THE INTEGRATION OF REMOTE SENSING AND G.I.S. FOR ENVIRONMENTAL DECISION ANALYSIS

MELIADIS IOANNIS (*)

ABSTRACT

The integration of remote sensing tools and technology and the spatial analysis orientation of geographic information systems is a complex task which nevertheless is a very serious step in the management of the environment. This paper focuses on the issues of making data available and useful to the users which are working on environmental management problems. More specific the data from LANDSAT TM7 was associated with the (digital) spatial data derived from analogue maps in order to evaluate the environmental parameters that are affecting the management of a specific environment. The study area is the central part of Greece and is characterized as Special Protected Area, due to its importance of the wild fauna. In this study a thematic land cover map has been produced by a satellite image with an accuracy of 81.5%. This map has been processed with the soil map in order to find the spatial distribution of the vegetation cover types. The land capability map of the area derived using the land cover types, soil parent material, soil depth and aspect maps. The study proved that the integration of remote sensing data and Geographic Information Systems is the decision making tool for developing contingency plans for the management of the environment.

RÉSUMÉ

L'intégration des outils de télédétection et de technologie ainsi que l'orientation vers une analyse spatiale des systèmes d'information géographique est une tâche complexe qui, toutefois, constitue un pas sérieux dans le domaine de la gestion de l'environnement.
Cet article met l'accent sur les façons de rentrer les données tant disponibles que commodes pour les usagers travaillant sur des questions de gestion de l'environnement. Plus précisement, les données de LANDSAT TM7 ont été associées aux données spatiales (numériques) extraites de cartes analogiques afin d'évaluer les paramètres naturels qui influencent la gestion d'un milieu spécifique. La région étudiée consiste en la partie centrale de la Grèce, caractérisée comme réserve naturelle en raison de l'importance de sa faune sauvage.
Dans cette étude une carte d'usages différents du territoire thématique a été produite par une image de satellite d'une acuité de 81.5%. Cette carte a été traitée avec la carte du sol en vue de découvrir la distribution spatiale des types de végétation. La carte, qui indique les capacités de la terre de la région, a été produite au moyen des types d'usages différents du territoire, du premier matériel du sol, de la profondeur du sol et des cartes d'aspect. L'étude a prouvé que l'intégration de données de télédétection et de Systèmes d'Information Géographique constituent l'outil spécifique pour le développement de projets de contingence nécessaires à la gestion de l'environnement.

INTRODUCTION

The study of environmental dynamics needs a distributed analysis which can be carried out, in our days, by the means of computer systems capable of acquiring, managing and spatially elaborating a great amount of information concerning topography, hydrography, climate, geological characterization of the soil, plant cover, etc.

Also using data produced from Earth Observation missions into GIS database development can be considered one of the major applications of remotely sensed data (Mast et al. 1997).

Digital remote sensing data are very flexible and have the potential for many resource applications.

More specific the remotely sensed imagery is an important source of current and repeatable information about the location, quantity and quality of land cover (Lannom et all, 1998) and has been extensively used to produce geographic data to be introduced into a GIS (Dykstra J; 1990, Eckhardt et al., 1990).

All the information, which makes up different informative layers inside a GIS, can be analysed by means of a set of map operations that, on one hand, allow better understanding of the observed phenomena, and on the other, the examination and testing of the model used.

It is obvious that the environmental monitoring requires the use of new techniques (Goward et all, 1987) for obtaining, processing and displaying spatial information in a timely and cost effective way.

The purpose of this paper is to explore the emerging role of the integrated spatial information technologies of remote sensing and GIS and to examine their utilization in environmental management.

The objectives of this study were:

1. Use satellite image to identify the land cover types of the study area.
2. Use different environment parameters to evaluate the distribution of land cover types on different soil types.
3. Evaluate the effectiveness of the overlay analysis procedure to create the forest potential map of the study area.

THE STUDY AREA

The area which has been selected for the purpose of this study was the Mountain Antichasia - Meteora found in the middle part of Greece (**Fig. 1**).

The area is 826.000 Ha and belongs to the Mediterranean zone.

