Article

Multi-temporal Landsat image classification and change analysis of land cover/use in the Prefecture of Thessaloiniki, Greece

Meliadis Ioannis[1], Miltiadis Meliadis[2]
[1]NAGREF-Forest Research Institute, GR570 06 VASSILIKA, Greece
[2]Department of Forest Management and Remote Sensing, School of Forestry and Natural Environment, Aristotele University of Thessaloniki, Greece
E-mail: meliadis@fri.gr

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Abstract
This paper describes the methodology and results of classifications of multi-temporal Landsat TM/ETM+ data of the Prefecture of Thessaloniki, Macedonia Greece for the years 1986, 1999 and 2008. Nine different land cover/use categories have been used, named coniferous, broadleaves and mixed forest, agriculture lands, rangelands, grasslands, water bodies, urban areas and others uses. The overall classification accuracies were 85% for the three years, and the change detection accuracy was 88-91%. One of the most important results for the classifications is the fluctuation of the areas of the water bodies, mainly of the lakes, the decrease of the grasslands areas and the increase of forests, agricultural lands and rangelands. The results are being used to project future analyze landscape diversity and fragmentation, and examine different scenarios for more ecological management. The classifications have provided an economical and accurate way to quantify, map and analyze changes over time in land cover.

Keywords remote sensing; GIS; multi-temporal images; land cover/land use; Thessaloniki.

1 Introduction

Land-cover refers to the physical characteristics of earth’s surface, captured in the distribution of vegetation, water, soil and and/or artificial structures. Land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. Land cover/land use is a composite term, which includes both categories of land cover and land use. Land cover/land use change information has an important role to play at local and regional as well as at macro level planning and management. Most of the time the planning and management tasks of the environment are troubled due to insufficient information on rates of land cover/land use changes. The land cover changes occur naturally in a progressive and gradual way, however some times it may be rapid and sudden due to anthropogenic activities (Butenuth et al., 2007).

Imagery in the form of aerial photographs and satellite images has been demonstrated to be the most cost effective method for land cover mapping throughout the world (Trisurat et al., 2000). Historically, remote sensing in the form of aerial photography has been an important source of land cover and land use information. However, the cost of aerial photography acquisition and interpretation of cover types is prohibitively expensive for large geographic areas. An alternative is to acquire the needed information from digital satellite imagery such as Landsat TM and ETM+ (Meliadis, 2005; Meliadis et al., 2005).This approach has several advantages: (1) the synoptic view of large geographic areas, (2) the digital form of the data facilitating the more efficient analysis and (3) land cover maps can be generated at considerably less cost than by other methods.

GIS is the systematic introduction of numerous different disciplinary spatial and statistical data that can be used in inventorying the environment, observation of change and constituent processes and prediction based on current practices and management plans (Ramachandra and Kumar, 2004).

Change detection as defined by Hoffer (1978) is temporal effects as variation in spectral response involves situations where the spectral characteristics of the vegetation or other cover type in a given location change over time. Singh (1989) described change detection as a process that observes the differences of an object or phenomenon at different times.

Digital change detection is the process that helps in determining the changes associated with land use and land cover properties with reference to geo-registered multi-temporal remote sensing data (Papadopoulou and Tsakiri-Strati, 1993; Lu et al., 2004). It helps in identifying changes between two or more than two dates of the area under study. Change detection is useful in many applications such as land cover / land use changes, rate of deforestation, rate and success of reforestation, habitat fragmentation, landscape evolution, through the synergetic use of the spatial and temporal analysis techniques of Geographic Information System (GIS) and Remote Sensing along with digital image processing techniques (Foody, 2002; Malinverni et al., 2003). So, the remote sensing data at different time interval help in analysing the rate of changes as well as the causal factors or drivers of changes. Hence it has a significant role in regional planning at different spatial and temporal scales. This along with the spatial and temporal analysis technologies of GIS and Global Positioning System (GPS) help in maintaining up-to date land-use dynamics information for a sound planning and a cost-effective decision. In such a way it is possible to be developed a multi-temporal atlas of the area under investigation with all the metadata needed for the record of the area. Science and reporting information needs for monitoring dynamics in land cover over time have prompted research, and made operational, a wide variety of change detection methods utilizing multiple dates of remotely sensed data. Change detection procedures based upon spectral values are common; however, landscape pattern analysis approaches which utilize spatial information inherent within imagery present opportunities for the generation of unique and ecologically important information (Gitas et al., 2009). While the use of two images may provide the means to identify change, the use of more than two images for long-term monitoring affords the ability to identify a greater range of processes of landscape change, including rates and dynamics (Frey and Butenuth, 2009).

