Αναφορά

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Temporal Evolution of Forest Landscapes in Relation to Socioeconomic Changes: the case of Hortiatis Watershed in Greece.

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ABSTRACT: Forest landscapes of Greece have been significantly changed over the last 50 years. These changes have the form of land use/cover transformations and spatial modification of landscape pattern. Hortiatis watershed, located south of Lake Koronia, was chosen as a study area. Demographic and socioeconomic changes have modified the landscape. The general trend and the temporal transformation of the landscape were evaluated by means of Geographic Information Systems (G.I.S.) and the digital process of two sets of aerial photographs (1945 and 1993), which resulted in the creation of a map and a diagram of temporal transformation of the landscape. Changes in landscape pattern were evaluated with landscape indices (edge, shape, interspersion and diversity metrics). Demographic and socioeconomic inventory data were collected from diachronic census reports of the National Statistical Service of Greece. It was found that land use/cover transformations have resulted in an increase of forests and shrublands and a decline of grasslands. Main feature of forest and shrubland change was a shift from sparser to denser cover types. Landscape indices showed a decrease of landscape geometry, diversity and heterogeneity. Population ageing and a significant decline of people employed in the primary economic sector affected landscape pattern and evolution.

Keywords: aerial photograph, Geographic Information Systems (GIS), landscape pattern, landscape indices.

Introduction

Forest landscapes of Greece have changed significantly over the last 50 years. These changes have usually the form of forest expansion in mountainous and semi-mountainous areas followed by a significant increase of their crown cover density due to land abandonment processes (Bankov, 1998; Ispikoudis and Chouvardas, 2005; Chouvardas 2007).

Landscape evolution through time consists in land use/cover transformations and spatial modification of landscape pattern. Remote sensing information, produced by satellite or aerial photography, combined with Geographic Information Systems (GIS) have become powerful tools for evaluation of land use/cover and monitoring its changes (Farina, 1998). Several studies have been carried out over the last years describing methods for analyzing these changes through time with the use of aerial photography and GIS in several parts of the world (e.g., Duncan *et al.*, 1999; Lopez *et al.*, 2001; Zaizhi, 2002; Mazzoleni *et al.*, 2004). Socioeconomic changes combined with the results of photointerpretation can produce valuable information regarding the causes of landscape evolution (Bankov, 1998; Torta, 2004; Papanastasis and Chouvardas, 2005; Chouvardas, 2007).

Social, cultural and economic conditions are potentially the most influential factors in forming landscape pattern and its change (Fukamachi, *et al.* 2001). Changes in landscape pattern can influence a variety of ecological processes (Hulshoff, 1995). Quantification of landscape pattern through time can be evaluated with the use of landscape indices or metrics (McGarical and Marks, 1995; Tischendorf, 2001; Li and Wu 2004). According to

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Chouvardas (2007), landscape indices can produce valuable information regarding the ecological and functional status of landscapes.

The aim of this study was to detect, map and analyze the land use/cover changes in the Hortiatis forest landscape with the use of GIS, as well as to study the effects of socioeconomic and demographic changes on landscape patterns, with the use of landscape indices.

Methods

The landscape of Hortiatis watershed, located south of Lake Koronia, was chosen as a study area (Figure 1). It covers an area of 1,757.26 Ha, sited 15 km east of the city of Thessaloniki in Central Macedonia region of north Greece. It is inhabited by two village communities (Hortiatis and Agios Vasileios) and extends from less than 100 to more than 1000 m altitude.

