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DIGITAL TERRAIN MODELS – A HELPFUL TOOL FOR SUSTAINABLE MANAGEMENT AND DEVELOPMENT OF DEGRADED GREEK FOREST ECOSYSTEMS

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Abstract

Most of the ecosystems of our country are classified as degraded natural ecosystems, due to more or less human impact on the near or distant past. Many of these ecosystems are currently experiencing an evolutionary process, after their relief of adverse human activities, which mainly depends on the condition of the soil, the ecological diversity of the region and the rational and sustainable human management. The digital representation of the terrain, with software easy to handle, is a key task of the Geotechnical – Engineering Scientist. Furthermore, it is necessary for the upgrade of the existing environment that the current state of the ground (aspects, soil-cover) and the proposed one (roads, new soil-cover, micro-works) are depicted on three-dimensional intelligibly form. This process requires detailed surveying with geodesic station or GPS and automatic transfer into an appropriate software for processing – a comparison of existing and proposed state, through several options. Consequently, the following problem is raised: farming and sustainable management of the forest without road openings is unrealistic, on the contrary most of our country's forests are degraded and with low productivity. Therefore, it is difficult to find the golden mean between the services of the needs of the forest exploitation and protection and the principle of the optimization that should apply in all economic-technical studies. The aim of this essay is to examine the contribution of the digital elevation model and generally, the high technology, to setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests in Greece. The background on which the modern analysis and design of the site takes place, is a digital design in two-dimensional and three-dimensional forms. In relation to the above both the design and construction of forest roads ought to depend on digital technology. It is the largest infrastructure work in the mountainous area and contributes to the intensification of forest exploitation in economic growth and gradual improvement of degraded mountain areas.

Key words: AutoCAD, sustainable development, geoinformatics, digital terrain model.

Introduction

The optimization of the opening up of the forest is to rationalize their management so that, in relation to forestry purpose, their better utilization, the on-time and effective protection against biotic and abiotic factors and the maintenance of the ecological balance of the region are satisfactorily achieved.

In productive forests, in particular, one of the main purposes of the opening up of the forest is the contribution to the sustainability of fruitfulness and the optimization of wood production, in quantitative and qualitative terms. The wood, which is produced from Greek forests, is categorized into stacker (crushed-wood and firewood) and technical (round). In productive forests, forests with wood stock (> 2 $m^3.ha^{-1}.year^{-1}$), the ratio for stacker to technical wood is about 60% to 40%, while in non-productive forests stacker wood amounts to 80–100% (Doukas 1984).

Most of the ecosystems of our country are classified as degraded natural ecosystems, due to more or less human impact on the near or distant past. Many of these ecosystems are currently experiencing an evolutionary process, after their relief of adverse human activities, which mainly depends on the condition of the soil, the ecological diversity of the region and the rational and sustainable human management (Doukas 2004).

The background on which the modern analysis and design of the site takes place, is a digital design in two-dimensional and three-dimensional forms. The digital representation of the terrain, with software easy to handle, is a key task of the Geotechnical – Engineering Scientist (De-Cambray et al. 2007). Furthermore, it is necessary for the upgrade of the existing environment that the current state of the ground (aspects, soil-cover) and the proposed one (roads, new soil-cover, micro-works) are depicted on three-dimensional intelligibly form. This process requires detailed surveying with geodesic station or GPS and automatic transfer into an appropriate software for processing – a comparison of existing and proposed state, through several options (Tsouxlaraki 1996).

The problem of the optimal opening up of the forest and the construction of forest roads in particular, is complex and in Greece, it is even further exacerbated by the steep slopes and the terrain generally, and the low productivity of most of our mountain forests (FAO 1998). Consequently, the following problem is raised: farming and sustainable management of the forest without road openings is unrealistic, on the contrary most of our country's forests are degraded and with low productivity. Therefore, it is difficult to find the golden mean between the services of the needs of the forest exploitation and protection and the principle of the optimization that should apply in all economic-technical studies.