2 Study Area

The study area is the Prefecture of Thessaloniki which stretches between 40° 41′ 1.32″ N, 23° 16′ 42.96″ E. The population is about 1.099.598 and the area is 3,682,736 km^2. It is surrounded from the Thermaikos Gulf to the Strymon Gulf. Two bodies of water stretch to the north, Lake Koronia in the heart of the prefecture and Lake Volvi to the east. The mountains are in the central and the northern parts, farmlands are in the western and the south western part and few to the northeast, the northern portion and along the Axios valley. The mountains include the Hortiatis to the west central part, the Vertiskos to the north and parts of the Kerdylio mountains to the northeast. The prefectures is bounded with the Imathia prefecture to the southwest, Pella to the west, Kilkis to the north, Serres to the east and Chalkidiki to the south (Fig. 1). From forestry terms dominate evergreen broadleaf (65.5%) and oak (27.3%), while smaller areas are covered by trees (2.6%), beech (2.6%), Aleppo pine (2.0%), chestnut (0.9%) and black pine (0.1%) (Ainalis et al., 2007). In the region there are important points of petrochemicals and cement, oil refineries and steel mills Prefecture of

Thessaloniki presents unequal distribution of water resources. The mountainous and hilly in parts (as opposed to the lowlands) have poor hydrodynamic basement. Also, the population surge in suburban municipalities, combined with the existence of large industrial activity creates progressively increasing competitive demands and pressures on the environment. Its climate includes hot Mediterranean summers and cool to mild winters in low lying areas and its plains. Winter weather is very common in areas 500 m above sea level and into the mountains.

The county is significant in terms of agricultural production which requires studies and Environmental Impact Assessment for the protection of land resources (Ainalis et al., 2010).

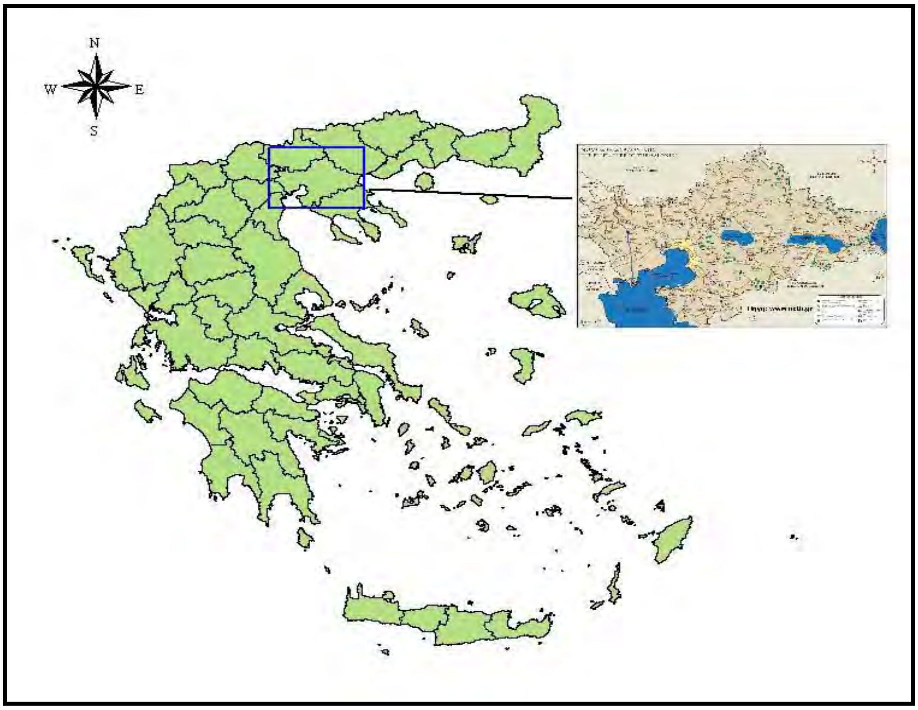

Fig. 1 Orientation map of the study area, Prefecture of Thessaloniki, Greece.

3 Objectives

The objectives of this study include:

Identification of land cover / land use and the spatial distribution;

Development of digital data land cover database;

Create a digitally historical atlas of the Prefecture of Thessaloniki with the different land cover / land use changes;

Continuation of the multi–temporal research of the environmental changes.

