Application of Gis Land Capability Classes for Forestry

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***Abstract*—** *Environmentalists' decision makers need the ability to integrate and correlate information from many different sectors in such a way that their relationships are more easily understood. To assess the potentials and carrying capacities of environmental systems, to monitor trends, to make projections, and to test solutions, managers require greatly improved access to information and better analytical support for decision making. Geographic Information Systems (GIS) represent an important approach that can provide this support. In this paper the land capability classes for forestry based on physiographic factors such as parent material, soil depth, aspect, slope, rill erosion and the vertical distribution of land cover classes have been used in order to give the forest manager of natural resources benefits from knowledge of the location, extent, and quality of the resources being managed.*

Management and Policy Implications

The various countries where the economy is based on agriculture, such as Greece, a very important factor is the implementation of a single agricultural policy with future plans based on correct directions. In the forestry sector, where planning application times are much longer than in other rural areas, planning should be based on the European action plan for sustainable and diversified management of forest resources.

In this paper, new technologies are used as means of making scientific decisions for forest policy (local and national). New technologies allow the use of Decision Support Systems (D.S.S.) which is a category of information systems that support the activities leading to decision making. A properly designed D.S.S. is an interactive software system which aims to help those who make decisions to obtain useful information from a combination of raw data, documents and personal knowledge, or business models in order to identify, solve problems and make solutions.

In this study, an attempt is made to use a DSS considering environmental factors (local climate, parent material, soil depth and aspect) to find areas that can be developed productive forests and woodlands. The specific area, which belongs to the northern part of Greece and has an area of 19000 km^2, no other similar studies have been made and an approach will help forest managers in making science-based decisions which of course will be consistent with the Global Strategy for sustainable development of forests. The production of the map of areas with productive forest land may be the guiding thread of economic and rural development of the region for years to come.

***Keywords*— GIS, land capability classes, forest timber production, forest treatments.**

I. INTRODUCTION

The environment is a complex matrix of interrelated components access. The natural resources tapped for development require careful planning in order to decide the extent of its use for the present versus the reserves for the future thus adopting the sustainability concept. This essentially required first the extent of present use and the available potential. These data are to be provided to decision makers in order to help them to take scientific decisions.

Much information has traditionally been kept in hard copy (i.e., printed) format, as maps, reports and studies, or bulky data books and statistical tables. If the data can be digitized, a well-designed GIS can greatly enhance the accessibility and the utility of these materials for decision makers.

One of the current uses of GIS in support of sustainable development implementation is the estimation of natural resource capabilities (Luis Diaz-Balteiro and Carlos Romero 2008, Meliadis I. & M. Meliadis 2011).

The first stage in evaluating land and preparing a land-use plan to gather data to classify the land according to their use (called land suitability). Land capability, which is also considered as land suitability (FAO, 1978, 2000) is primarily the potential biological productivity of land. Productivity of land can be determined by four main components of the environment namely climate, local topography (ruggedness, steepness, exposure-which cause local variation in climate and disposition of soil type), soil and existing vegetation. The land capability classes place soils into general order of suitability or unsuitability for cultivation, forestry, grassland or other uses for sustained production. The soils that have the least limitation or hazard and respond best to management are placed in the higher order. It also evaluates soils with respect to their susceptibility to erosion, soil depth, drainage problem and other soil characteristics that would affect to sustained production of crops. In this district five different land capability units were identified.

The objective in programs involving GIS and environmental parameters is to integrate the many variables that affect the long-term sustainability of economies, social systems, and the biosphere.

Land suitability is the fitness of a given area of land for a defined land use. Depending on the mapping scale, land evaluation can be qualitative or quantitative. Qualitative land evaluation systems give the suitability of land based on physical characteristics (attributes) of the land which can be measured. Quantitative evaluation systems on the other hand specify, in economic terms, the input and the production from the forms of land use under consideration. Qualitative land evaluations are employed in reconnaissance surveys and quantitative evaluations are more common for moderately detailed surveys.