The need to approach and access the forests and the mountainous areas, in general, is the beginning of the economic exploitation, the protection and the operation of all functions within the multipurpose forestry-science. Moreover, the opening up of the forest and the opening of forest roads, in particular, is a project with social implications, as they are the most important infrastructure work in the mountainous areas and contributes to the intensification of the forest exploitation, the economic growth and the gradual improvement of degraded mountain areas (Liu and Sessions 1993).

The aim of this essay is to examine the contribution of the digital elevation model and generally, the high technology, to setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests in Greece.

Material and Methods

The public forest of Cithaeron mountain is located west of Athens at a distance of 60 km away from Egalaio area, where the office of the Forest Service exists, nearby the boundaries of Boeotia prefecture. The public forest of Cithaeron mountain extends to the S – SE slopes of the main ridge of Cithaeron mountain, and especially on the slopes which are N, NW and W of the town of Vilia among the coordinates (Figure 1):

Latitude North 38° 11´ 30´´, South 38° 09´ 00´´

Longitude East 23° 23´ 00´´ West 23° 13´ 00´´

It is a long stretch from E to W along and south of the Ridge of Cithaeron Mountain, about 16 km long, in central Greece, standing between Boeotia in the north and Attica in the south. The area that lies within these boundaries is 1,582.5 Ha, in accordance with the land uses as presented on Table 1 and Fig. 2.

The whole area on which lies the under study forest has a general south aspect. Due to the relief of the area, local slopes appear W, SW, E, NE and a little bit N aspect. The slopes of the ground differ from mild to moderate and to intense, with a higher coverage rate of 40.02% of the total surface slopes of 21–40%. The slopes are generally steeper on the west side of the mountain. The above

Fig. 1. The research area.

Table 1. Land use.

Land use	Coverage rate, ha
1. Wooded area	698.1 ha
2. Partially wooded area	57.2 ha
3. Scrubs - Evergreen Broadleaved	732.7 ha
4. Agricultural lands	27.8 ha
5. Bare - grassland	65.7 ha
6. Settlements	0.9 ha
Total	1582.5 ha

sea level starts at 420 m just above Vilia and reaches 1.407 m on the top of the Prophet Elias pick of Cithaeron Mountain. The entire area is strictly mountainous. It is mainly composed of limestone.

For research purposes, namely the contribution of digital terrain models in the sustainable management and development of degraded Greek forest ecosystems, DTM is created concerning a typical forest with low productivity (<1 m^3 per year and ha), after having obtained the necessary forestry, technical and economic data from the forest management plan for Cithaeron forest for the years 2000–2009.

The maps of 1:50000 of the area were used with the help of the most modern tools such as powerful computers and programs i.e. the Geographic Information Systems (GIS), automated design (CAD) and Digital Image Analysis (Image Processing).

We placed the boundaries of the complex, the forest sectors and stands (Figure 3) and various land uses of the area (wooded, partially wooded land, agricultural lands, bare lands, evergreen broadleaved, grassland and settlements) and then became the area measurement

