres (PNPG). The Geres National Park contains one of the most important oak woods, consisting predominantly of a centuries-old oak forest (carvalhal da Albergaria) where is noticed the presence of fauna and flora species characteristic of gerensiana formation. PNPG, it is classified as a Zone of Partial Protection of Natural Environment Area and Rede Natura 2000 (Anonymous, 1995). In general, this area can be classified as an area of mountainous altitude, since about 82% of the territory, has altitudes ranging between 700 and 1400 m.

Due to its morphological characteristics, which result from the conjunction of four mountains (Peneda, Soajo, Amarela e Gerês), this area creates a natural barrier to hot and wet air coming from Atlantic Ocean. This results in high values of mean annual rainfall, ranging from 2400 mm to 2800 mm, or 3000 mm in very wet years. This is the wettest area in Portugal and even in Europe (Fontes, 2005). In this territory we can find several forest species, with high productivities as pines, eucalyptus, oaks and much other conifers and deciduous species. The most species are well adapted and in equilibrium in the ecosystem, however, many introduced species became invaders (e.g. *Acacia dealbata, Acacia melanoxilon*).

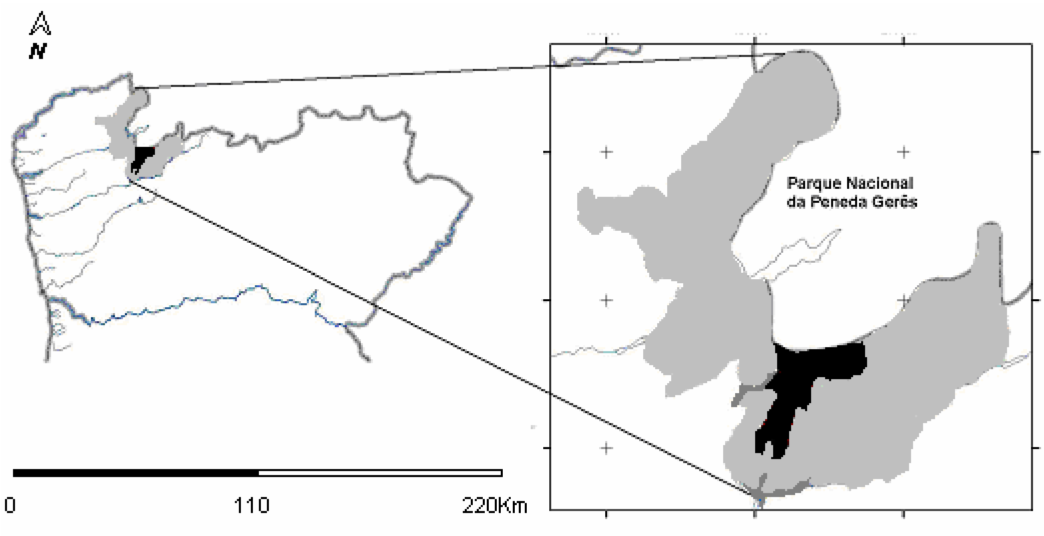

Figure 1: Study area location

2. Methodology

They were used satellite images (Landsat-5 TM, 5/July/1995, Landsat-5 ETM+, 1/April/2001, Landsat-5 TM, 4/August/2006 and Landsat-5 ETM+, 16/June/2009), ancillary data such as: topographic maps at the scale of 1:25 000 with a 10m contour interval, orthophotomaps from 1995, 2000 and 2005 at a scale of 1:10 000, cartographic elements in vector format such as roads, rivers, administrative boundaries and environmental characteristics.
In previous intensive fieldwork, information about land cover classes and ground control points (GCP) were collected using a DGPS (Differential GPS). The GCP were collected in road crosses, barrages or other notable points perfectly visible in the images (Toutin 2004). This data was used as auxiliary tools in the geometric correction, in the definition of training classes and in the validation stage (Lillesand et al. 2004, Toutin 2004, Eastman 2006, Scally 2006, D' Iorio et al. 2007, Tsai 2007
A digital elevation model (DEM) was created from 10m interval contours, collected from the 1:25000 topographic maps of representing the study area, in order to calculate slope and aspect and to apply images topographic normalization.
The conceptual framework of the research included pre-processing stage, image enhancement, image transformation (RGB composition, vegetation indices calculation and principal component analysis), image classification and interpretation and accuracy assessment. It was used IDRISI 32 (Eastman 2006) image processing software for image data processing, and ArcGis 9.x (ESRI 2004) software for GIS based analyses procedures.
During previous field work for data collection, it was used a DGPS (Differential Global Positioning System) in training areas mapping (e.g. coniferous stands, burnt areas, acacia areas, etc.) and ground control points collection (e.g. roads intersection). DGPS data was corrected with Trimble® GPS Pathfinder® Office software.
The adopted land use/cover scheme, used in image classification, was based upon Corine Land Cover classification (CLC2000).

In a first image classification stage, they were used nine land cover classes, in order to create a general land cover map. In a second stage, using a local scale and after fieldwork with a DGPS (Differential Global Positioning System) for accuracy assessment, land cover maps were updated during, in order to assign the correct forestry class name to each land cover class. In total, fifteen land use/cover classes were considered in this study:

- Shrubs,
- Pinus sylvestris,
- Acacia dealbata,
- Quercus robur;
- Mixed Broadleaves;
- Mixed Coniferous;
- Mixed Coniferous and Broadleaves;
- Chamaecyparis lawsoniana,
- Mixed Shrubs and Quercus sp.;
- Fagus sylvatica;
- Acacia melanoxylon;
- Pinus pinaster;
- Pinus nigra;
- Arbutus unedo; and
- Betula celtiberica.