Land use is the outcome of human and biophysical processes that operate in a landscape, with regard to biophysical, socioeconomic, and cultural conditions and constraints, and political context (Mather 1995, Geist and Lambin 2001, Lambin et al. 2003). It is recognized that over short time periods most of the land use in an area does not change. However, where change does occur, land managers are influenced by a number of factors when deciding on the type of land use for their holding, resulting in a particular land cover on their land.

Geographical Information Systems (GIS) is an information technology that has been used in public policy-making for environmental and forest planning and decision-making over the past two decades (Bassole et al. 2001, Nurcan Temiz and Vahap Tecim 2009**,** Meliadis I.1997, 2008, Zucca 2008).

Forest management has become more complex as there are now multiple objectives to attain, as well as multiple criteria and constraints to address (Warnecke et al., 2002 Mui-How Phua & Mitsuhiro Minowa, 2005). Recently, there have been attempts to combine GIS with optimized land allocation techniques. In most of these, integration is achieved sequentially or in a linear fashion; that is, optimized allocation is performed independently using various types of optimization models, then the results of the optimization is exported to GIS for mapping and displayed (Jones et al. 1995, Church et al. 1995, Chuvieco 1993, Campbell et al. 1992, Carver 1991). While this approach is reasonable in some applications, an alternative approach is to impose the integration simultaneously rather than sequentially. That is, the site suitability estimates serve as the defining variables for land allocation. Thus, optimized allocation is done internally within the GIS system.

In this study, GIS represent an integrated planning and problem-solving approach, which can be of considerable use to managers and decision makers. As results will be the following: provide feedback on quality of data and their utilization. Prepare profiles of forest resources at periodic intervals; develop model and solutions for timber planning problems. To provide analyzed information to the local Services and other line departments on the management of natural resources for scientific decision making and planning.

II. THE STUDY AREA

The Region of Central Macedonia (RCM) is one of the thirteen peripheries of Greece, consisting of the central part of the region of Macedonia. It is divided into the prefectures of Chalkidiki, Thessaloniki, Serres, Kilkis, Pella, Imathia and Pieria. The borders of the Region of Central Macedonia are the Region of Western Macedonia in the west, the Region of Eastern Macedonia in the east and the Aegean Sea in the south and FYROM Republic and Bulgaria in the north (Figure 1).

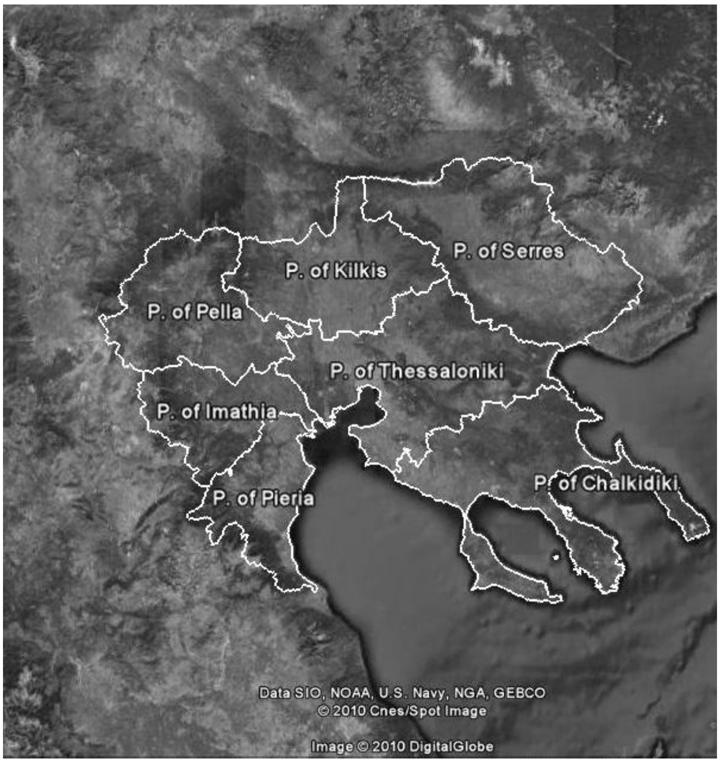

FIGURE 1. THE REGION OF CENTRAL MACEDONIA, GREECE

RCM is a predominantly mountainous area, with an elevation range from sea level to approximately 3000 m (Mount Olympus). The land surface is broken by hills and high mountains, usually steep and eroded. The climate is Mediterranean to Continental and characterized by long summer drought periods with high temperatures.

