Sustainable forest harvesting operations using digital methods

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Abstract:
Sustainable development of the planet depends, in fact, on recycling of resources rather than their extraction and eventual discard following use. Sustainable development in mountainous regions has an objective to increase the economic investments to profit residents of the region, without drastically influencing the natural environment. To utilise Greek forests, environmentally sound management procedures should be applied by forest managers. The principal objectives of this paper were to optimise the forest operations using digital terrain model (DTM) in the context of sustainable development for Greek mountainous conditions. Forest operations are one engineering sector aiming to maximize efficiency while minimizing adverseeffects. To estimate and choose a specific harvesting operation till now has been limited only by the availability of machineries and workers knowledge. In this paper we are going to provide an integrated harvesting planning solution for a characteristic mountainous area in Greece based on GIS techniques.

Keywords: natural environment, digital terrain model, forest harvesting operations, sustainable development

1 Introduction

Sustainable development of the planet depends, in fact, on recycling of resources rather than their extraction and eventual discard following use. Sustainable development of mountainous regions has as objective to increase the economic investments to profit of residents of region, without however it influences drastic the natural environment. The respect to the natural environment and the goods that offers to us, gives the possibility of its sustained use. To exploit Greek forests, environmentally sound management procedures should be applied by forest managers.

Forest harvesting operations should be based on environmentally friendly principles, humanized labour and minimum costs of a carefully selected and optimum work method.

The impacts of the logging technique on remaining stand have to be understood as complex (Frohm, 1993; Spinelli, 1999). Skidding, as a part of logging, means transport through the forest. This means also taking into consideration, in addition to machines and techniques, the way the machine approaches the tree or timber. A closer look at the true interrelation between silvicultural and operational planning in respect of young forest damage can be achieved by examining tractor skidding only.

The interest in technical development of forestry in Europe is growing very significantly. It is connected with growing of human work costs and with society efforts of eliminating health risks, ensuring sustainable forest management, retaining forest production capacities, ensuring fluency of production with the help of multioperational machines.

Until the late 20th century forest exploitation relied mainly on man, because felling and processing were made by axes and hand saws, and wood was transported by animals or by water, i.e. gravitation. Only in the late 20th century, the use of chainsaws for felling became more intensive, as well as the use of tractors for skidding and trucks for transport to greater distances.

In carrying out forest operations, terrain conditions determine the mobility of vehicles and people (Mellgren, 1980; Conway, 1984; Berg, 1992). The limiting factors of forest operations in Greece mountainous stands are terrain slope, micro-relief with surface obstacles, bearing strength of deep soils during periods of increased moisture, snow and ice conditions in winter and stand conditions of selection-managed forests. When speaking about economic forests in the mountainous area of Greece, the interest should be focused on natural, mixed and uneven-aged forests managed by selection felling, group and individual tree felling with a 10-year felling cycle.

The forest harvesting operations are usually applied from the Forest offices or from enterprises. To estimate and choose a specific harvesting operation till now has to do only with the availability of machineries and workers knowledge.

The last decade new trends in forest harvesting operations lead us to the implementation of digital technology in order to have a reliable background in two and three dimensional forms.

The digital representation of the terrain with simple to use software is a key task of the Forest Engineer - Environmentalist scientist and the new trend in sustainable forest harvesting operations. This requires detailed mapping on a large scale (> 1:1000) with modern surveying instruments or digital photogrammetric methods and automatic transfer to special software for processing.

It is necessary to simulate the classic design and planning activities based on modern environments of representation (Digital Terrain Model - DTM) and digital data management (GIS) (Drosos, 2000; Drosos, Doucas, 2000), also planning forestry projects requires the use of reliable DTM. Also the creation of reliable DTM can be done with a laser scanner and contribute through the increased cultivation of agricultural and forestry production, environmental protection, sustainable development et al. (Drosos, Farmakis, 2006; Drosos, 2007).

In this paper we are going to provide an integrated harvesting planning solution for a characteristic mountainous area in Greece based on GIS techniques.