This biotope has been characterised as a Special Protected Area (SPA) according to the EC Instruction 79/409/EC, due to its importance for the wild fauna. For this reason the E.E. has included the biotope in the Life - Nature network.

(*) N.AG.RE.F - Forest Research Institute Lab of Remote Sensing & G.I.S. Vassilika, Thessaloniki 540 06 Greece, e-mail: meliadis@fri.gr

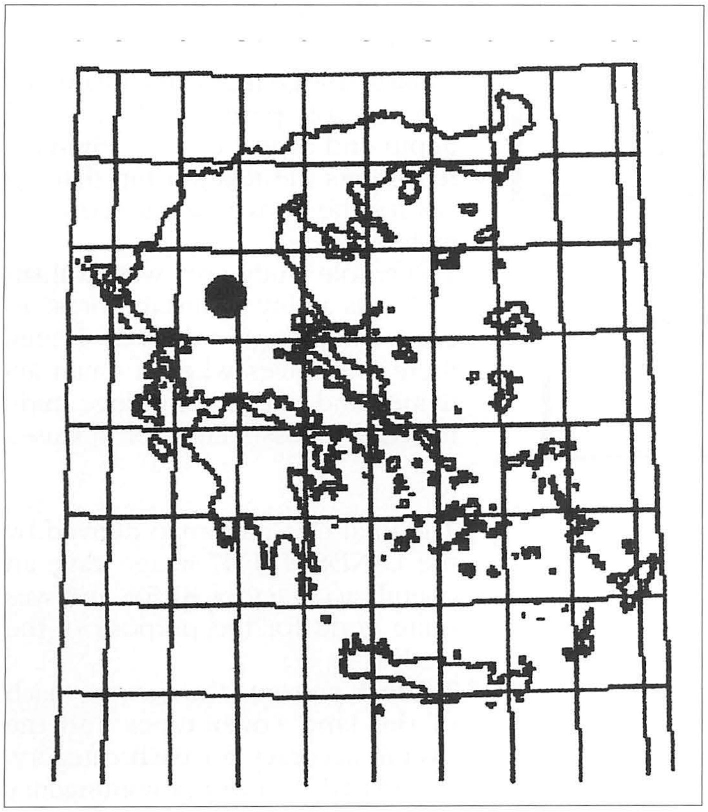


Fig. 1 - Orientation of the study area.

The range of the altitude is between 250 and 1.400 m.
The area is characterised by the presence of well developed ecotypes, which appear as a mosaic of high trees, maquis and brushlands (Meliadis et all, 1995).
The area has a poor economic development, the people deal with agriculture, animal husbandry and forestry.

Methodology

The image selected for processing was acquired in June 1999 (**Fig. 2**). It presented good cloud-free coverage in the study area and convenient phenological conditions for discriminating different vegetation species. The objective of the digital classification was to produce a detailed map of the vegetation types and characteristics of the study area.

The information obtained with the image through the classification process is a raster map where each pixel was assigned to one of the classes shown in Table 1.

In the preprocessing phase the unsupervised classification was used to obtain a better statistical definition of the land cover classes. Aerial photographs, at a scale 1:35.000, were used to select the training fields. For the final production of the land cover map the supervised maximum likelihood classification was performed.

The following steps were the digitization of the Soil maps of the study area and to update the polygon attributes with data. The parameters used were:

– soil parent material (eight categories for the study area)
– soil depth (three categories for the study area)
– aspect (nine categories for the study area)
– slope (ten categories for the study area).

Each of these variables were considered as a different layer of information for the integrated analysis. The overlaying of the land cover and soil types digital maps gave the distribution of the vegetation within the different soil parent material types. This was the first indication how the land cover was distributed in different micro-environments and how they were adapted to the present situation. The overlaying of the rest variables on the combined digital map of land cover and soil types made possible to define the land capabilities (Meliadis et al., 1998) to maintain forest areas for timber growth. The main factors that in-