The population is 1.874.590 (year of inventory 2011), the second biggest in Greece and occupies 19,147 km^2 (14.51% of the country).

In central Macedonia Region many important ecotypes, wetlands and other sensitive areas occur protected by International, European and National laws and agreements. The most important wetlands of the Region are:

- **International importance (RAMSAR Convention):** Delta of the rivers Axios, Loudias, Aliakmonas and Alykes of Kitros Pierias, Volvi Lakes and Koronia Lake, Kerkini Lake.
- **Other significant:** Artzan Swamp, Doirani, Pikrolimni, Strymonas River estuaries, Gallikos River estuaries, Kalochori Swamp, Lagoon of Epanomi, Lagoon of Alykes Aggelochori, Agras Island Lake, Vegoritida Lake, Chavrias River Estuaries, Agios Mamas Swamp, Nea Fokea, Stavronikitas Swamps.

III. METHODOLOGY

Considering the size of the study area and the limited information availability on soil, it was decided that the climate is constant. The scale of the base land map of the Region of Central Macedonia region is 1:50,000 and a quantitative land evaluation system would have been more desirable. Lack of sufficient information on present and potential productivity of the forests in the area forced to use a qualitative evaluation system based on the following physical and biological characteristics of the land:

a) Regional climate, as expressed by natural vegetation.

b) Nature of the soil parent material.

c) Soil depth, and

d) Aspect, which directly affects productivity.

These characteristics have also been used for the description of the various land associations (mapping units) of the base land map. Soil information is a vital component in the planning process, reflecting directly upon land-use suitability (Nakos 1979, Nakos 1983, Coleman & Galbraith 2000).

For the study the following data have been used:

1. The Corine digital map (year 2012, scale 1:100,000)
2. The Soil Map (scale 1:50,000)
3. The Vegetation Map (scale 1:50,000)

The maps were scanned & screen digitised and the thematic layers were prepared with the help of GIS. The boundaries of the Region of Central Macedonia have been defined, with the use of the Free Open Source GIS Software Qgis ver. 2.8. This file is used to define the boundaries of the study area to the rest digital maps. The digital maps of Corine, forest vegetation, and contours were combined (union) in order to define areas showing the land cover classes. This combination was necessary because the vegetation map gives a better impression of the forest categories in the study area. Thereby the created map has database the cover classes and contour lines. Since the purpose of this study was to find for areas covered by forest vegetation database the land categories of non-forest value were masked, e.g. rural, residential, industrial areas, artificial structures. The whole area of the Region was reduced almost to 77%.

The gradients of the physical characteristics used for the evaluation of forest productivity were:

a) Regional climate: fir-beech zone / deciduous oaks zone / pseudoalpine
b) Nature of soil parent material: Flysch and schist colluvium, tertiary deposits, alluvium / sandy flysch, schists, limestone and peridotite colluvium / mixed and argillaceous flysch, peridotites / hard limestones.
c) Soil depth classes: deep soils / shallow soils / bare soils
d) Aspect classes: Northern aspects/ southern aspects.

The map features on the (forest) coverage combined with soil map, which were the parameters of the parent material, soil depth, and gully erosion aspects. On the map the criteria of Table 1 was applied, using the capabilities offered by GIS software (Query Builder). The result was the creation of the map of suitability for forestry production in the Region of Central Macedonia (Figure 3).

