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Multitemporal land use changes in a region of Pindus mountain, central Greece

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Abstract: Natural ecosystems are renewable resources with special environmental, social and economical attributes and characteristics. The increasing need of the human beings for a better environment leads to the use of new technologies that offer many advantages in detecting changes in the ecosystems. In this study the integration of remote sensing tools and technology and the spatial orientation analysis of Geographical Information Systems (G.I.S.) combined with *in situ* observations were used in determining any changes in land cover categories along an 18 year period. The study area of 9,287 ha extends to Pindus mountain, in the municipality of Plastira, central Greece. The results have shown that the current technologies can be used for the modelling of environmental parameters improving our knowledge on its attributes, characteristics, situation, trends and changes of natural ecosystems. The multitemporal changes that were observed are mostly due to vegetation evolution and less to socioeconomic reasons. The basic management strategy for the specific area should combine forest, pasture and livestock in such a way that each component produces usable products, while in the same time preserves sustainability.

Keywords: G.I.S., Image Processing, Multitemporal Analysis, Range Management, Land Use, Livestock Fluctuation

1. Introduction

The internal observation of vegetation changes requires a series of parameters which can be met not only with terrestrial methods of the landscape observation, but also with the use of remote sensing and digital image processing. All these, offer the possibility of developing and applying methods and techniques for studying environmental problems and phenomena of monitoring changes in vegetation cover classes, specifically in areas with significant importance to nature conservation. The changes in these characteristics can be recorded over time in order to understand the multitemporal dynamics. To perceive this objective, we must first identify the vegetation classes and the land use at the reference time. Moreover, an important element in the temporal classification of vegetation is the livestock fluctuation. The reduction or increase of grazing animal number differentiates succession of vegetation, bringing about positive or negative results (Noitsakis et al. 1992, Milchunas 2006).

A wide range of remote sensing and G.I.S. applications in geotechnical sciences refers to multitemporal studies (Richards 1993, Lillesand and Kiefer 1994). Examples of applications in environmental studies refer to land cover changes (Chavez and MacKinnon 1994, Mas 1999, Houvardas et al. 2001, Ainalis et al. 2006, Ainalis et al. 2007, Platis et al. 2009), forest fires and deforestation (Kuntz and

Karteris 1993), coastal changes in the prefecture of Magnesia, Greece (Perakis et al. 1997), habitat changes of protected areas (Meliadis et al. 2004, Platis et al. 2004) and rangelands inventory (Platis et al. 2001). Various evaluation methods have been proposed by researchers on the assessment of land cover changes (Sunar 1998, Mas 1999, Wrbka et al. 1999).

The purpose of this study was the recording of multitemporal land use changes, especially vegetation changes, in the area of the municipality of Plastira and specifically in Pindus mountain, central Greece, using satellite images and *in situ* observations.

2. Materials and Methods

The study was conducted in an area of Pindus mountain, located in the municipality of Plastira, central Greece (Fig. 1). It extends from 200 m to 1,200 m above sea level and its largest part is covered with grasslands, shrublands and broadleaf forests.

The survey has covered an area of 9,287 ha in the west – southwestern part of Karditsa prefecture, located at the north side of Lake Plastiras. Part of the study area is designated as a Special Protection Area (SPA).

The prevailing parent rocks in the study area are colluvium shale located around the lake. These are deposits of the Tertiary period in the lowland areas and flysch in the other regions (Barntovas and Rantogianni - Tsiampaou 1983). The soil is sandy-clay and clay with moderate organic matter (Nakos 1977). The climate is continental with cold, rainy and several times snowy winters and hot, dry summers (Mavrommatis 1980).

Information concerning the annual rainfall for the period 1989 – 2007 were taken from the nearest meteorological station of Kalambaka region situated at an altitude of 450 meters (60 km NW of the municipality of Plastira) (H.N.M.S. 2013). The region belongs to the Mediterranean mountain ecological zone (*Quercetalia pubescentis*) (Dafis 1973).