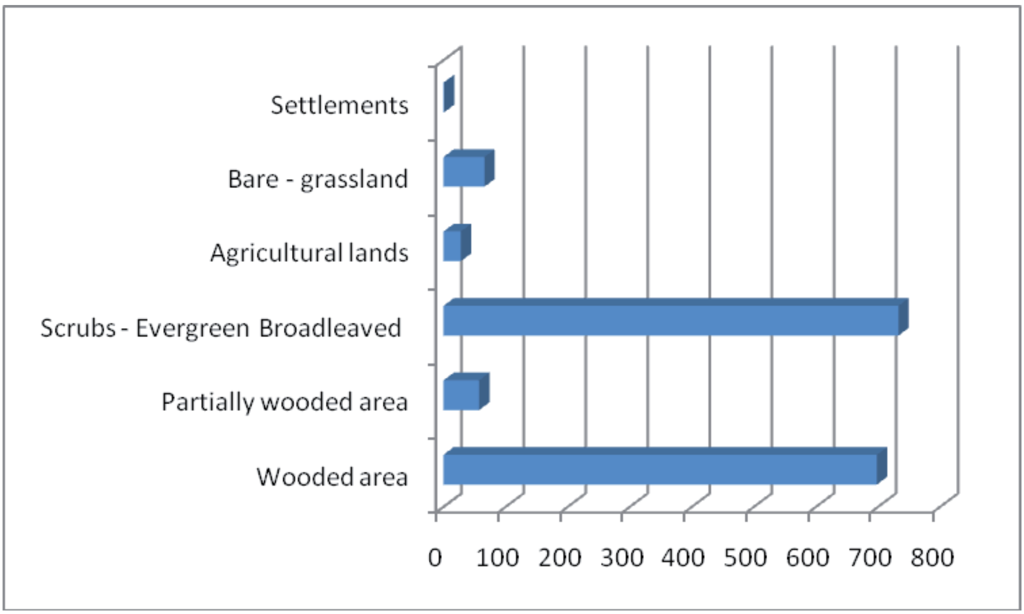

Fig. 2. Land use percentage of the study area.

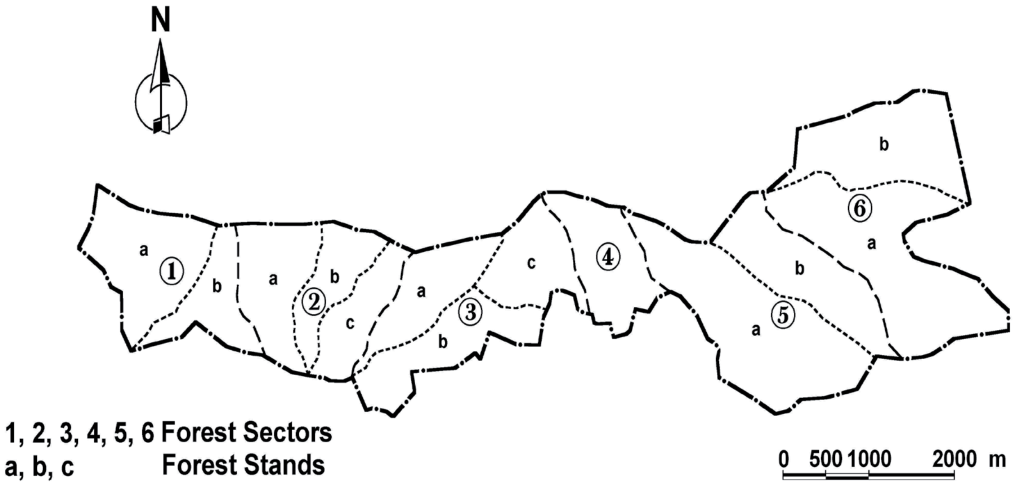

Fig. 3. Forest sectors and stands of the study area.

automatically by using a command of AutoCAD named: “lift”. The current road density of the region was estimated by using the AutoCAD.

Digitization is the digital mapping of the characteristics of a map. Substantially through the digitization of the spatial features of an analogue map (points, lines, and surfaces) are converted into digital (x, y) which in turn are stored in specific files on the computer. Specifically a pair of coordinates (x, y) represents a point, while a series of points represents a line. One or more lines delimit a region using a label point represents a surface (Papadimitriou 1980).

On a practical level, as the map is pasted on the panel of digitization, points or lines that represent captured by the digitizing cursor. By activating the cursor, the computer records the position of the point he intended. A necessary condition is the digital encoding of digital records in a common reference system. Practical means to convert the local coordinates of the device in a common geographic reference system such as UTM coordinates or coordinate system H.G.R.S. 87. Most commercial GIS packages containing the software to convert the coordinates facilitating the cartographer to any changes they desire (ACSM 1988).

Results and Discussion

In Figure 4 we can see the under study area with contour lines of 100 m, roads and the control points of the digitization. In Figure 5 is shown the digital terrain or elevation model with the forest road network in 2-D and 3-D. In Figure 6 we can see the silvicultural map of the study area, with contour lines of 100 m and 20m, roads and streams. In figures 7, 8 and 9 are shown the diagrams of altitude percentage, slope percentage and aspects percentage of the study area.