TABLE 1
LAND CLASSIFICATION BASED ON PHYSICAL CHARACTERISTICS

Classes	Physical characteristics of land cover
1	*Lands without physical limitations for timber growth.* Includes land types with deep soils derived from tertiary deposits, schists, sandy or mixed flysch, hard limestones, peridotites, colluvial and alluvial deposits: 1. In the fir-beech zone, and 2. On northern aspects in the deciduous oaks zone.
2	*Lands with slight limitations for timber growth.* Includes: 1. Land types with deep soils derived from tertiary deposits, schists, sandy, mixed or argillaceous flysch, hard limestones, peridotites, colluvial and alluvial deposits on southern aspects in the deciduous oaks zone. 2. Land types with shallow soils derived from the above mentioned (case 1.) kinds of soil parent materials on northern aspects in the fir-beech zone.
3	*Lands with moderate limitations for timber growth*. Includes land types with shallow soils derived from tertiary deposits, schists, sandy, argillaceous or mixed flysch, hard limestones, peridotites and colluvial deposits 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*. Includes land types with shallow soils derived from tertiary deposits, schists, sandy, mixed or argillaceous flysch,hard limestones, peridotites and colluvial deposits on southern aspects in the deciduous oak zone.
5	*Lands with extremely severe limitations for timber growth*. Includes land types with bare soils regardless of nature of soil parent material, vegetation zone and aspect and all land types in the pseudoalpine zone.

IV. RESULTS AND DISCUSSION

In Greece, at the last decades, intensive forest land use changes were taken place, due to great wildfires, overgrazing, indiscriminate exploitation of woody vegetation, socio-economic pressures and land use conflicts, political and military events and finally the lack of an appropriate and effective forest policy for a very long time (Kokkinidis et al. 1984, Tsitsoni Th. 2001, Thornes, J. 2002).

In Greece, the vegetation and diversity of plant species are influenced by the Mediterranean climate and human activities such as pasture, harvestings and hunting throughout successive historical periods (Georgiou K. and P.Delipetrou, 2009). Based on Table 2, it is estimated that the broadleaves are the main forest species in the RCM and this is due to the fact that most of the area belongs to the Submediterranean vegetation of *Carpinus orientalis* and to the Thermophiles subcontinental formation of *Quercus* sp.

TABLE 2
FOREST CLASSES IN STUDIED AREA (RCM)

Forest classes	Area (ha)	% of the total area
Coniferous	94,681	11.48
Mixed coniferous	4,376	0.53
Deciduous broadleaves	301,837	36.59
Mixed Deciduous broadleaves	98,377	11.93
Mixed forests	21,863	2.65
Evergreen broadleaves	272,226	33.00
Broadleaves bushes	31,598	3.83