2 Material and methods

2.1. Research area

The under study area is the public forest complex of Ano Rou Mornou, which is spreading, as shown in figure 1 in South Greece, particularly in Sterea Hellas, on the southern slopes of Mount Oiti, on the eastern slopes of Vardousia Mountains and the northern slopes of Mount Giona. It is located at the northernmost tip of Fokida prefecture in 50 km road distance from Amfissa that is the capital of the prefecture, and the seat of the Forest office.

The research area is included among 38° 39′ 00′ to 38° 48′ 30′′ North latitude and -1°24′ 30′′ to -1° 37′ 20′′ longitude east of Athens meridian. Also the region is included among the following coordinates in Hellenic Geodetic Reference System ’87: north: 4294877.87329971, south: 4278326.16774873, east: 354089.16952994 and west: 333725.97936053.

The area of the complex lies within these borders is 16,278.47 Ha and distributed as follows: forest areas 6,599.08 Ha i.e. percentage 40.54%, partially forested areas 2,241.00 Ha i.e. percentage 13.76%, scrubs - evergreen broadleaves 249.12 Ha i.e. percentage 1.53%, agricultural lands 1,880.00 Ha i.e. percentage 11.50%, bare grasslands 4,920.92 Ha i.e. percentage 30.23%, riparian vegetation 109.78 Ha i.e. percentage 0.67% and barren land - settlements 278.59 Ha i.e. percentage 1.71%.

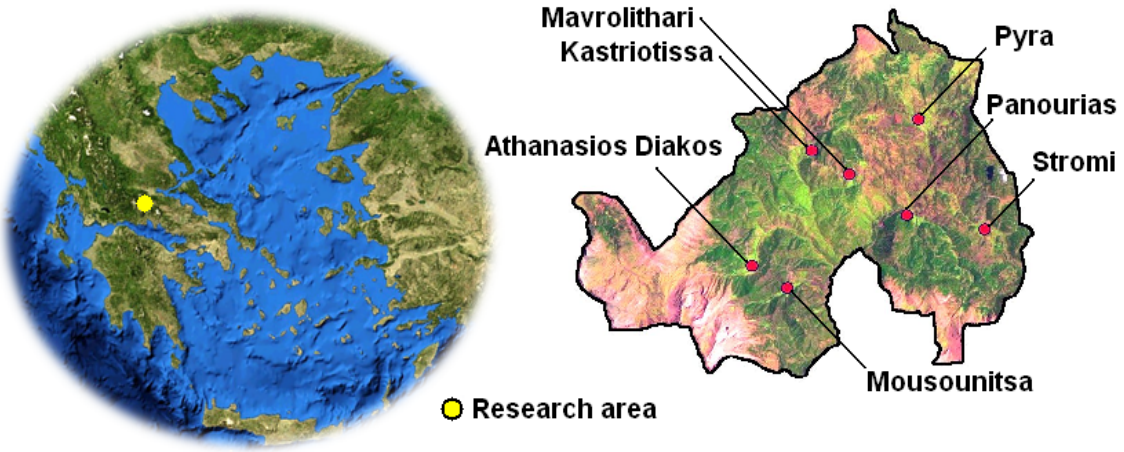

Figure 1: Research area.

The complex has a general orientation of S, with aspects mainly S, W and E, but due to its varied relief appearance with many ridges and gullies, because of the many different directions of streams running through it, eventually formed all aspects, recorded on an aspects map. The terrain slope is different in places, from mild, moderate to steep and very steep in positions in the following variants as these are also recorded on the slopes map. The above sea level height starts at 580 m in the bed of Mornos the southern boundary (area Mousounitsa) and reaches 2,510 meters at the top of the Pyramid of Giona. A clearer picture of the topography and terrain maps given by the slopes, Exhibitions soil Relief (shaded terrain model) and their respective Boards of reports and slip territories annexed. Generally the configuration of the region is clear mountainous. The area expansion of the cluster is part (the highest), of the Mornos basin.