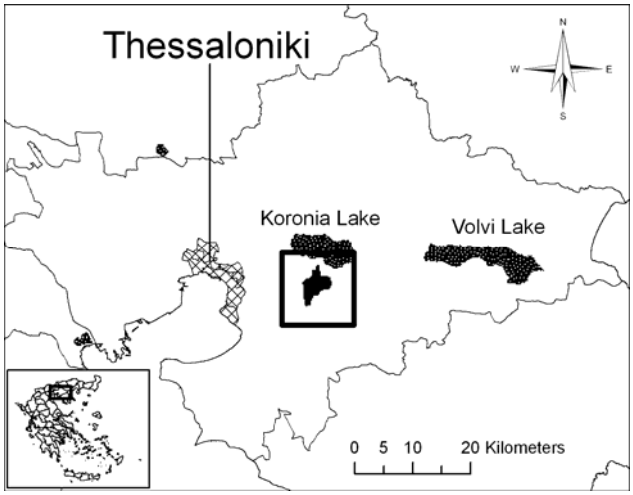

Figure 1. Orientation map of the study area

The general trend and the temporal transformation of the landscape were evaluated by the means of Geographic Information Systems (GIS) and the digital process of two sets of aerial photographs (1945 and 1993). The air photographs were transformed into raster format and were registered, rectified, geometrically corrected, and joined with the use of the special computer software Erdas Imagine v8.5 (Erdas, 1999). The joined air photographs finally produced photo mosaics for each period of 1945 and 1993, similar to orthophotos. To determine the land use/cover categories, the proper classification system was chosen based on the land use/cover nomenclature used by the Greek Forest Service (Karteris, 1990). Each photo mosaic was interpreted on the computer monitor screen and the land cover/ use polygons were digitized using the ArcGIS v 9.0, computer software (ESRI, 2004). The topology of a GIS was constructed in these polygons and a proper database was built up (ESRI, 2004). The results from on-screen interpretation were confirmed using classical stereoscopic interpretation techniques such as standard photographic keys (tone, texture, pattern, shape, and size) on the original air photographs (Lopez et al., 2001), and with several field trips on site. In the final step of the procedure, digital diachronic land use/cover data sets were created and a graphical presentation of an empirical model of land cover/use change trend for the time period 1945 – 1993 was constructed.

Demographic and socioeconomic inventory data were collected from diachronic census reports of the National Statistical Service of Greece (NSSG). More specifically, information on human population employed in the primary sector of the two village communities, namely in agriculture, forestry, and livestock husbandry, as well as its age structure, was collected from statistical records of 1961 and 1991, the years when census data were available (NSSG, 1962; NSSG, 1994).

The programme Patch Analysis v 3.1 (Elkie *et al.*, 1999) which is an extension of the ArcView GIS software was employed to quantify landscape pattern and compare patterns of the landscape through time. Land use/cover digital maps for 1945 and 1993 were the main source for landscape spatial pattern analyses. Five indices were included in the study (McGarical and Marks, 1995): Number of Patches (NP) as an overall measure of landscape fragmentation, Edge Density (ED) as a measure of the amount of ecotones (Farina, 2000), Area Weighted Mean Shape Index (AWSI) as a measure of landscape geometry (patch shape irregularity), Interspersion Juxtaposition Index (IJI) as a measure of patch dispersal and heterogeneity, and Shannon's Evenness Index (SEI) as a measure of landscape diversity and heterogeneity. The mathematical formulas of the chosen indices can be viewed in Patch analyst and Arc Fragstats user manuals (McGarical and Marks, 1995; Elkie *et al.*, 1999).

Results and Discussion

A land use/cover change map and data sets (Figure 2, Table 1) were created for the time period of 1945 and 1993, based on aerial photographs.