Figure 1. *General map of the study area in Pindus mountain, central Greece.*

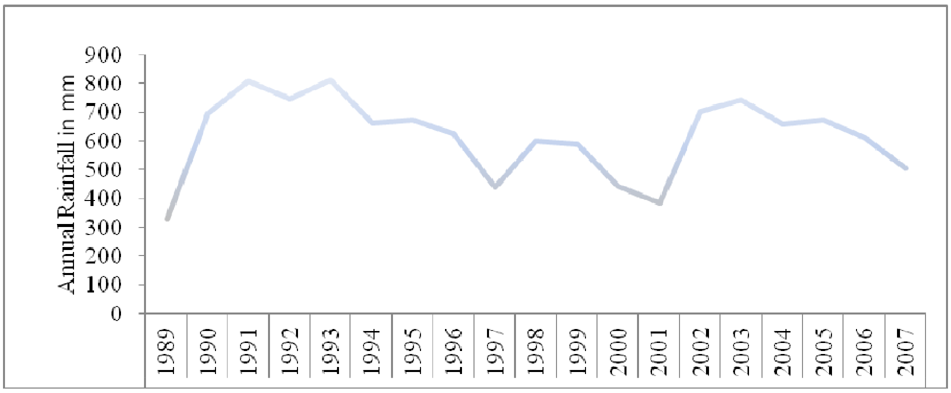

Figure 2. *Annual rainfall in the period 1989 – 2007 from the meteorological station of Kalambaka in central Greece.*

The data sources used are from satellite images that were taken at three different times, during an 18 year period: in 1989, 2000 and 2007. The images of 1989 were obtained from the satellite LANDSAT 5 TM (Thematic Mapper) with code 184 – 033 and date July16, 1989, while the images of 2000 were obtained from the newest satellite LANDSAT 7 ETM+ (Enhanced Thematic Mapper Plus) with code 184 - 032 and date May 02, 2000. Finally, images of 2007 were obtained from the satellite LANDSAT 7 ETM with code 184 - 033 and date June 24, 2007 (Fig. 3).

The following vector and point data such as: roads, hydrographical network, contour lines, boundaries settlement, and local names were used as auxiliary elements. The recording was at an average scale (1:50,000) detailing the corresponding pixel size of the satellite images used (30x30m).

The methodology was distinguished in four separate stages: a) the preliminary processing of satellite data (corrections, georeference, etc), b) the classification of satellite data, c) the detection of temporal changes and d) the use of a Geographic Information System (G.I.S.), namely ArcGis 9.3 for the processing of the maps. In the final stage of the investigation, the thematic maps generated by the second stage combined with the results of temporal changes in a common geographic database.

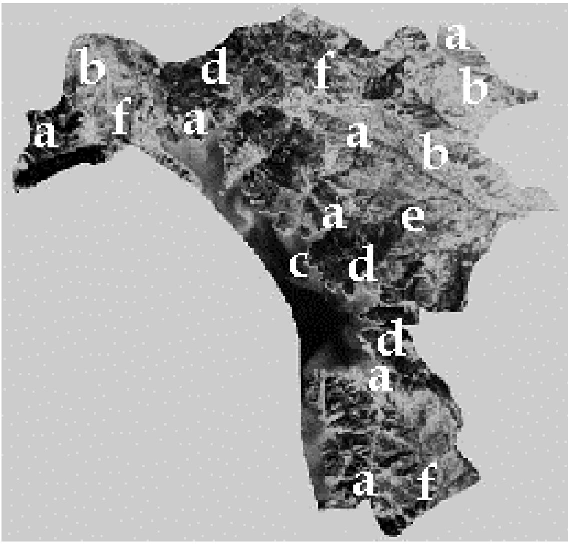

Figure 3. *Satellite image processing for the year 2007 showing vegetation changes in the study area of Pindus mountain, central Greece (a: rangelands, b: agricultural lands, c: lake surface, d: forests, e:urban areas , f: flooded lands).*

The images were geometrically rectified and registered to the same projection namely GGRS87 (Greek Grid Reference System) to lay them over each other.

The initial (1989) the middle (2000) and final (2007) Landsat imageries were subjected to a classification of zones. Supervised classification was utilized to classify the images to different land use categories.