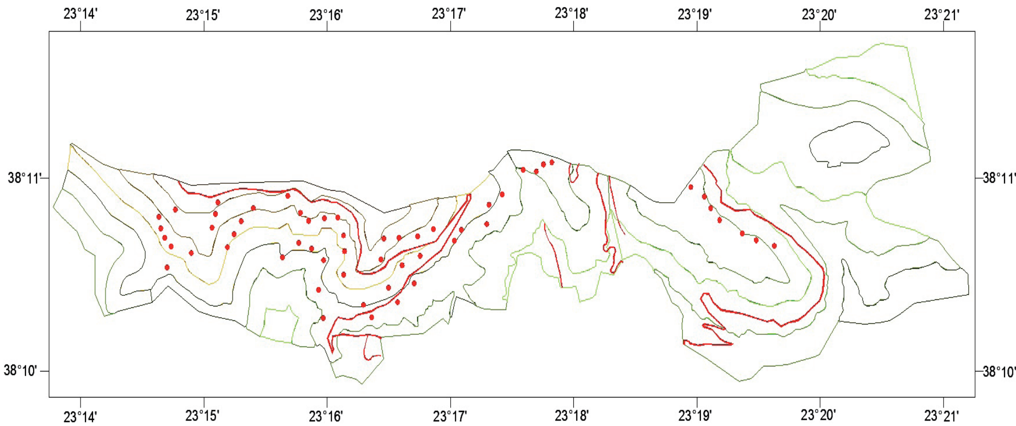

Fig. 4. Research area with contour lines of 100 m, roads and the control points of the digitization.

Finally in figure 10 is presented the research area with the points of interest.

Considering the facts that the wooded area is very small, the actual condition of the forest that is degraded, with very low wood stock and the proposed management which does not evaluates the wood production, but the protection, preservation and improvement of the forest, the protective, aesthetic, health, etc. effects should be considered and evaluated and appropriate measures for the protection of the existing forest and the improvement and expansion of it should be suggested.

Generally, it is not vital to apply specific restrictions on the management of the forest, accounting the hydronomic and protective nature of the forest and its health, aesthetic, etc. effects, except for the need for the durable existence of the forest, the improvement and the rational management, by stand, according to the forestry and biological requirements of the prevailing species.

Apart from the hydronomic and protective nature of the forest, the assessment of the healthy, aesthetic character of the forest is valuable and growing, both by local residents and tourists who come around during the summer months in the region and in transit to Porto Germeno resort.

The area is a resort for Athenians and those who originate from there. The forest offers the beauty of the Fir tree in the wider area covered with Pine trees. Finally, on the top of the Cithaeron Mountain remarkable view in every direction is provided. The Boeotia plain, Euboea, Parnitha Mountain and the other mountains of Attica, the Saronic islands, the mountains of the Peloponnese, much of the Corinthian Gulf and Parnassus Mountain can be observed from there.

The existence road density is:

D_{ex} = 18,848 m / 1,582.5 ha = 11.91 $m.ha^{-1}$

This is quiet efficient for a forest with hydronomic-protective role. This is the minimum required road density in the region, which has a key protective role.

In non-productive forests, road density that amounts to 12.5 m.ha^{-1} should be achieved, which is the minimum one for the protection of forests from fires (Doukas et al. 1995) and may also contribute to the economic-technical skidding of the stacker wood. In case of forest areas with very low productivity, where the road opening should serve mainly the protection of these areas from fires, the road density is based on the technical capabilities of fire fighting-vehicles (with pipe-length of 450 m), the method of movement of fire-fighters (easier drive downhill than uphill) and the reaction time of the fire crews (about 15 min).In these circumstances, the road distance must be between 670–800 m, i.e., road density of 12.5 m.ha^{-1} – 15