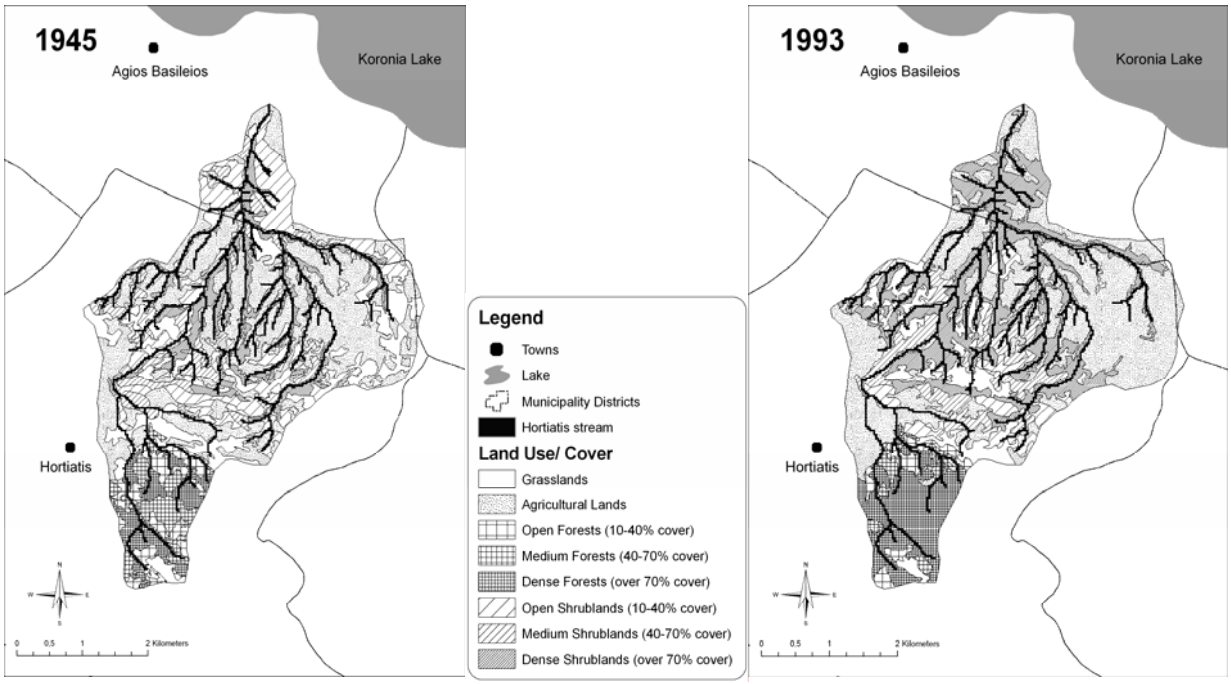

Figure 2. Land use/cover change map (1945 – 1993) of the Hortiatis landscape)

It is clear from table 1, that all major land use/cover types were increased from 1945 to 1993 except grasslands. More specifically, the largest increase occurred in forests (by 10.42%), and shrublands (by 10.48%), followed by agricultural lands (by 1.69%). On the contrary, grasslands were significant decreased (by 45%). Looking at the three cover classes of forests and shrublands, it is obvious that the dense class increased significantly (by 99.73% and 129.93%, respectively), while the open and medium classes were reduced. These results suggest that woody vegetation cover increased substantially in the landscape over the 48-years period. These results can be observed in the land use/cover change map in figure 2, especially the great expansion of the dense forest in the south part and dense shrublands in the north and central part of the landscape.

In relation to the results of table 1, the trend of change (1945 – 1993) among the different land use/cover types (Figure 3) also show that the main feature of forest and shrubland change was a shift between sparser to denser cover types. Forests received a light input from grasslands (7.80%).

Table 1. Land use/cover types (Ha) in 1945 and 1993 of Hortiatis landscape.

Type	1945	1993	Difference (%)
Agriculture lands	658.69	669.83	1.69
Grasslands	227.34	125.02	-45.01
Shrublands	647.95	715.85	10.48
Open (10-40%)	279.09	95.82	-65.67
Medium (41-70%)	162.24	163.54	0.81
Dense (71-100%)	206.62	456.48	120.93
Forest	223.29	246.56	10.42
Open (10-40%)	72.06	41.38	-42.57
Medium (41-70%)	65.67	34.30	-47.77
Dense (71-100%)	85.55	170.88	99.73
Total	1757.26	1757.26	0.00

Significant changes also occurred within forest cover classes, where there was a progressive increase in the cover, particularly from the open and medium classes to the dense. However, this increase was not totally linear since a small reduction of dense cover in favour of the medium and open ones occurred. Similar development was also observed in shrublands. Grasslands were mainly transformed into agricultural lands (52.97%) and secondly into forests. Agricultural lands apart from grasslands, also received significant input from open shrublands (21.23%).