To study forest complex Ano Rou Mornou owned full right distribution, possession and ownership of the Greek State, as the successor of the Ottoman government. The products can be produced from this forest are mainly Fir round wood of various categories, industrial wood and firewood, also small amounts of plane timber and firewood of oak-tree. The forest tree species are: Fir (*Abies cephalonica)*, Oak (*Quercus sessiliflora, Quercus conferta*), Plane tree (*Platanus orientalis*), Walnut tree (*Juglans regia*), Hornbeam tree (*Carpinus orientalis*), Willow (*Salix fragilis, Salix viminalis, Salix caprea*), European black alder (*Alnus glutinosa*). The total road network of the area is 288.61 km.

2.2. Methodology

In detail the stages of an integrated harvesting planning solution for a characteristic mountainous area in Greece are the following:

• Recognition of Forest (Location and boundaries of the forest, forestry species composition, forest structure, management form, management classes, and access roads, facilities and settlements, etc.).

• Data collection from municipalities (Socioeconomically-census data, grazing, hunting, tourism, protection, etc.).

• Data collection from Forest Service (meteorological data, proprietary conditions, maps, data of prior management, etc.).

• Supply additional cartographic and aerial material from the Military Geographical Service and the Ministry of Rural Development and Food (Topographic maps of various scales, recent taking aerial photos, orthophotomaps).

• Data collection, drawing up and creation of land uses map, scale 1:20,000.

• Creation of relief map scale 1:20,000 with the sectors of the forest.

• Installation of sampling surfaces from the crews of field data collection.

• Carrying out field investigation with data collection, based on sampling method and description of the stands.

• Drawing up and creation of additional forest maps of slopes and aspects.

• Data processing.

• Drawing up and creation of a forest harvesting operations 10 years map.

• Drawing up and creation of a two dimension map; proposed the different ways of harvesting for the research area. In this map we can see how they are applied to the research area

In this paper we are going to use a GIS technique and modelling as a Spatial Decisional Support System (SDSS). The model calculates by using the: slope, roughness of terrain, distance between the operational places and the roads, amount of yield and the grade ability.

The grade ability is a percentage that is calculating by the available data which are used inside the model and based on the soil geology and stability and to the annual precipitation.

The most frequent database used for designing the models is Digital Terrain Model (DTM) which serves as a powerful means for acquiring solutions of forest openness on steep terrains.

3 Results

In figure 2 the digital terrain model (DTM) of the research area is represented. In figure 3 we have the land use map for the under study area as it arose from the digital photogrammetry method and with the on-the-spot investigation.

In figure 4 is shown the relief map of the area with the numbers and boundaries of sectors on it. The stands that are going to log within a 10-year felling cycle are shown in figure 5.

The figure 6 gives in a two dimension map; the three different ways of harvesting: Animals, with a tractor and a cable crane that are proposed for the research area. In this map we can see how they are applied to the research area, depending on the slope degree.

4 Discussion

Only in 2009 was the first time of using small size forestry tractors for the skidding of wood, but because of extra steep slopes prevailing in the harvested stands it would be good to introduce small-scale mobile cable crane or tracked or articulated tractor is capable and for farm work which are an important part of land uses.