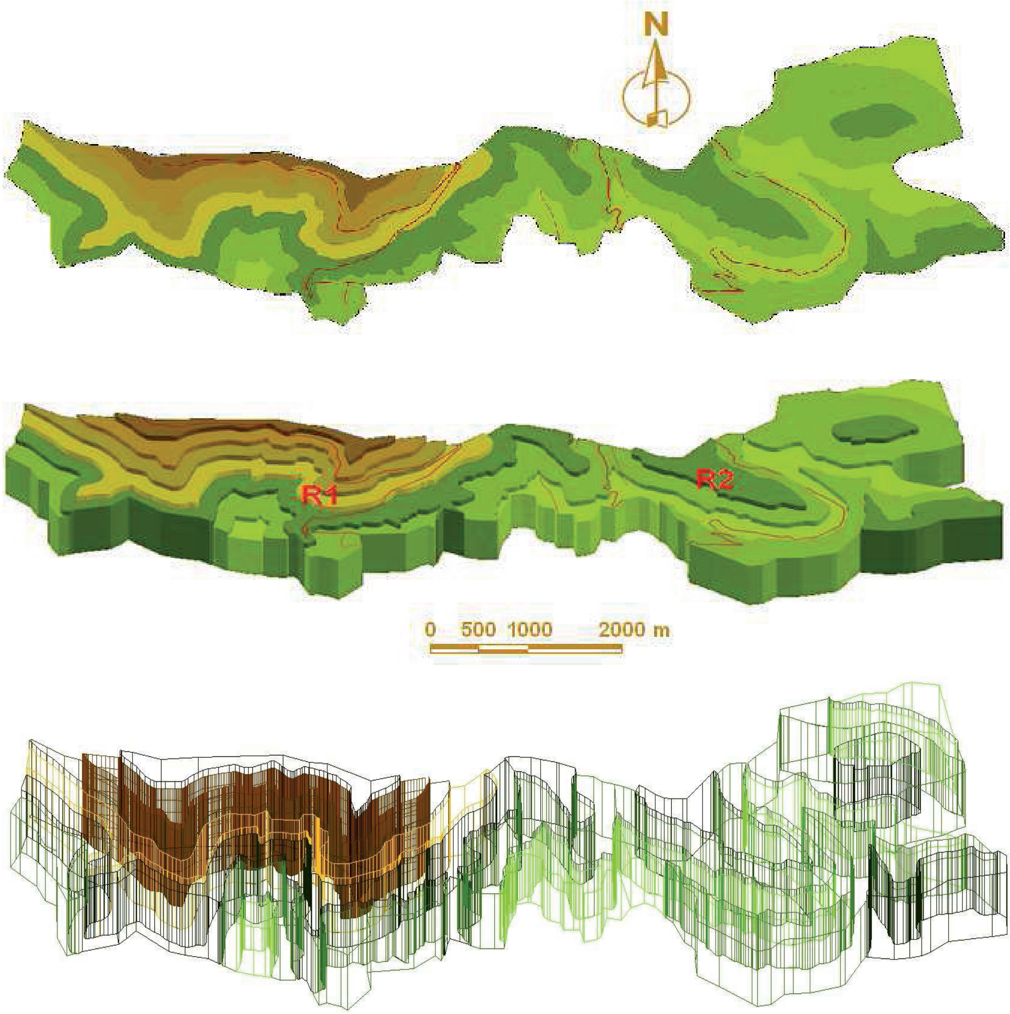

Fig. 5. DTM of the study area with forest road network.