TABLE 3
THE COVERING AREA OF THE DIFFERENT FOREST SPECIES IN RCM

Forest species	Area (ha)	Forest species	Area (ha)
Abies sp.	14,531.1	*Pinus nigra-Pinus silvestris*	405.9
Pinus halepensis	49,895.5	*Pinus nigra-Pinus halepensis*	1,248.9
Pinus nigra	25,890.1	*Fagus-Pinus nigra*	2,755.1
Pinus silvestris	3,900.1	*Fagus-Pinus nigra*	1,368.5
Pinus leucodermis	3,508.7	*Pinus halepensis-Castanea*	195.6
Pinus pinea	28.5	*Pinus nigra-Castanea*	17.2
Abies sp.-*Pinus nigra*	5,368.0	*Alnus glustinosa*	6.0
Fagus sp	79,305.8	*Pinus silvestris-Pinus nigra*	472.0
Castanea sativa	12,586.5	*Pinus pinea-Pinus halepensis*	223.9
Quercus sp.	192,225.5	*Pinus leucodermis-Pinus nigra*	56.2
Evergreen broadleaves	272,023.2	*Pinus halepensis-Pinus nigra*	339.0
Platanus orientalis	16,894.8	*Quercus-Fagus*	7,091.1
Rest deciduous	818.6	*Platanus orientalis-Quercus*	669.9
Juniperus sp.	209.8	*Quercus* sp.-*Platanus orientalis*	53.8
Picea excels	4.9	*Fagus* sp.-*Alnus glutinosa*	21.6
Abies sp.-*Pinus leucodermis*	112.5	*Castanea sativa-Fagus sp.*	409.0
Abies sp.-*Fagus* sp.	382.1	*Castanea sativa-Quercus* sp.	3,701.1
Pinus nigra-Quercus sp.	2,491.6	*Fagus* sp.-*Platanus orientalis*	574.2
Pinus silvestris-Quercus sp.	64.3	*Platanus orientalis-Fagus* sp.	11.4
Pinus halepensis-Quercus sp.	473.4	*Platanus orientalis-Alnus glutinosa*	122.0
Fagus sp.-*Quercus* sp.	7,478.3	*Quercus sp.-Pinus halepensis*	62.9
Fagus sp.-*Castanea sativa*	1,200.6	*Quercus-Pinus nigra*	2,149.1
Quercus sp.-*Castanea sativa*	3,282.6	*Pinus silvestris-Fagus* sp.	619.6
Pinus halepensis–Pinus pinea	374.3	*Fagus* sp.-*Abies* sp.	3,191.4
Pinus nigra-Faqus sp.	285.2	*Quercus* sp.-*Pinus halepensis*	97.0
Quercus sp.-*Abies* sp.	598.0	*Abies sp.-Castanea sativa*	238.7
Pinus leucodermis-Fagus sp.	11.1	Deciduous bushes	30,547.3
Castanea sativa-Abies sp.	334.2	*Quercus* sp.-Deciduous bushes	64,005.8
Deciduous bushes – *Quercus* sp.	8,079.5	*Pinus nigra-* Deciduous bushes	220.2
Deciduous bushes-*Pinus nigra*	49.5	*Fagus sp.*- Deciduous bushes	1,284.6
Deciduous bushes-*Fagus* sp.	391.3		

The covering forest species in RCM (Table 3) are composed by species that needed management according to adaptation in vegetation zones, land types for timber production (Figure 2) and land classification (Figure 3). Flammable conifers (*Pinus halepensis, P. pinea*) are grown well in low elevations (0-500 m; two vegetation zones, Mesomediterranean vegetation of *Q. ilicis* & Submediterranean vegetation of *Carpinus orientalis*), *Pinus nigra* in moderate (500-800 m, one vegetation zone, Thermophilus subcontinental formation of *Quercus*) and cold conifers (*Abies* sp., *Pinus silvestris*, *P. leucodemmis)* in high (800-1200 m; two vegetation zones, Fagus *moesiaca* and *Abies borissii regis* & *Pinus silvestris* and *Picea excelsa*). A high percentage of deciduous broadleaved (*Quercus* sp.) and mixed forests (*Pinus nigra*-deciduous broadleaved) adapted well to grow in moderate elevations with slight and moderate land capability classes.

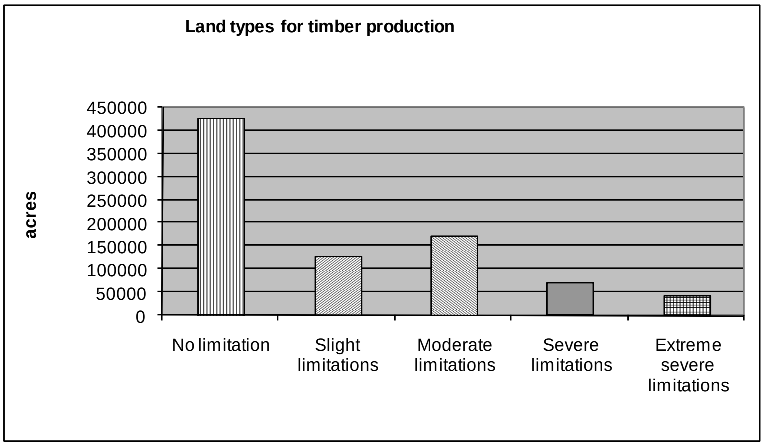

FIGURE 2. LAND TYPES' REPRESENTATION SUITABLE FOR TIMBER PRODUCTION.