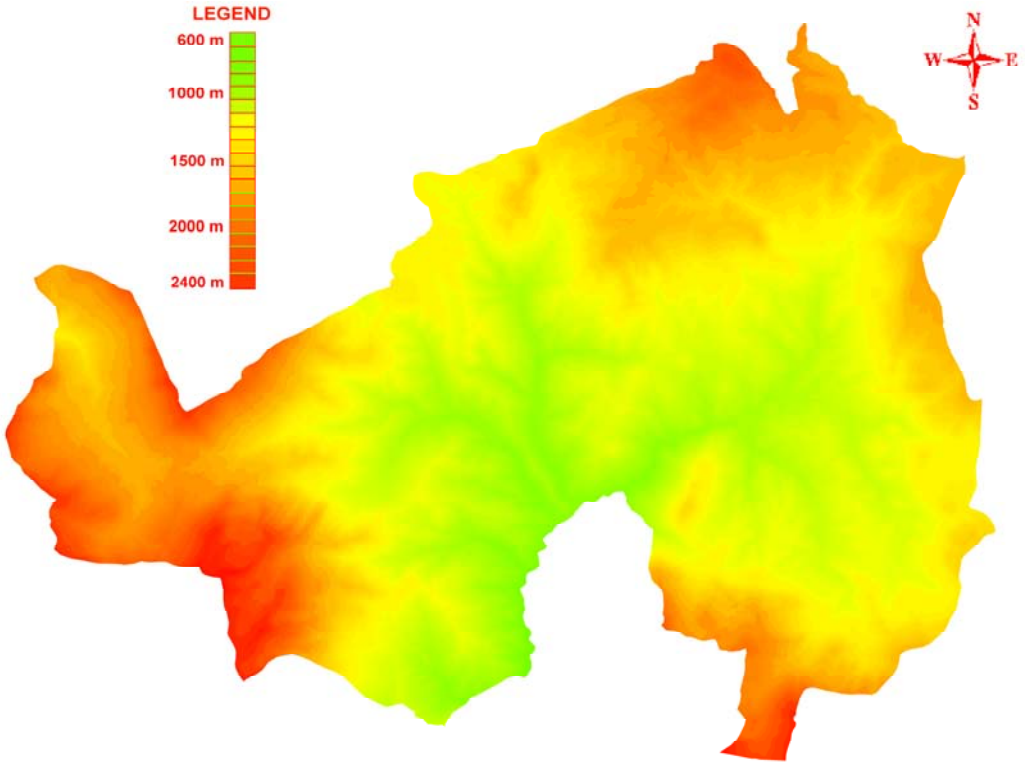

Figure 2: The digital terrain model (DTM) of the research area

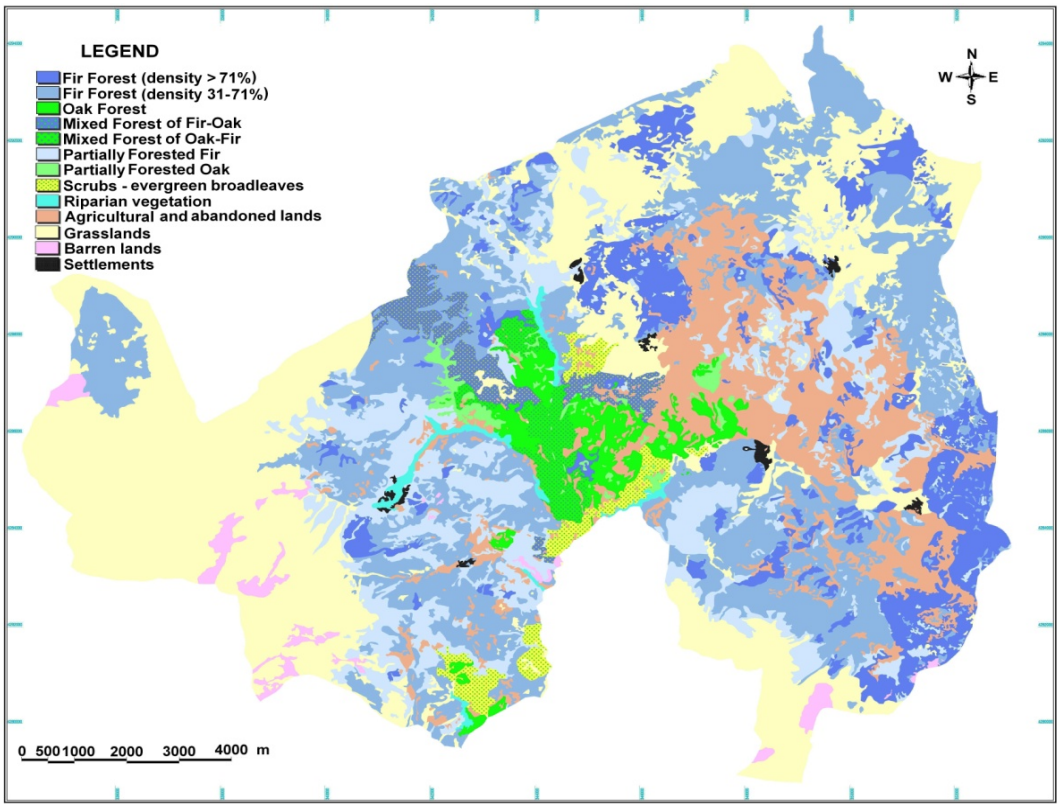