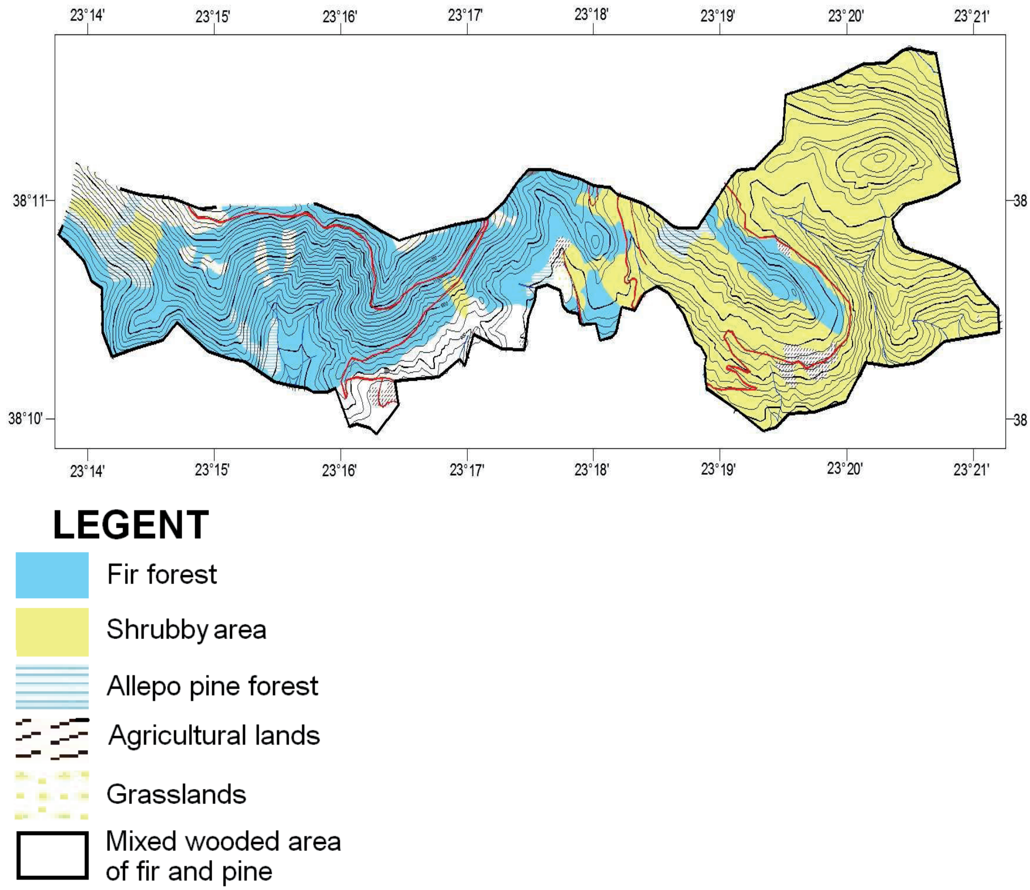

Fig. 6. Silvicultural map of the study area, with contour lines of 100 m and 20 m, roads and streams.

m.ha^{-1} (Rizopoulou and Bazigou 1990). Because of the low productivity, light traffic of vehicles is planned in the coming years for these forests. In the forests with productivity more than 2 m^3.year^{-1}.ha^{-1}, optimum road density should be calculated based on the forest exploitation data and technical and economic data of the area.

As shown in the forest map, with the help of Figure 3, forest stands 1a, 1b, 2a, 2b, 2c are not adequately served by the existing road network. A road with a start from the hairpin turn (also hairpin bend, hairpin corner or switchback) at the lower boundary of stands 2c and 3a and a general western direction to the western boundary of the forest in study would meet this need.

Conclusions

The forest, though, as mentioned above, will not be exploited for the production of forest products. The opening of a road, under the existing local conditions, will negatively affect the environment and cause damage on an already degraded forest.

The construction of another road, a little bit further, outside of the Fir-forest boundaries and through the Aleppo-Pine forest, would cover some needs of the