4 Methodology

The main goal of this study is to reveal environmental changes using multi- temporal satellite data, in order to extract changes. The digital image-processing software Erdas imagine 8.6 were used for the processing, analysis and integration of spatial data to reach the objectives of the study. Erdas Imagine was used to generate the false colour composite, by combing near infrared, red and green which are bands 4, 3, 2 together for both images. This was done for vegetation recognition, because chlorophyll in plants reflects very well to near infrared than the visible. For image classification, nine classes was defined which are Water bodies, Agricultural land, Urban areas, Rangelands, Coniferous forests and Broadleaves forests, Mixed forests, Grasslands, and Other uses.

Multi-temporal Landsat TM/ETM+ data acquired on early and mid to late summer dates in 1986, 1999, and 2008 have been used to classify level I and II land cover. Processing and classification of data for 2010 which will extend the temporal series is currently underway. It has been found that the combination of early summer (late May or early June) with mid to late summer (August or early September) images provides the highest classification accuracy. The most noticeable remarks were that the early images fields planted to annual crops respond as bare soil and are distinguishable from forests which are already fully leafed out. When only a summer image is used, forests and some crops, especially corn, are spectrally similar. Conversely, the later summer image is needed to separate those same crop fields from urban areas with significant amounts of impervious surfaces that are spectrally similar to bare soil.

Ground control points obtained using a Global Positioning System from locations in relation to the classes of the study area was plotted on Landsat ETM+ image, which was used to verify the training sites (defined classes) as regards the spectral signature. Supervised classification for the various classes was performed using and finally maximum likelihood classification was used for the classification of the images.

The data structures (raster and vector) in ArcGis package offered versatile user friendliness in the preparation of various databases like thematic, topographic, soils, land cover and land use maps as well as attribute databases. Some of the important capabilities of the above package which are reclassifying, overlaying and digitizing were used in this part of the procedure given in Fig. 2. The GIS software will be used to assist planners in the analysis of such changes, by combining the maps derived from the classified images from the years 1986, 1999 to 2008 and integrating the multiple (spatial and attribute) databases.

The development of the databases of the multi-temporal land cover/use maps was one of the objectives of this study and the success (or not) will work as a pilot application for other areas. The combination of these maps with other thematic maps as soil, road network, fire risk maps, and vegetation density maps will give answers to the changes of the land cover / land use categories and in some cases the reasons of the changes.

5 Results

The unsupervised image classification method carried out prior to field visit, in order to determine strata for ground truth. Fieldwork carried out to collect data for training and validating land-use/cover interpretation from satellite image of 2008, and for qualitative description of the characteristics of each land-use/cover class. The land-cover/ land use maps of 1986, 1999 and 2008 were produced by using supervised image classification technique based on the Maximum Likelihood Classifier (MLC) and 832 training samples. Fig. 3 and Fig. 4 present the classification of the study area of the years 1986 and 2008.