Figure 3: The land use map of the research area

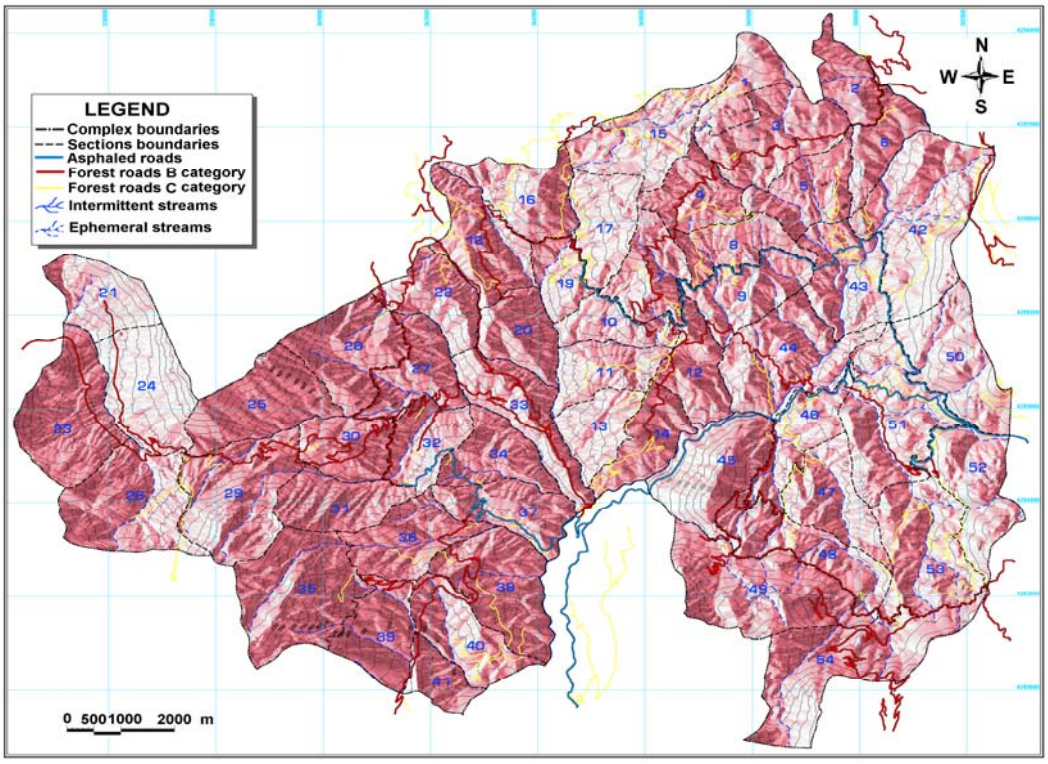

Figure 4: The relief map of the research area