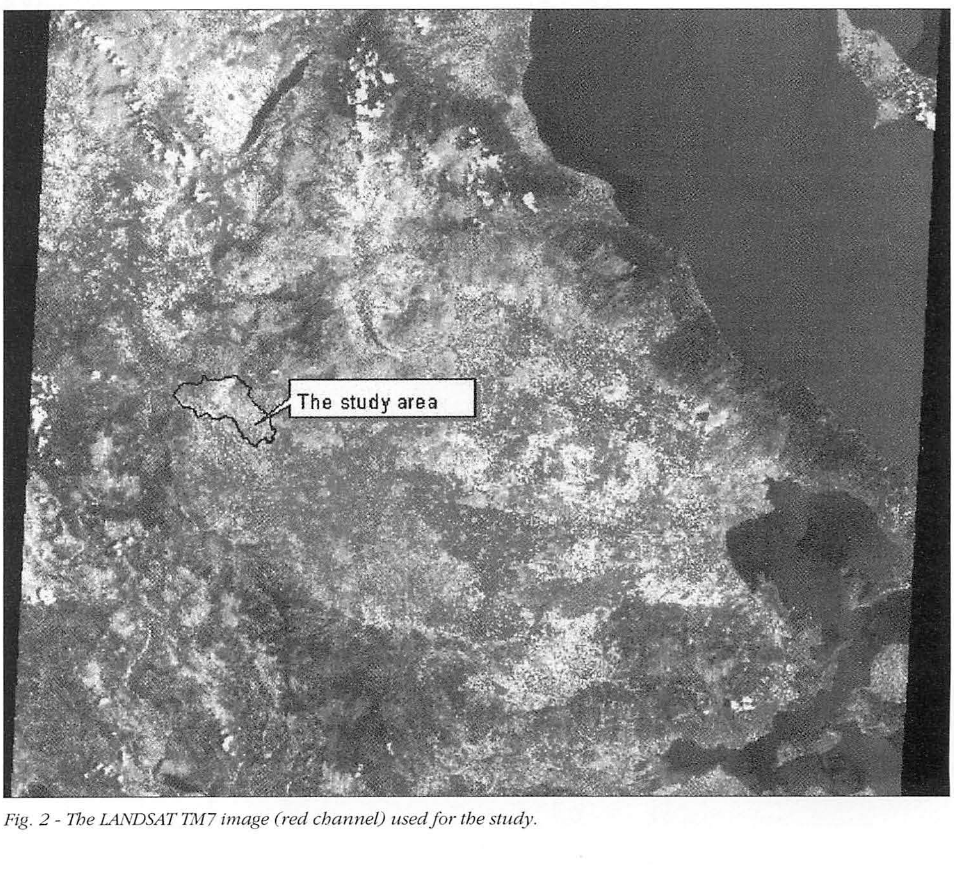


Fig. 2 - The LANDSAT TM7 image (red channel) used for the study.