The classification of the 1989 image was collated with the images of 2000 and 2007 and then the classification - application of the majority filter was followed (Meliadis et al. 2009). Finally, the maps of the three years (1989, 2000 and 2007) were compared, using as reference year the 2007. Ground-based observations were taken *in situ* during 2007. Livestock numbers, animal species, grazing period, grazing system, shed position, site quality and range condition were recorded and then marked on maps. Range condition was classified following the criteria on table (1) (Papanastasis 1989).

The sheep and goats were the main livestock species grazing in the study area. A few cattle were also grazing in this area, but cattle farming were mostly limited. Grazing was performed for seven months per year, following a traditional continuous grazing system. The average stocking rate in the study area was estimated as the number of small ruminants per ha. One cattle was assumed equal to five small ruminants (Holechek et al. 1989). Grazing capacity was evaluated taking into account the dry matter production of the rangelands, the total rangeland area and the forage needs of domestic animals (Athanasiou et al. 2007).

Table 1. *Criteria for range condition classification (After Papanastasis 1989).*

Class	Desirable plants	Vegetation cover	Shrub characteristics		Erosion
			High	Cover	
Good	≥ 70%	≥ 2/3	≤ 1m	≤ 40%	No evidence of erosion
Fair	40% - 70%	1/3 – 2/3	≤ 1m	≤ 70%	No evidence of accelerated erosion
Poor	< 40%	< 1/3	≥ 1m	≥ 70%	Signs of accelerated erosion

3. Results and Discussion

Livestock capital in the area was averaged to 8,200 small animal units, during the period of 1994 to 2008, with a mean grazing pressure of 0.18 a.u.m./ha on land available for grazing, while the grazing capacity did not exceed 0.14 a.u.m./ha for seven months grazing (Athanasiou et al. 2007).

The majority of rangelands in the study area were classified in fair condition (Table 2). Especially, in the grasslands, some desirable plant species for livestock (*Festuca valesiaca* Schleich.*; Poa bulbosa,* L.*; Trisetum flavescens, (*L*)* Beauv.*; Trifolium hirtum,* All.*; T. campestre,* Schreb.*; T. nigrescens,* Viv.*; T. glomeratum.* L.*; T. angustifolium,* L.*; Medicago minima,* Crufb.*; M. lupulina.* L.*; Vicia sativa,* L.) participated in relatively low percentages in the vegetation composition (Athanasiou et al. 2007). A significant part of the total rangeland area was in poor condition (28%) with signs of accelerated erosion, especially in high altitudes and steep slopes (Table 2). Only 9% of the total rangelands were classified in good condition and were present mainly in medium elevated sites with slopes not exceeding 15%.

The prevailing site quality in the rangelands was site class I and II (Table 3). The 62% of the rangelands in the study area was classified as site class I having a deep soil (>30cm) (Table 3), 33% was classified as site class II (with soil depth between 15-30cm), while the rest area was classified as site class III (Table 3).

Table 2. *Range condition classes in the study area of Pindus mountain.*

Range class	Area	
	ha	%
Good	131.36	9.00
Fair	919.47	63.00
Poor	408.65	28.00
Total	1,459.48	100.00

Table 3. *Site quality classes in the rangelands in the study area of Pindus mountain.*

Site class	Area	
	ha	%
I*	904.88	62.00
II	481.62	33.00
III	72.98	5.00
Total	1,459.48	100.00

* I: soil depth >30cm, usual slope <15%, II: soil depth 15-30cm, usual slope 15-30%, III: soil depth <15cm, usual slope >30%

The monitoring implementation has shown that the dominant vegetation for livestock grazing was classified in the type of evergreen broadleaf shrublands, followed by the abandoned fields, the grasslands and the grazed open forests. The area changes in hectares per land use category over the years are shown in table (4). An increase in the coverage of land uses was recorded at the end of the study period for the categories of grasslands (158.3%), forests (14.9%), agricultural land (14.4%), lake water surface (10.2%) and the urban areas (17.7%), corresponding to a decrease recorded for the categories of abandoned fields (67.2%), evergreen broadleaf shrublands (37.5%), grazed open forests (68.3%) and barren areas (61%) (Table 4). The forests covered 46% of the total area and were mainly coppice forests of deciduous broadleaf species, such as *Quercus conferta,* Kit. and *Q. petraea,* L. (*Q. sessiliflora,* S.) (Table 4).