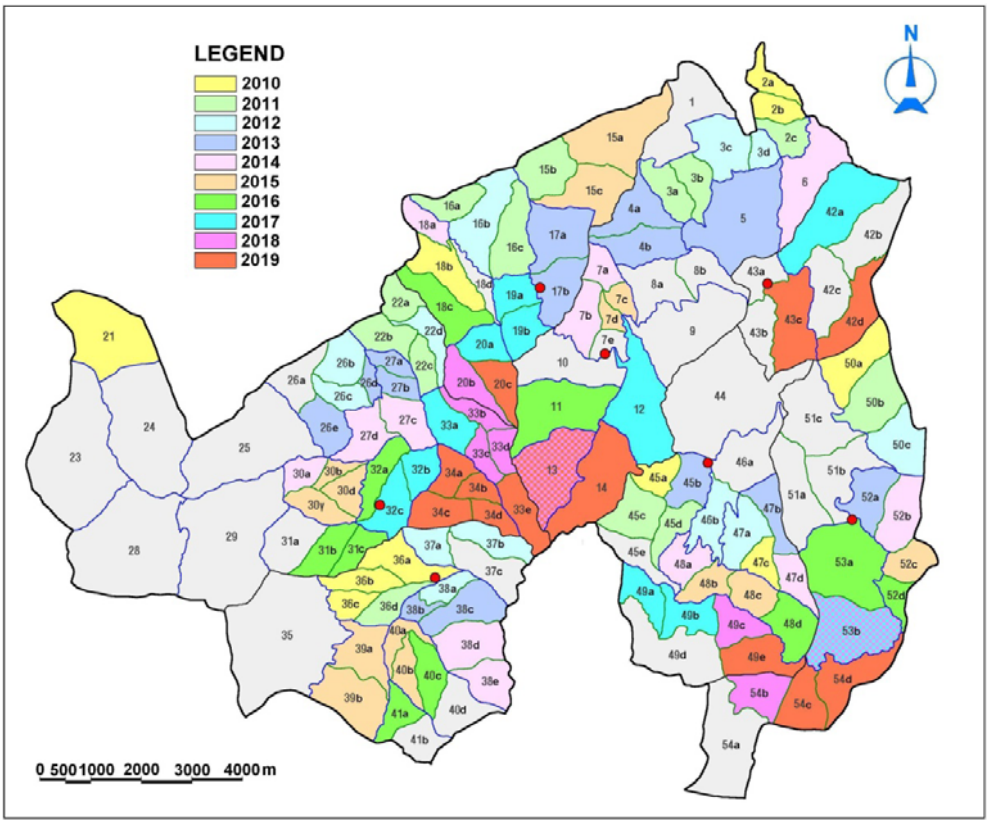

Figure 5: Stands that are going to log within a 10-year felling cycle.