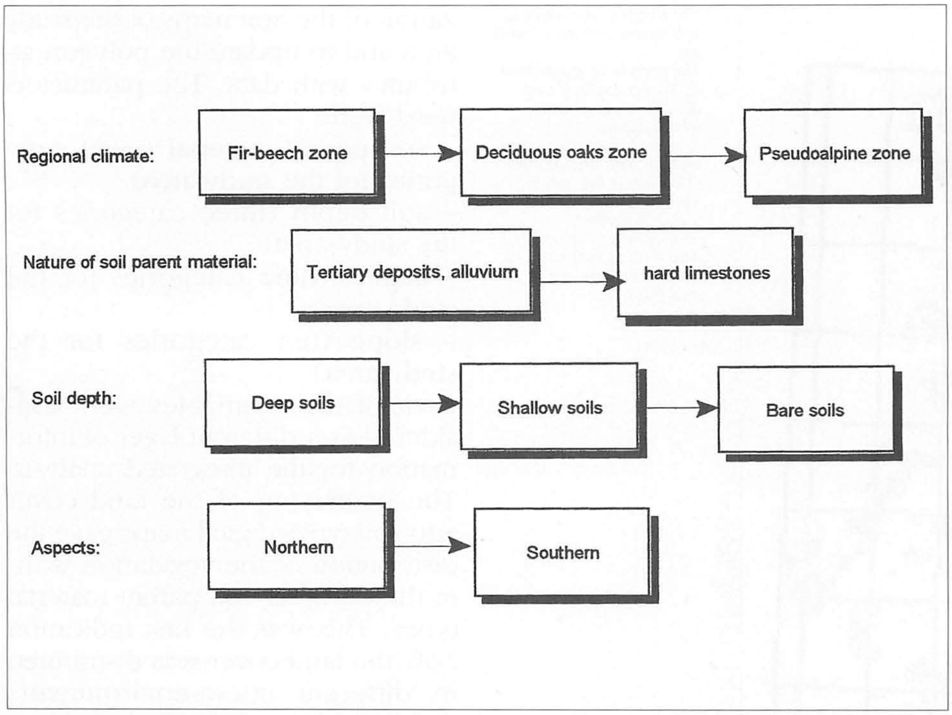


Fig. 3 - Gradients of the physical characteristics used for the evaluation of forest productivity.

fluence the land to physical sustain forest areas for timber growth are (Nakos, 1991): regional climate, nature of soil parent material, soil depth and aspect classes. **Figure 3** represents the relationship that exists for the above mentioned parameters.

The whole study area was evaluated for its ability to sustain forest areas for timber growth even though there are places where human activities and overgrazing have minimized the possibilities for this use.

RESULTS

The final classified map derived by the LANDSAT TM7 image gave an overall accuracy of 81.5% and was quite good for the purpose of the study.

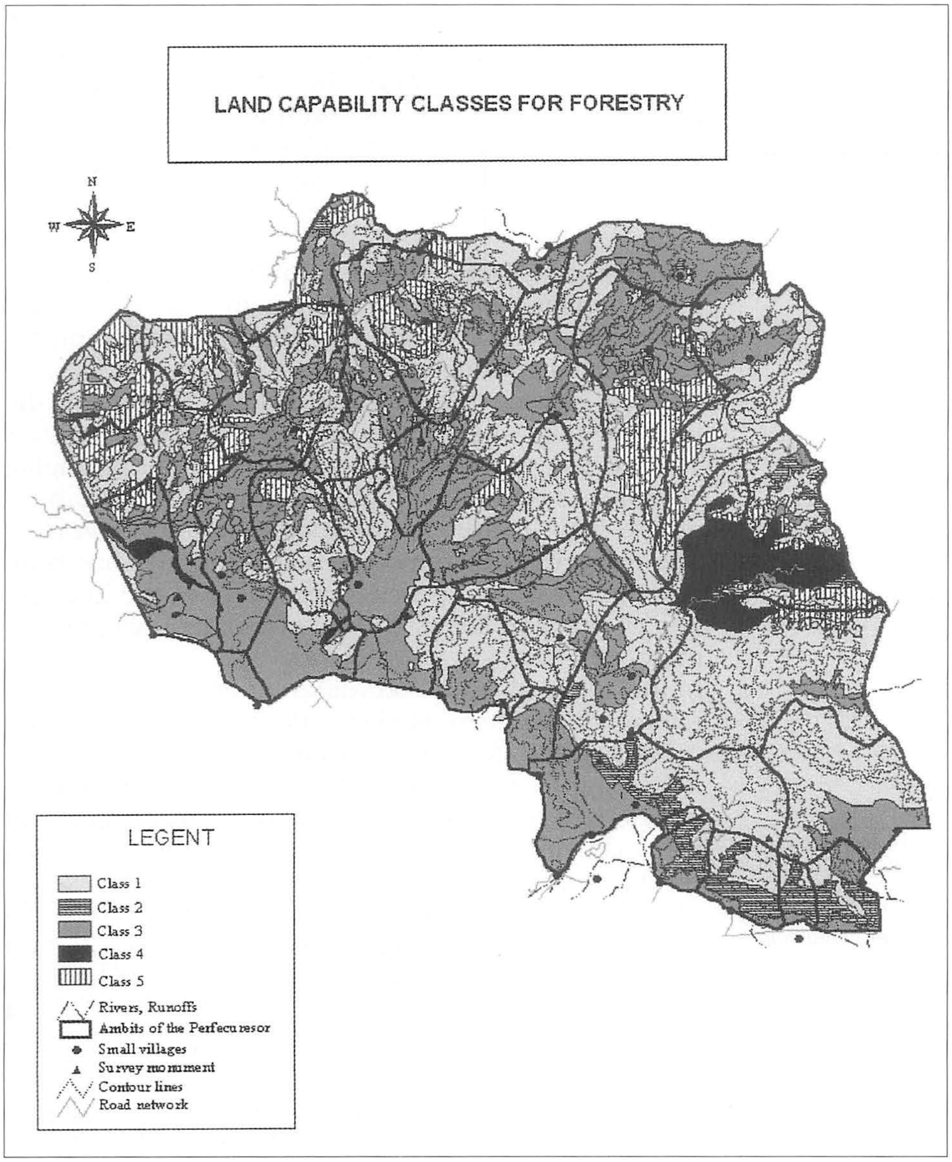
Table 1 presents the area for each of the land cover types and the overall accuracy for each category. This accuracy was calculated by using a contingency table between the map and true categories with confidence level 95%.