Table 4. *Land uses (in ha) in the study area of Pindus mountain, central Greece, during the period 1989 - 2007.*

Land use categories	**Years**		
	1989	**2000**	**2007**
Rangelands	1933.63	1502.04	1459.48
Abandoned fields	485.12	292.28	158.89
Grasslands	231.09	321.03	596.93
Evergreen Shrublands	1031.10	775.88	644.63
Grazed Open Forests	186.32	112.85	59.03
Forests	3723.12	4089.27	4277.45
Other Areas	3630.26	3695.70	3550.08
Agricultural lands	2159.90	2323.25	2470.00
Flooded lands	761.12	605.18	296.71
Lake surface	690.12	744.97	760.87
Urban areas	19.12	22.30	22.50
Total	9287.01	9287.01	9287.01

Table 5. *Multitemporal land use differences (positives and negatives) (in ha) between the years 1989- 2000, 2000-2007 and 1989-2007.*

Land cover categories	**Differences between 1989 - 2000**		**Differences between 2000 - 2007**		**Differences between 1989 - 2007**	
	Positive	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**
Rangelands	89.94	-521.53	275.90	-318.46	365.84	- 839.99
Abandoned fields		-192.84		-133.39		326.23
Grasslands	89.94		275.90		365.84	
Evergreen Shrublands		-255.22		-131.25		386.47
Grazed Open Forests		-73.47		-53.82		127.29
Forests	366.15		188.18		554.33	
Other Areas	221.38	-155.94	162.85	-308.47	384.23	-464.41
Agricultural lands	163.35		146.75		310.10	
Flooded lands		-155.94		-308.47		464.41
Lake surface	54.85		15.90		70.75	
Urban areas	3.18		0.20		3.38	
Total	677.47	- 677.47	626.93	- 626.93	1304.40	- 1304.40

Throughout the period of 18 years (1989 – 2007) the land uses were diversified (Table 5). Among the increased land uses, forests contributed by 54% to the increase for the period 1989 – 2000, by 30% for the period 2000 – 2007 and by 42.5% for the whole period of 1989 - 2007 (Table 5). These changes were probably due to the gradual decline of transhumance grazing in mountain areas (Fig. 2).

More specifically, the gradual decrease of sheep number (19.8%), especially during the period between 2000 and 2008 (Fig. 4) as well as the gradual decrease of goats (26.7%) for the whole period (Fig. 2), contributed to the decrease of grazing pressure especially in the shrublands. As a result the evergreen shrublands were grown in height and thicken taking the form of forests contributing to the increase of the forest area (Papanastasis 2003, Athanasiou et al. 2007). The decrease of evergreen shrublands contributed by 37.7% and 20.9%, respectively, to the total negative change of land use area in the two periods (1989 – 2000) and (2000 – 2007) and by 29.6% as a total for the whole period (Table 5).

The increase of agricultural land use contributed by 24.1% and 23.4%, respectively, to the total positive change of land use area in the two periods (1989 – 2000 and 2000 – 2007) or 23.8% for the whole period (Table 5). The increase of agricultural land was mainly due to the reduction of the abandoned fields, which was in a large degree a result of the return of land owners back to farming.

The reduction of the abandoned fields contributed by 28.5% and 21.3%, respectively, to the total negative change of land use area in the two periods (1989 – 2000 and 2000 – 2007), and by 25% as a total for the whole period (Table 5).

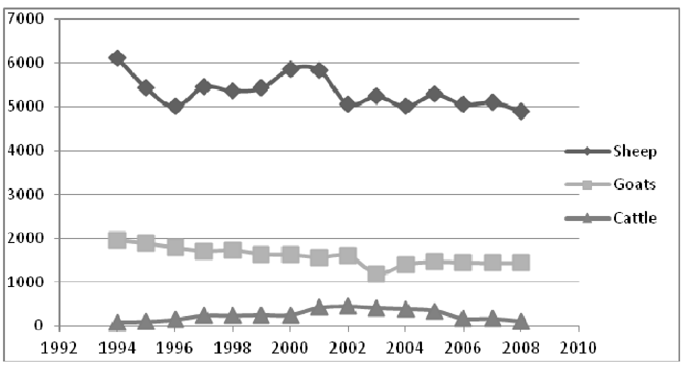

Figure 4. *Multitemporal annual changes of animal number, grazing in the study area of Pindus mountain, central Greece, during the period of 1994–2008.*