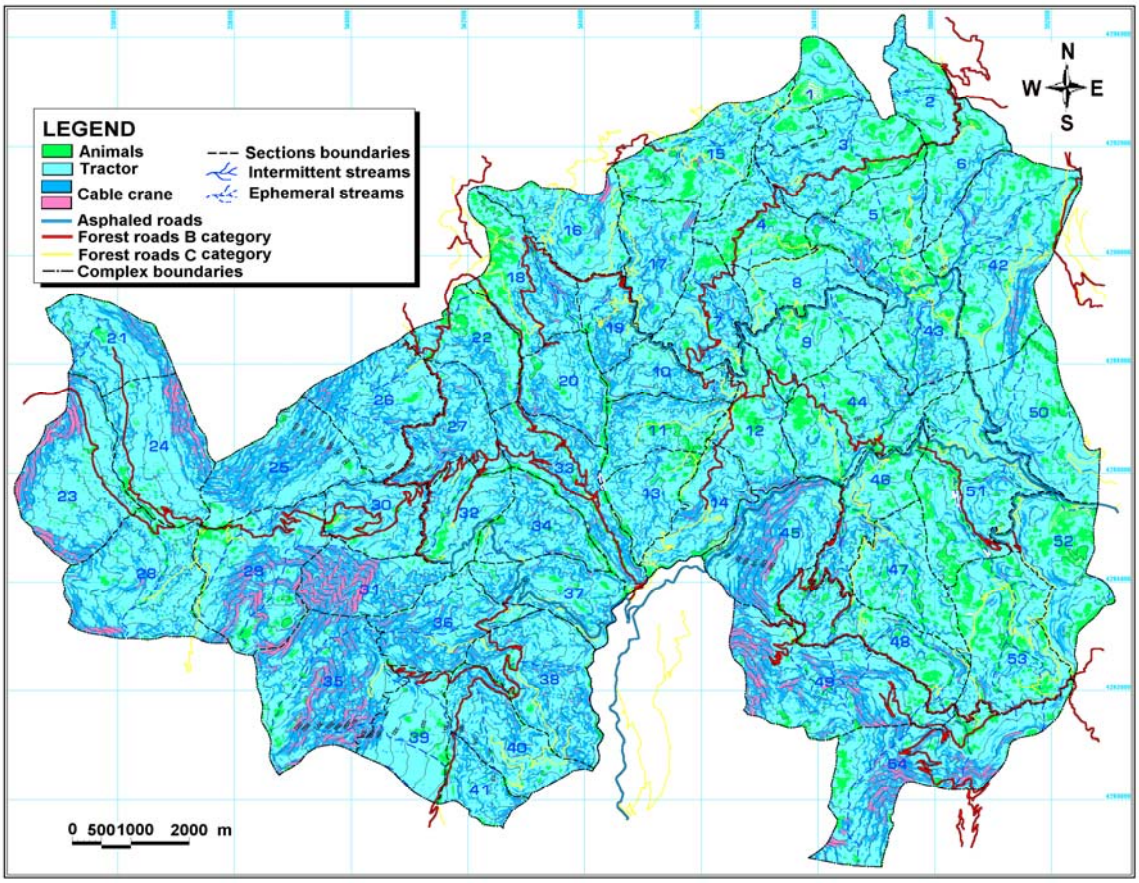

Figure 6: Three types of forest harvesting operation by tractor, cable crane and animals

The model that has been applied is a Spatial Decisional Support System based on rules that have been set by the forest harvesting experience for an integrated harvesting planning proposal. Concluded the main benefits expected are:

a) The better planning of coverage of individual needs of residents in firewood, and technical timber.

b) The setting of sheep and goats stockbreeding in space and time, with the use in grazing barren lands of the forest complex that may be available for this reason, improved, but this proves to be no way at the expense of forest and its rational management.

c) The satisfaction of all kinds' needs of society related to the existence and function of forests as part of multipurpose forestry, such as hunting, tourism, recreation, hiking, fishing, work, etc.

d) Ensuring the greatest possible of financial revenue from the marketing of the produced forest products.

e) With the proper management of the forest due the proposal integrated harvesting operation planning maintaining and improving the protective-hydrologic role of the forest, particularly in relation to the increase of its water supply, the reduction of sediment, ensuring smooth and proper functioning of the lake Mornos. Lake Mornos supplies with water Athens, the capital of Greece.

The key problems are the following:

• Harvesting operations in the field often results in environmental damage,

• Human presence demands exploitation of the natural environment.

• Yet it causes interference sometimes with a negative effect.

All these problems can be solved in the basis of a rational, integrated harvesting operation plan that is founded on reliable data coming from on-the-spot investigation and the help of the the most contemporary leading-edge technology i.e. the digital terrain model (D.T.M.). Based on this we can produce a DTM for the better comparison and consideration of several alternatives.

Any kind of interventions in forests should be governed by the following three principles:

- The principle of preserving and protecting the natural environment,

- The principles of landscape architecture and

- The principle of resistance (limit) of the ecosystem in the various activities exerted on it.

Eventually D.T.M. provides the basis for developing a wide range of applications related to both the protection and rational management of the natural environment. The D.T.Ms. can be used in combination with Geographic Information Systems (GIS) to create a land information system, necessary for the protection and sustainable development of forest areas and especially for forest harvesting operations. The GIS combined with modelling techniques of the relief is the appropriate approach for analyzing spatial data.

The DTM often comprises much of the raw dataset, which may have been acquired through techniques such as photogrammetry, LiDAR, IfSAR, land surveying, etc.

The DTM are the future design development. So by creating a DTM sets out the creation of a cartographic database, which is a component of a digital map. Provide the basis for developing a wide range of applications related to earth sciences. Geoinformatics enable modeling and performance analysis of spatial phenomena related to topography or other areas with similar spatial properties.

Finally, there are potentialities for forest harvesting operations development under the slogan “environmental design for sustainable development and management” where they will offer various benefits as for the area as for the whole country.

Similar issues can be also addressed by the research project dealing with forest road network density, forest roads layout in relation to the environment and the choice of skidding means mainly comparison between the tractor and cable skidding or between animals and tractor skidding.

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