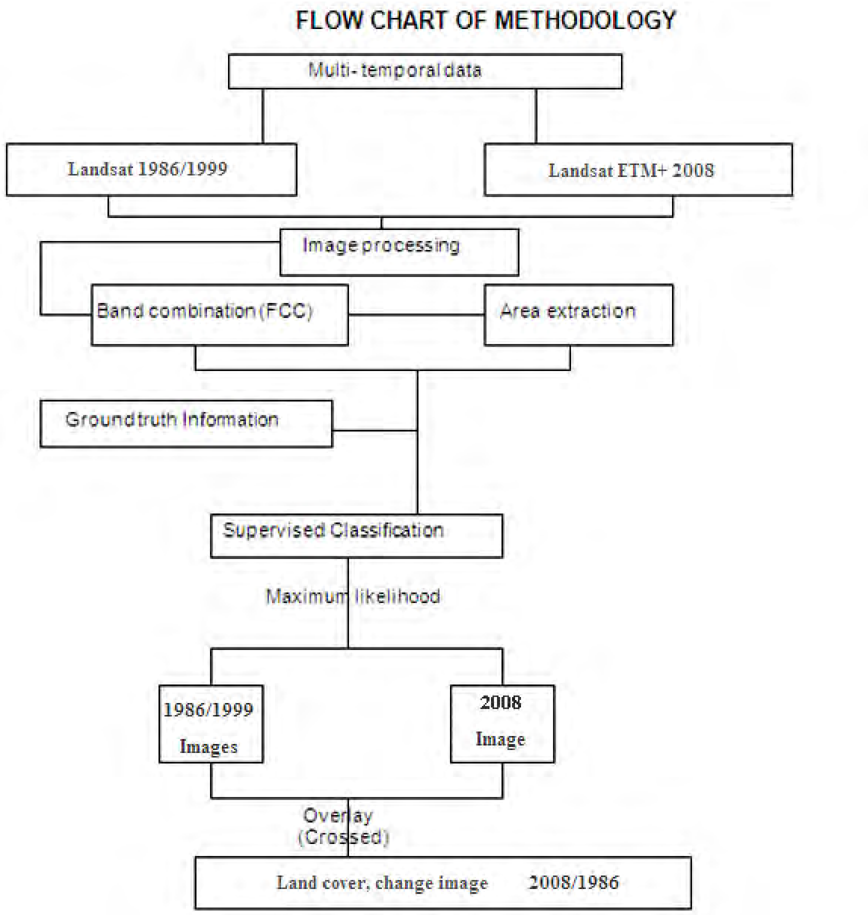

Fig. 2 Flow chart of the methodology used in the study.

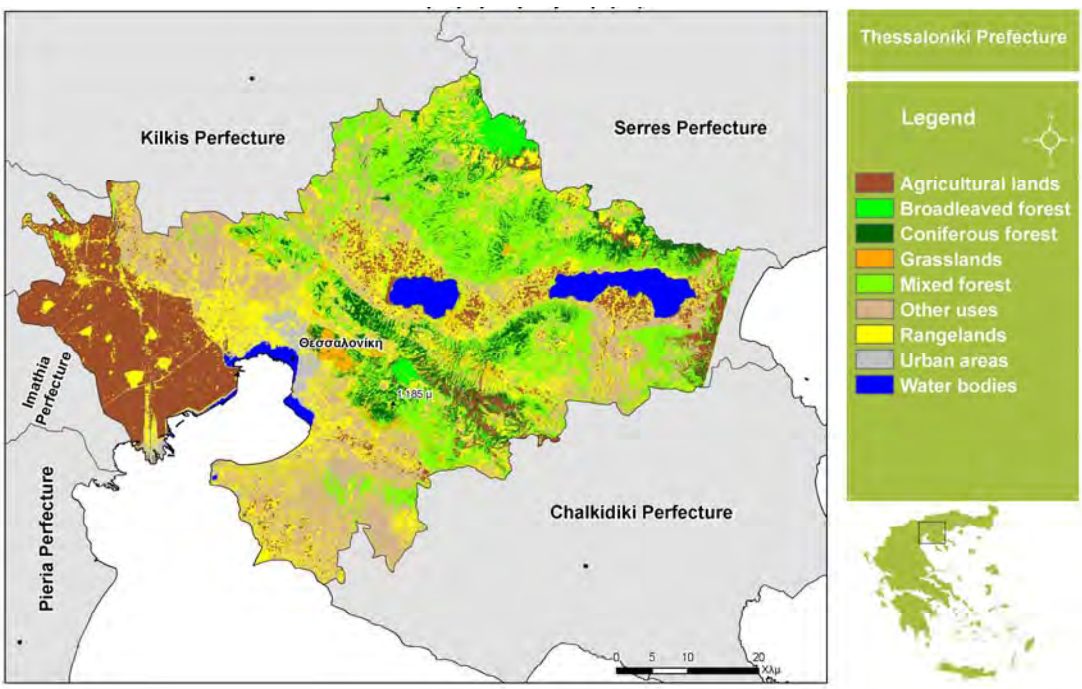

Fig. 3 The classified image of the year 1986.