They were performed several automatic classification methods, including unsupervised models and Principal Component Analysis (Asner 1998, Song et al 2001, D' Iorio et al. 2007, Tsai et al. 2007). Supervised classification of multispectral images was performed, running the Maximum

Likelihood classifier (MLC) and the Minimum Distance to Means classifier (MDMC) (Lillesand et al. 2004, Eastman 2006, Scally 2006).
The accuracy of a classified image refers to the extent to which it agrees with a set of reference data. Thus, an error matrix was created in order to compare the accuracy of maps obtained from satellite images classification. The error matrix provides a mean to calculate the overall accuracy and to compute accuracies of each category (Congalton and Green 1999).
It was calculated Kappa statistic (Cohen, 1960), because of its ability to provide information about a single matrix and to statistically compare matrices, in order to get another measure of agreement between the predicted values and the observed values, the, (Cohen, 1960, Rosenfield and Fitzpatrick-Lins 1986, Congalton and Green 1999, Meidinger, 2003).

For land cover changes detection, it was used a pixel-to-pixel comparison of classified images, because it is a method widely used and easily understood. This step preformed by Land Change Modeler (LCM - IDRISI Andes, Eastman, 2006) and aimed to compare the images generated for the different years of study.
Land Change Modeller (LCM - IDRISI Andes, Eastman, 2006) enable landscape changes analysis; Shaping the potential transition of the land cover classes, provide the direction of changes in the future, assessment to their implications for biodiversity and to evaluate plans of action for ecological sustainability maintenance.
At the final stage, land cover maps, created from 1995 to 2009 satellite images, were submitted to pattern analysis in order to assess landscape structural quantification. This stage was performed by means of Patch Analyst 4 (Rempel, 2008), which is a working modulo available in ArcGIS 9.x GIS software.

3. Result

The observed changes, in terms of net percentage change, are more significant in classes: mixed conifer, Shrubs with oaks self seeding, *Arbutus unedo*, *Betula Celtiberica*, *Acacia dealbata*, *melanoxylon Acacia*, *Quercus robur*.
The most important modification was recorded in oak areas (*Quercus robur*) with an effective reduction of about 444 ha, representing a decrease of 113.9%. Classes of increasing land cover are: *Acacia dealbata* increased more than 200ha, and *Acacia melanoxylon*, with more than 30ha.
The substitution of pure *Quercus robur* stands by shrubs, in a such large area, was due to strong shrub's developed, which is replacing the younger oak areas. It was also noticed that some *Quercus robur* some pure stands, classified in 1995, were classified in 2009 as deciduous and coniferous mixed stands, which can lead to gradual replacement of deciduous trees on these areas.
Analysing the global balance of *Acacia dealbata* changes (gains and losses), *Acacia dealbata* increased its area over *Pinus pinaster* pure stands (80ha) and shrub areas (120ha).
The *Acacia melanoxylon* increasing area was made, as for Acacia dealbata, by the replacement of *Pinus pinaster* pure stands (30ha), and these changes correspond to about 8% decrease of pine in the global balance of gains and losses in forest occupation of this class
Despite the total area assigned to *Pinus pinaster* stands (polygons and 35 319ha in 1995 to 64 292ha in 2009 polygons) and to shrub land (3580ha polygons and 88 in 1995; 3232ha polygons and 522 in 2009) had not varied greatly, in absolute values, the spatial distribution has suffered a large increasing in fragmentation. In the case of shrub land, it was observed that some areas have be replaced by a mix of young oaks and shrubs. The *Pinus pinaster* stands were replaced by scattered trees and shrubs, as well by *Acacia dealtata*, as previous presented. In Table 1 are presented the calculated results for metrics of diversity and inter dispersion for 1995 and 2009.

Table 2: Metrics of diversity and inter dispersion for 1995 and 2009

Metrics	Acronym	1995	2009
Mean shape index	MSI	1.56	1.60
Area weighted mean shape index	AWMSI	5.22	6.42
Mean polygon fractal dimension	MPFD	1.07	1.08
Landscape shape index	LSI	8.46	10.42
Metrics of diversity and inter dispersion			
Mean distance to nearest neighbour (m)	MNN	282.50	186.50
Mean proximity index	MPI	771.39	1680.10
Index of dispersion and overlapping (%)	IDO	43.61	59.20
Shannon diversity index	SDI	1.02	1.13
Simpson diversity index	SIDI	0.47	0.46
Shannon equity diversity index	SEI	0.38	0.42
Simpson equity diversity index	SIEI	0.50	0.49
Modified Simpson diversity index	MSIDI	0.63	0.61
Modified Simpson equity diversity index	MSIEI	0.23	0.23

4. Discussion

Results from this research showed that the vegetal land cover within Mata Nacional of Peneda Geres National Park is under high changing dynamic. For the period in analysis, some land cover classes evidenced significant lost (e.g. *Quercus robu*r) and significant gains (e.g. *Acacia dealbata*).

The achieved results for *Quercus robur*, the ex-libres of Mata Nacional of Peneda Geres National Park showed a strong area decrease, with tendency to be smaller in a new future. This is a strong cut in landscape value and biodiversity.

Open areas within *Quercus robur* stands mapped in 1995 were now occupied by *Pinus pinaster*, *Fagus sylvatica*, shrubs and *Acacia dealbata*.

In general, *Pinus pinaster* and shrubs presented a stabilised land cover area, these classes evidenced some dynamic, but the total areas assigned to both classes are near the same in both dates.

One of the most significant results was achieved for alien trees (*Acacia dealbata* and *Acacia melanoxylon*). According to prediction maps, these species are those with higher potential to enlarging their actual area. These tow trees species are well known because of their strong invasive behaviour, which leads to additional worry, as they can quickly colonize almost all Mata Nacional, leading to a severe ecosystem disturbance.

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