Table 1 ***Area of land cover types in the study area, and their overall accuracy according to the classified raster image.***

Land cover Types	Area	% of the total area	Overall accuracy (%)
Beech forests	9,019	1.09	75.00
Oak forests	163,651	19.81	80.00
Evergreen deciduous trees	244,201	29.55	85.50
Brushlands	83,149	10.06	85.70
Agricultural lands	208,845	25.27	83.30
Black pine forests	269	0.32	75.00
Spartial forested oaks	68,492	8.29	90.90
Sparse brushlands	25,267	3.05	80.00
Sycamore clusters	1,967	0.24	93.30
Urban areas	21,357	2.58	80.00
Unclassified	140	0.02	
Total Sum	**826,357**	**100.00**	

Table 2 ***Types of soil parent material in the study area.***

Soil types	Area	% of the total area
Alluvium	105,875.77	12.81
Riverbed	7,602.01	0.92
Hard limestones	70,593.24	8.54
Laying down cones	152.70	0.02
Tertiary deposits	345,597.47	41.82
Schists	176,237.75	21.33
Gneiss	120,298.45	14.56
Total Sum	**826,357.37**	**100.00**



Map 1 - Land capabilities for forestry in the biotope of Antichasia-Meteora.

From the digitized soil map it was found that the tertiary deposits are the main soil types (**Table 2**) in the study area followed by schist, gneiss and alluvium.

The urban areas have been masked and excluded from the digital image in order to use only the vegetation cover of the study area. The spatial overlay of the masked classified image and the soil map produced a new thematic layer presenting the distribution of the different cover types on the soil parent material. The statistical evaluation of this data showed 48 different categories.

Figure 4 presents for each land use category the maximum appearance in the eight different soil type categories.

The land capabilities map for forestry derived using the next identification parameters (**Table 3**).

According to the classes in Table 3 and the combined digital maps of land covers, soil parent material, soil depth and aspect the map of land capabilities for forest timber production was evaluated (**Map 1**). The statistical analysis of this thematic map showed that most of the area is suitable for forest timber production (**Table 4**).

The results showed that most of the study area is capable for timber production (63.42%) and only 36.58% have severe limitations. The latter is due to the overgrazing and human activities. The management plan that is now in use by the local authorities is based mainly on the social sector of the area and has differences from the results that derived from the above analysis. And that was more obvious when the land capability map was overlaid with the maps of the present land use and the ownership status quo. The statistical analysis of the land use layer showed that 59.99% of the area is forests and forested areas, 12.75% is rangelands, 24.65% is agricultur-

Table 3 ***The classes of the land capabilities for forest timber production.***

CLASS	IDENTIFICATION	EXPLANATION
1	Lands without physical limitations for timber growth	Lands with deep soils derived from tertiary deposits, schist, hard limestone and alluvial deposits1. In the fir-beech zone 2. On northern aspects in the deciduous oak zone.
2	Lands with slight limitations for timber growth	Land with deep soils derived from tertiary deposits, schist, hard limestone, alluvial deposits on southern aspects in the deciduous oaks zone. Lands with shallow soils from the above kinds of soils on northern aspects in the fir beech zone.
3	Lands with moderate limitations for timber growth	Lands with shallow soils derived from tertiary deposits, schist, hard limestone on southern aspects in the fir beech zone and on northern aspects in the deciduous oak zone.
4	Lands with severe limitations for timber growth	Lands types with shallow soils derived from tertiary deposits, schist, hard limestone on southern aspects in the deciduous oak zone.
5	Lands with extremely severe limitations for timber growth	Land types with bare soils regardless of nature of soil parent material, vegetation zone and aspect in the pseudoalpine zone.