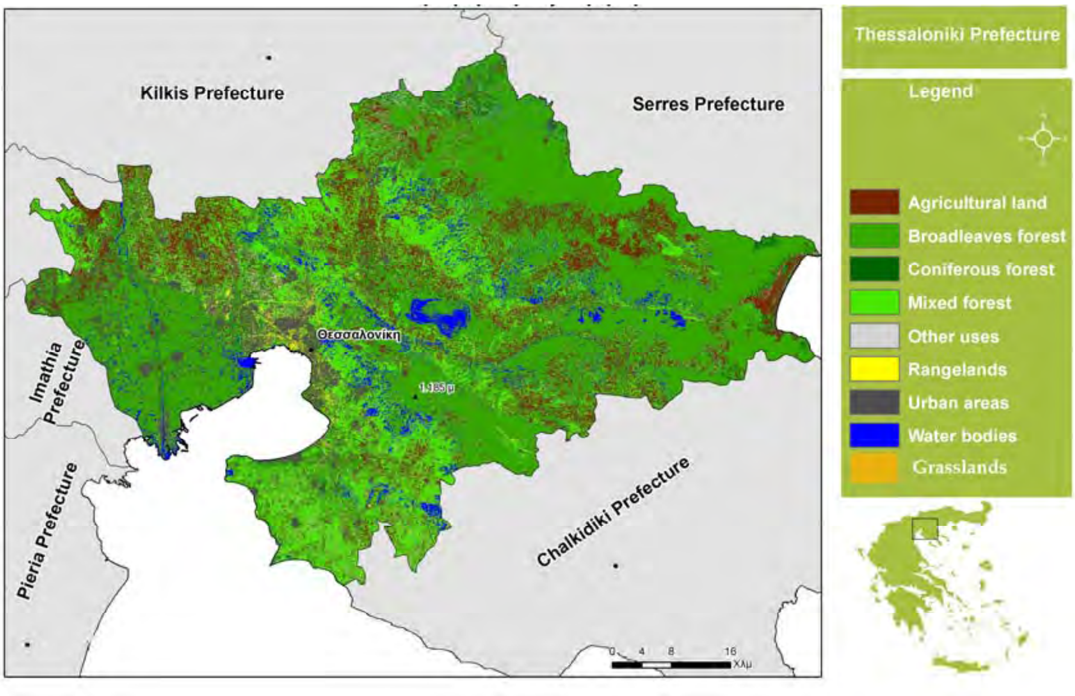

Fig. 4 The classified image of the year 2008.

Table 1 presents the area occupied by the nine categories during 1986, 1999 and 2008. Error matrices as cross-tabulations of the mapped class vs. the reference class were used to assess classification accuracy. Overall accuracy, user's and producer's accuracies were then derived from the error matrices. A multi-date post-classification comparison change detection algorithm was used to determine changes in land cover in three intervals, 1986–1999, 1999–2008 and 1986–2008 (Table 2).

Table 1 The areas of the land cover categories for the years 1986, 1999 and 2008.

Land cover /Land use	1986	% of the total area	1999	% of the total area	2008	% of the total area
Coniferous forests	22984.23	6.24	22890.56	6.22	24760.88	6.72
Broadleaves forests	31342.31	8.51	38783.21	10.53	39735.48	10.79
Mixed forests	8911.78	2.42	8902.12	2.42	12201.82	3.31
Rangelands	7901.21	2.15	5839.50	1.59	9682.778	2.63
Grasslands	31498.60	8.55	35356.40	9.60	25154.09	6.83
Agricultural land	207234	56.27	222856.20	60.51	211362.5	57.39
Water bodies	35012.12	9.51	5409.62	1.47	12000.23	3.26
Urban areas	3011.82	0.82	3138.40	0.85	4174.432	1.13
Other uses	20403.93	5.54	25123.99	6.82	29227.8	7.94
TOTAL	368300	100.00	368300	100.00	368300	100.00

Table 2 Land cover / land use changes between 1986-1999, 1999-2008 and 1986-2008.

Land cover /Land use	1986	1999	Change	1999	2008	Change	1986	2008	Change
Coniferous forests	22984.23	22890.56	-93.67	22890.56	24760.88	1870.32	22984.23	24760.88	1776.65
Broadleaves forests	31342.31	38783.21	7440.9	38783.21	39735.476	952.266	31342.31	39735.476	8393.17
Mixed forests	8911.78	8902.12	-9.66	8902.12	12201.817	3299.697	8911.78	12201.817	3290.04
Rangelands	7901.21	5839.5	-2061.71	5839.5	9682.778	3843.278	7901.21	9682.778	1781.57
Grasslands	31498.6	35356.4	3857.8	35356.4	25154.09	-10202.31	31498.6	25154.09	-6344.51
Agricultural land	207234	222856.2	15622.2	222856.2	219362.5	-3493.705	207234	219362.5	12128.50
Water bodies	35012.12	5409.62	-29602.5	5409.62	12000.23	6590.61	35012.12	12000.23	- 23011.89
Urban areas	3011.82	3138.4	126.58	3138.4	4174.432	1036.032	3011.82	4174.432	1162.61
Other uses	20403.93	25123.99	4720.06	25123.99	21227.801	-3896.189	20403.93	21227.801	823.87