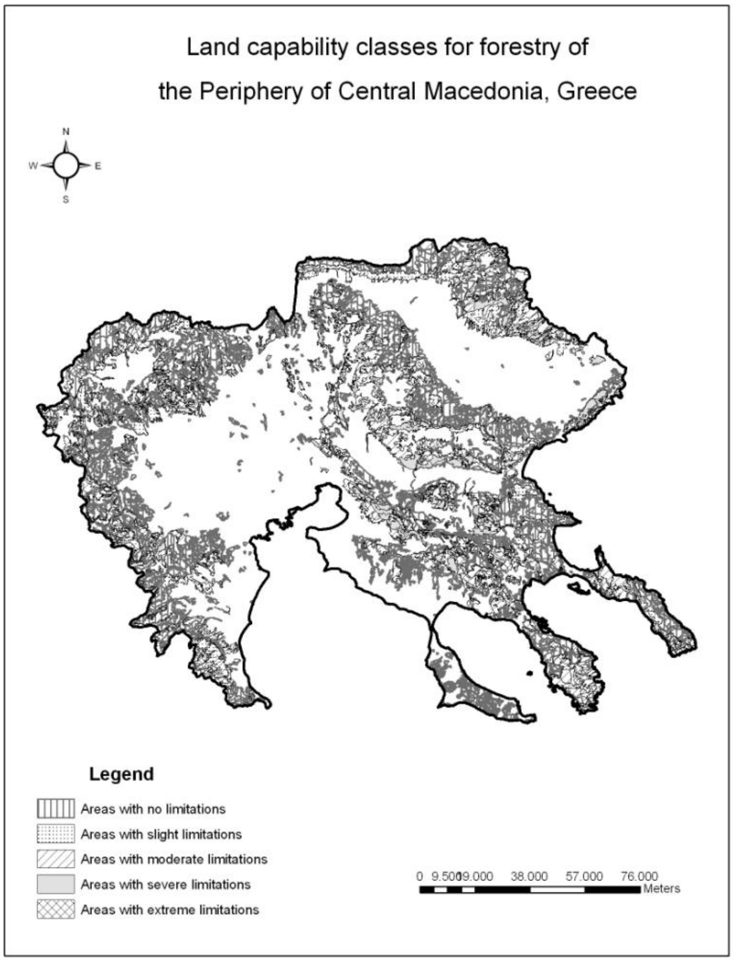

FIGURE 3. THE LAND CAPABILITY CLASSES OF REGION OF CENTRAL MACEDONIA, GREECE.

According to classification of land types for timber production in RCM (Figure 3) almost 50% of the areas under study show no limitations to timber production followed by the categories of moderate limitations, almost 20% and with little limitations, 15%. The rest areas with limitations to timber production can be found in more or less degraded areas.

V. CONCLUSION

This study demonstrates an attempt to use the available spatial information for the identification of suitable areas for forest timber production. According to the results of the study, it can be concluded that there is a high potential for forest timber production in the study area. The ability to incorporate and manage the different drivers of land-use change in a modelling process is one of the key challenges because they are complex and are both quantitative and qualitative in nature.

The area, which is suitable for timber production covers 800.343 hectares. In the area there are ten Forest Inspections which must be focused on each own area but having in mind the results of the surrounding areas, evaluating the use of GIS for timber production and sustainability development. The spatial forest modelling using GIS can substantially enhance the planning of harvesting strategies. Locations of forest stands, timber inventory data, ecologically sensitive areas, key attributes of the terrain, and other important factors, could be mapped and included for spatial analysis necessary in harvesting plan preparation. According to the management treatments the needed adaptations must be based in vegetation zones, land types for timber production and land classification. Spatial modelling tasks could help the forest manager and government officials see the economic, environmental and social impacts of the proposed harvest. GIS tools also help harvest planners to evaluate several road access alternatives – focusing on costs and their possible impacts.

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