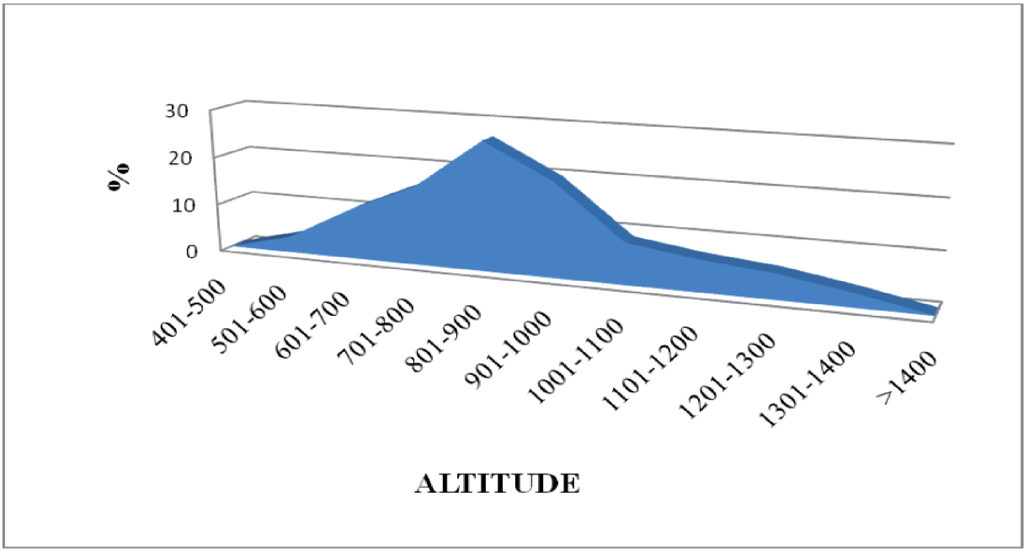

Fig. 7. Percentage distribution of altitude of the study area.

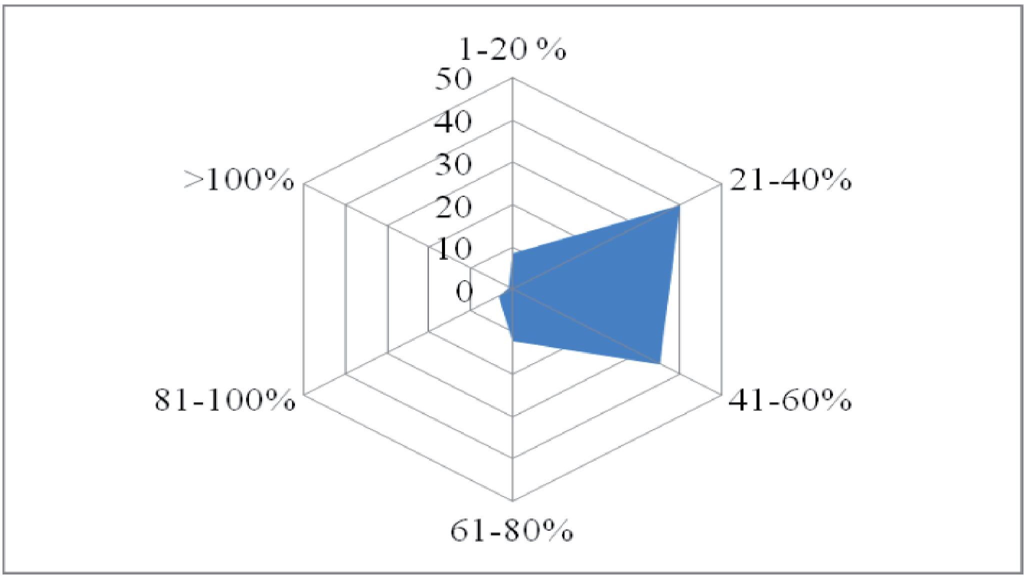

Fig. 8. Presentation of slope's percentage distribution in the study area.