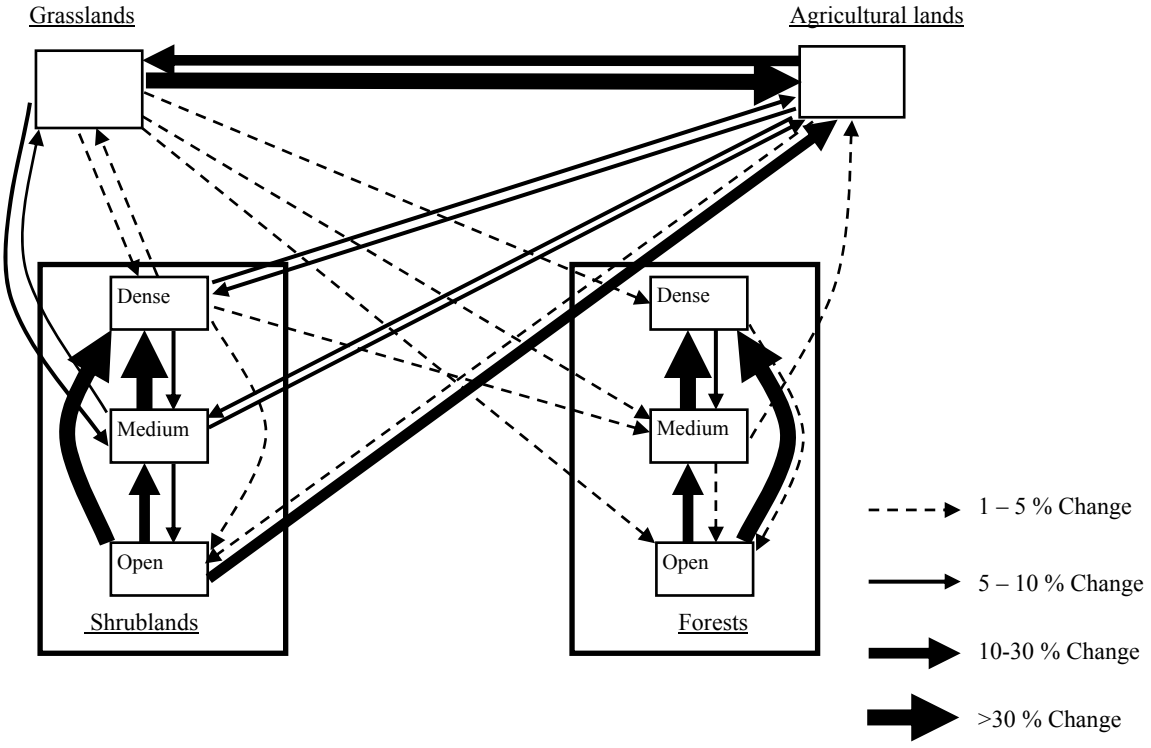

Figure 3. Trends of changes among different land use/cover types between 1945 and 1993 (The percentage change of the arrows refers to the original size of each type in 1945).

During the study period, significant socio-economic changes occurred, which apparently affected the management of forests and landscapes. The most dramatic changes, occurred in the population employed in the primary sector (agriculture, animal husbandry and forestry), which reduced from 72.13% in 1961 to 10.81% in 1991 (Table 2). In addition, the age

structure of the population changed, with fewer younger people staying in the area as compared to the older ones, who increased in 1991 compared to 1961 (Table 3).

This trend follows the general national trend of rural abandonment, which took the form of movement of young rural people from the mountainous and semi-mountainous areas to the industrial urban areas, resulting in the abandonment of traditional management activities (i.e. charcoal and fire wood production and extensive animal husbandry, Papanastasis and Chouvardas 2005). Land abandonment caused the observed increase of forest and shrubland areas and especially the shift from sparser to denser cover classes.

Table 2. Human population employed in the primary sector of economy in the study area in 1961 and 1991.

	1961 (%)	1991 (%)
Hortiatis	52.9	6.17
Agios Vasileios	89.4	17.6
Total	72.13	10.81

Table 3. Age class distribution in the study area in 1961 and 1991.

	%(0-44)	%(45-)	%(0-44)	%(45-)
Hortiatis	68.10	31.90	65.02	34.98
Agios Vasileios	75.78	24.22	59.96	40.03
Total	71.75	28.25	63.13	36.88

The application of landscape indices in Hortiatis landscape revealed (Table 4) a temporal decrease (1945 – 1993) of patch number (NUMP), edge size (ED) and patch geometry (AWMSI, higher values of AWMSI indicate more irregular structure). These changes probably occurred due to the diachronic decrease of human interventions (Table 2, Table 3) in the landscape and caused the decrease of patch fragmentation (NUMP), the amount of ecotone areas (ED) and the geometrical structure of patches (AWMSI). Finally and for similar reasons, interspersion (IJI) and diversity (SEI) metrics (Table 4) revealed that Hortiatis watershed was transformed over the years (1945 – 1993) to a less heterogenic and diverse landscape.

Table 4. Landscape indicators values in 1945 and 1993 of Hortiatis landscape.

	NUMP[1]	ED[2] (m/ha)	AWMSI[3]	IJI[4] (%)	SEI[5]
1945	144	228.09	3.66	72.96	0.89
1993	73	168.78	4.64	55.99	0.80

[1] Number of Patches, [2]Edge Density, [3]Area Weighted Mean Shape Index, [4]Interspersion Juxtaposition Index, [5]Shannon,s Evenness Index (McGarigal and Marks; 1995)

Conclusions

The main feature of the Hortiatis landscape was the expansion of forest and shrubland over the 48 year period (1945 – 1993) and a shift from sparser to denser cover classes. Landscape indices indicate that for the same time period Hortiatis landscape showed a decrease of landscape geometry, diversity and heterogeneity. Population ageing and a significant decline of people employed in the primary economic sector seems to have affected landscape pattern and evolution.

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