Fig. 5 represents graphically the above changes. To evaluate the change maps for the 1986 to 2008 interval, we randomly sampled the areas that classified as change and no-change and determined whether they were correctly classified. The maps showed that between 1986 and 2008 the amount of coniferous forests increased as 0.48% of the total area, the broadleaves forest also increased as 2.28% while the mixed forests increase 0.89%. The rangelands, urban areas and other uses increase 0.48, 0.32 and 0.22% respectively. The agricultural lands also increase as 3.29%, grasslands 1.72%. The water bodies show a decreased 6.25 and grasslands 1.78% respectively (Table 3). The overall nine-class classification accuracies averaged 85% for the three years. The overall accuracy of land cover change maps, generated from post-classification change detection methods and evaluated using several approaches, reached to 88-91%. The average accuracy for land cover land use of 2008 image was 89.56% and average reliability 88.86% and the overall accuracy 90.68%.

For the evaluation of the accuracy of classification a matrix of changes has been used (Table 4) for the image 2008 and the field control points.

It has also been investigated the changes in landscape diversity and fragmentation as a function of time from 1986 to 2008 using the Landsat classifications and landscape metrics (Fig. 6). Landscape diversity has remained relatively stable, but fragmentation, especially of coniferous and broadleaves forests, has increased significantly during this period.

The land cover/ land use classification maps will be inputs to models to simulate or predict future growth patterns. For the time being the Land Transformation Model (LTM) has been implemented which uses population growth, transportation factors, proximity or density of important landscape features such as rivers, lakes, recreational sites, and high-quality vantage points as inputs to predict land use changes. The model uses GIS and customized geospatial tools with land use data from at least two time periods (1999 and 2008) being a key input. Information derived from historical land use change is one of the most important factors used to forecast future trends and patterns. The model is also be used to help understand which factors are most important to land cover/land use change.

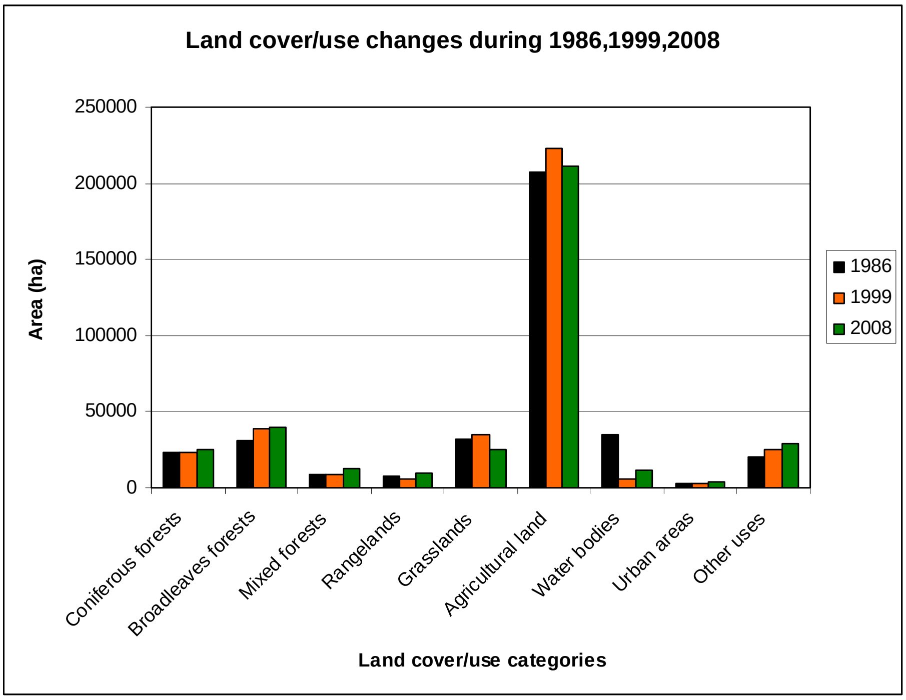

Fig. 5 Changes in the nine categories during 1986, 1999 and 2008

Table 3 Changes in land cover / land use between 1986 and 2008

Land cover/land use categories	1986	2008	Changes	% Change
Coniferous forests	22984.23	24760.88	-1776.65	-0.48
Broadleaves forests	31342.31	39735.476	-8393.166	-2.28
Mixed forests	8911.78	12201.817	-3290.037	-0.89
Rangelands	7901.21	9682.778	-1781.568	-0.48
Grasslands	31498.6	25154.09	6344.51	1.72
Agricultural land	207234	219362.5	-12128.495	-3.29
Water bodies	35012.12	12000.23	23011.89	6.25
Urban areas	3011.82	4174.432	-1162.612	-0.32
Other uses	20403.93	21227.801	-823.871	-0.22