The increase of grasslands contributed by 13.3% and 44%, respectively, to the total positive change of land use area in the two periods (1989 – 2000 and 2000 – 2007) and by 28% as a total for the eighteen years period. This probably happened due to the reduction of annual rainfall in the region within the period of 2000 and 2007 (Fig. 2) and the withdrawal of flooded soils which led to the increase of grasslands (Fig. 5). The reduction of grazed open forests by 10.8% and 8.6% during the two periods and by 9.8% as a total for the whole period (Table 5) was due to the restoration of density and growth in height of deciduous broadleaf species. This forest restoration was favored by the gradual decrease of grazing animal number, especially, in mountainous areas (Table 4 and 5). Furthermore, an increase of 8.1% and 2.5% in lake water surface was recorded, which is probably attributed to the date (early May 2000) of receiving the satellite imagery (moving along the shoreline of the lake during the year).

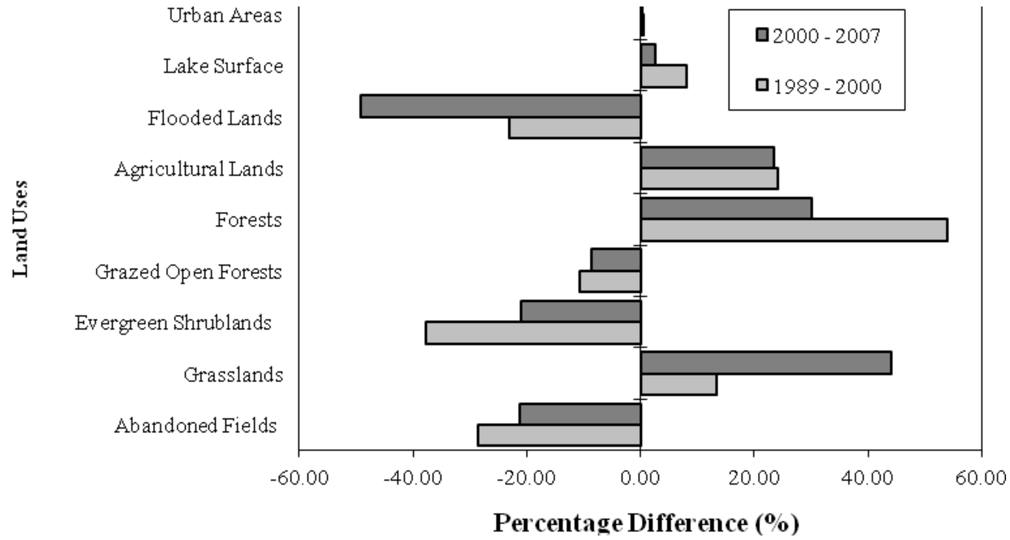

Figure 5. *Land use changes (%) in the study area of Pindus mountain, central Greece in the periods 1989 – 2000 and 2000 - 2007.*

Overall, the reduction of total grazing areas as a part of an overall reduction of land uses accounted to 63.7% in the first period (1989 – 2000) and to 6.8% in the second period (2000 – 2007) with a corresponding increase in forest and agricultural lands (Table 5 and Fig. 5).

4. Conclusions

The land use changes observed over time in a region of Pindus mountain, central Greece, are likely due to both, the evolution of vegetation and socioeconomic factors. However, some changes to a limited extent are probably due to errors in the classification algorithm. This might be a result of the spectral similarity of land use classes. The gradual dominance of forests in mountainous areas is the result of the reduction of transhumance grazing, a fact that along with the good site quality, has favored the forest cover increase. The study and the continuous monitoring of land use cover in the Plastira municipality, region of Pindus mountain, in central Greece, is imperative for the coming years in order to obtain the scientific information necessary for proper land management in the area.

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