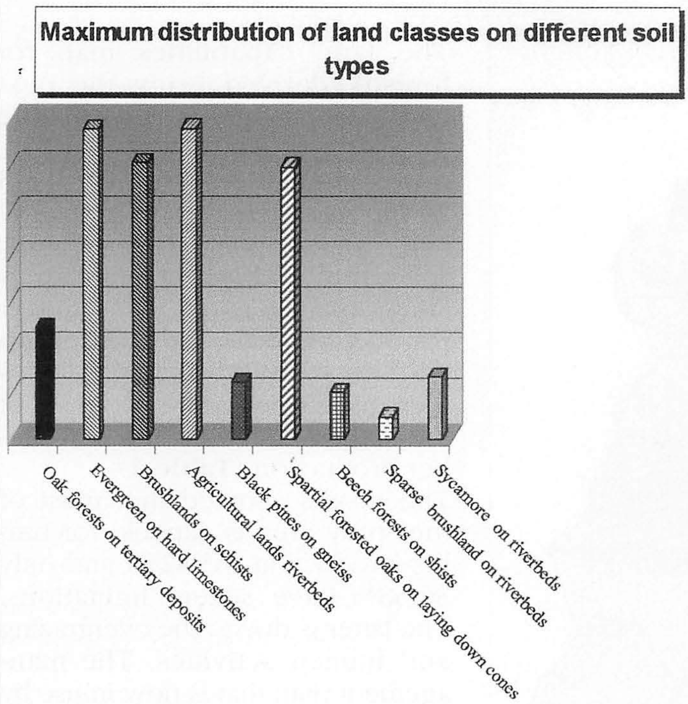


Fig. 4 - The maximum distribution for each land cover on the soil parent material types classes.

Table 4 *The available area of the five classes for timber production in the study area.*

	Area	%
Class 1	340,402.67	41.16
Class 2	93,867.11	11.35
Class 3	90,228.22	10.91
Class 4	292,518.03	35.37
Class 5	10,006.97	1.21

al lands and 2.61% is urban areas. This analysis underestimates the areas that are used as rangelands, because many forest and forested areas are also used for grazing.
The ownership layer proved that 34.65% belongs to the State, 54.75% belongs to the Communities, 9.01% belongs to the private sector and 1.59% belongs to the Monasteries.
The analysis of the land use and ownership layers showed that from the total rangeland area 35% belongs to the State and 38% to the Communities 14% to the private sector and 0.8% to the Monasteries.
That proved that 73% of the area under the pressure of the grazing and 35% of this amount belongs to the State and 38% to the Communities.

A new policy more scientific must be applied for the this area e.g. determine the carrying capacity of the land, in order to manage the environment in more productive way. For class 4 and less for class 5 a reformation of their use will lead to a proper use of their areas.

Conclusions

The method described in this study demonstrates that the capabilities of remote sensing and GIS techniques are useful decision support systems for processing environmental parameters.
Remote sensing has been useful for producing the land use map of the study area.
The GIS has proved to be a suitable tool for managing complex systems, where a number of variables, whose main feature is spatial location, are involved. The integration of remote sensing and GIS has been accomplished by a process consisting of the intersection of polygon layers with the classified image raster map.
In this regional study four different environmental parameters have been used in order to produce the land capability map for forest production.
According to the spatial analysis five different categories exist in the study area, and the most profound were classes with no serious limitations for timber production (63.42%).
The land capability map could be used for forest decisions and actions, such as regeneration, protection of fauna and flora, grazing and alternation of land uses, by the local authorities. ●

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