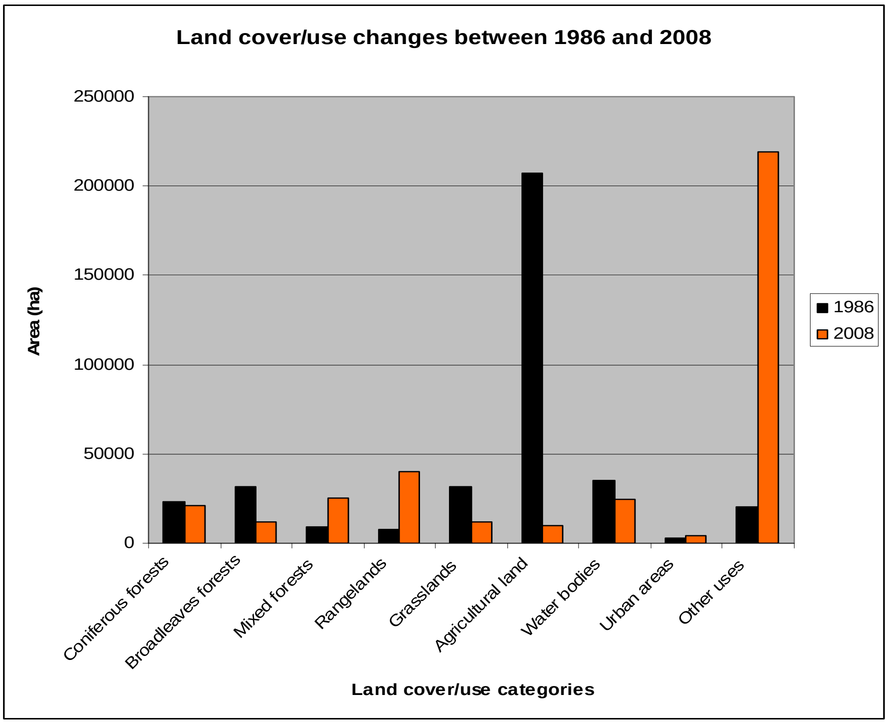

Fig. 6 Changes in the land cover/land use categories between 1986 and 2008.

Table 4 Matrixes of changes (hectares) in land cover of 2008

Land cover / land use categories	Coniferous forests	Broadleaves forests	Mixed forests	Rangelands	Grasslands	Agricultural land	Water bodies	Urban areas	Other uses	TOTAL	Producer's accuracy
Coniferous forests	20005.21	89.78	810.23			68.82			10.19	24760.88	80.79
Broadleaves forests	1115.02	37901.9		225.39						39735.476	95.39
Mixed forests	1640.65		9895.34		815.67	217.69			342.43	12201.817	81.10
Rangelands				8167.1	1535.23		20.23		198.88	9682.778	84.35
Grasslands		9912.08			24009.34			689.26		25154.09	95.45
Agricultural land		433.616	1391.58	1290.288		199882.23			4936.279	219362.5	91.12
Water bodies						13	11099.12			12000.23	92.49
Urban areas								3998.12	13.7	4174.432	95.78
Other uses								511.81	19012.0	21227.8	89.56
	22760.88	48337.37	12097.15	9682.778	26360.24	200181.74	11119.35	5199.19	1911513.5		
User accuracy	87.89	78.41	81.79	84.34	91.08	99.85	99.81	76.89	99.71	368300	

Average accuracy	89.56
Average reliability	88.86
overall accuracy	90.68

6 Conclusions

Remote sensing technology in combination with GIS can render reliable information on vegetation cover. The analysis of the spatial extent and temporal change of vegetation cover using remotely sensed data is of critical importance to much environmental management.