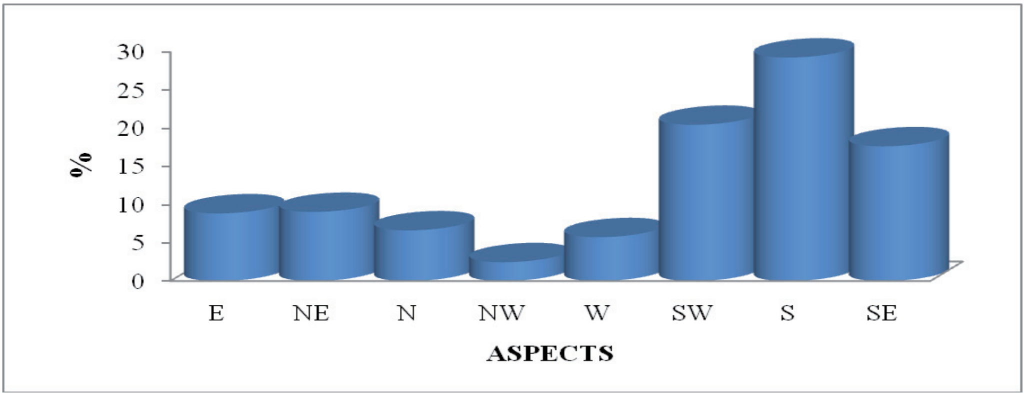

Fig. 9. Aspects' percentage distribution of the study area.

Fir-forest, while it would serve and the Aleppo-Pine forest.

As a consequence, the construction of any road is not suggested, nonetheless, we believe that the opening of a road in the area should be considered with the conditions which are developed above; the mutual service of the Fir-forest and the Aleppo-pine one.

It is not required to settle buildings and other facilities for the exploitation of the forest. The issue of the fire protection should be dealt with altogether for the entire region. Especially, in the hazardous forests that are endangered by fire, dead-end forest roads should be avoided, in order to eliminate the chance of the entrapment of forest fire-fighting vehicles.

Finally, the important issue of interventions in this area with the construction of various works that will serve the needs of mountaineers, tourists, forest recreation, etc. involving various bodies (local authorities, mountaineering clubs, hunting clubs, Forest Service, etc.), each one different and often conflicting priorities and views, must be addressed through true cooperation between these bodies and after a thorough study of all parameters and joint decision-making.

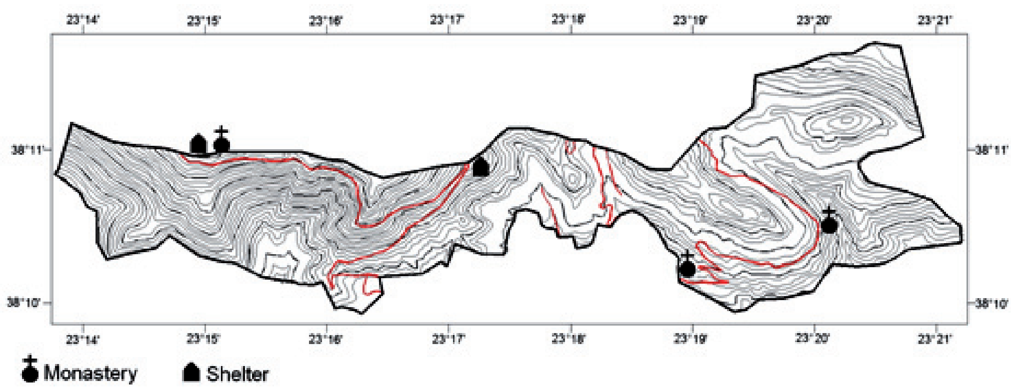

Fig. 10. The study area with contour lines of 100 m, roads and points of interest.

Whatever is concluded for this degraded forest, is a guide for the rest of the Mediterranean degraded forests of our country.

The digital elevation model is the base for the creation of utilization land use maps. Utilization maps can be very detailed and tremendously useful. They can highlight a variety of activities, including farming, mining, residential use, light industrial, heavy industrial, waste storage, and so forth so that people get a clear visual impression of how land in the area covered by the map can be used. Utilization land use maps can also be important from a development perspective because they provide data about historical use; land used for a tannery, for example, might not be a great place for a residential development and help in setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests.

Land use maps, records, and archives are often kept in central government buildings for the purpose of maintaining a coherent record. Researchers who want to study land use or the history of a region can access these archives, as can developers who want to know more about their land use options, and government officials who monitor land use. These maps can become important in zoning and property disputes, as people may be able to use them to prove or argue their case.

We can use land use data derived from satellites and aerial photographs to study the historic change in Land Use/ Land Cover for a region and to model the possible impacts of climate change on these trends.

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