The study has indicated the potential use of remote sensing data in studying land cover/ land use change. GIS techniques integrated in this study has proved beyond doubt its capabilities of spatial analysis. Information from satellite remote sensing can play a useful role in understanding the nature of changes in land cover/use, where they are occurring, and projecting possible or likely future changes. In this study Landsat images were used satisfactorily for the identification of the nine categories. It's observed that the some categories in the area under study changed during 1986- 2008 remarkably. Decrease in coniferous and broadleaves forests and water bodies, has been as a result of anthropogenic activities in the study area.

The growth of the size of cities, often at rates exceeding the population growth rate, and the accompanying loss of agricultural lands, forests and wetlands, escalating infrastructure costs, increases in traffic congestion, and degraded environments, is of growing concern to citizens and public agencies responsible for planning and managing growth and development. Information from satellite remote sensing can play a useful role in understanding the nature of changes in land cover/use, where they are occurring, and projecting possible or likely future changes.

In conclusion for detecting changes in areas based on a subject e.g population increase, vegetation etc, over a period of years both spatial and in quantitative way, integrating remote sensing data and GIS techniques will be useful Such information is essential to planning for development and preserving our natural resources and environment, and is needed by urban planners and citizens. Satellite remote sensing approaches provide a cost-effective alternative when more information is needed, but budgets are declining.

References

Ainalis AB, Platis PD, Meliadis IM, et al. 2007. Monitoring of vegetation changes of rangelands in the watershed of N. Apollonia prefecture of Thessaloniki and the insect species which occur in the area. Proceedings of the 13th National Forestry Conference, "Development of the mountainous areas Protection of the environment". 7-10 October, Kastoria, 394-412 (In Greek)

Ainalis AB, Platis PD, Meliadis IM. 2010. Grazing effects on the sustainability of an oak coppice forest. Forest Ecology and Management, 259(3): 428-432

Butenuth M, Gösseln GV, Tiedge M, et al. 2007. Integration of heterogeneous geospatial data in a federated database. ISPRS Journal of Photogrammetry and Remote Sensing, 62(5): 328-346

Foody GM. 2002. Status of land cover classification accuracy assessment, Remote Sensing of Environment, 80: 185-201

Frey D, Butenuth M. 2009. Classification system of GIS-objects using multi-sensorial imagery for near-realtime disaster management. In: International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol.XXX VIII (3/W4), 103–108

Gitas I, Meliadis M, Katagis T, et al. 2009. Monitoring land use/cover change with the use of object based image analysis and Landsat imagery. 3rd Workshop of the EARSeL Special Interest Group on Land Use and Land Cover. 25-27 November 2009, Bonn, Germany

Hoffer RM. 1978. Biological and Physical Considerations in Applying Computer- aided analysis techniques to Remote Sensor data. In Remote Sensing: The quantitative approach (PH Swam, SM Davis Eds), McGraw- Hill, USA

Lu D, Mausel P, Brondizio E, et al. 2004. Change detection techniques. International Journal of Remote Sensing, 25(12): 2365–2401

Malinverni ES, Fangi G, Salandin P. 2003. Spatial Modeling in a GIS for an environmental decision support system - Workshop Spatial Analysis and Decision Making SADM2003 . ISPRS . Commission II WG 5 and 6. Hong Kong, 229-241

Meliadis IM. 2005. Correlations of environmental parameters with the use of satellite technology and G.I.S. Forest Research, 17: 19-26 (in Greek)

Meliadis IM,Tsiontsis A, Daskalakis T. 2005. Estimation of the risk erosion in the soil of the county of Thessaloniki Proceedings of the 12th National Forestry Conference, Forest & Water Protection of the Environment. Drama 2-5 October, 433-440 (In Greek)

Papadopoulou M, Tsakiri-Strati M. 1993. The Monitoring of Environmental Changes with the combination of Aerial Photos and Satellite Images, 2nd Greek Convention, Solar and Space Research

Ramachandra T, Kumar U. 2004. Geographic Resources Decision Support System for land use, land cover dynamics analysis. Proceedings of the FOSS/GRASS Users Conference. 12-14 September 2004, Bangkok, Thailand

Singh A. 1989. Digital change detection techniques using remotely-sensing data. International Journal of Remote Sensing, 10(6): 989-1003

Trisurat Y, Eiumnoh A, Murai S, et al. 2000. Improvements of tropical vegetation mapping using a remote sensing technique: a case study of Khao National Park, Thailand. International Journal of Remote Sensing, 21: 2031-2042