Mapping the Optimal Access to the Natural Resources Based on Spatial Planning. The Case Study of Thassos Island, Greece

StergiosTampekis, Fani Samara, StavrosSakellariou, AthanasiosSfougaris, OlgaChristopoulou

Abstract— ***Small islands due to their small size face environmental risks, because of the pressures arising from the projects and actions aiming at economic development. Forests constitute vulnerable ecosystems that change at great speed. In most of the occasions the change is downgrading. The right management of the natural resources is the unique solution for the achievement of sustainable development. However, sustainable management of forests must be achieved with the respect and protection of nature and landscape. Sustainable management of forest resources can only be achieved through a well-organized road network, designed with the optimal spatial variability and the minimum environmental impacts. In this paper, we focus on the environmental impacts' intensity criteria evaluation and more specifically on the forest road density, the road spacing and the forest opening-up percentage evaluation. From the road density and the forest protection percentage evaluation, we can deduce that in the study area there have been opened a lot of forest roads. Nevertheless, with the integration of the intensity and the absorption multi-criteria evaluation we can deduce whether the existing forest roads in the study area have been designed with the optimal spatial planning. Consequently, with the application of the optimal spatial planning technique we will ensure the best protection and at the same time the sustainable exploitation of the forest resources. Additionally, it will be valued if there are any impacts to the natural environment and if some of the forest roads had been constructed legally or not according to the guidelines.***

Index Terms—***Forest opening-up,Geographic Information Systems (GIS), road density, spatial planning***

I. INTRODUCTION

A well-organized road network is crucial for the sustainable management of forest resources (wood production, ecotourism, water supply, or soil conservation) [1], [2], [4].Forest roads cause changes in the landscapes and losses in habitat and biodiversity [9], [10]. Therefore, a new method for the forest roads planning that includes financial, ecological and social parameters has to be developed [14].

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Some researchers analyzed the road network planning based on the environmental factors as well as by using the multi-criteria-based road design, such as timber volume, slope, ground condition, distance from existing forest roads, soil type, geology, hydrographic, aspect, elevation, and tree type [3], [7].An expert-based approach to the forest road network planning can be achieved by combining the Delphi method and the spatial multi-criteria evaluation. This methodology is useful in forest road planning because it takes under consideration environmental and cost parameters [13]. Additionally, the "Evaluation of Forest Road Network Planning According to Environmental Criteria" [8] and the "Impacts, management and functional planning criterion of forest road network system in Turkey" [4] are also a significant methods in forest roads network planning and environmental impacts' assessment. In the Multi-Criteria Evaluation (MCE) technique, an attempt is made in order to combine a set of criteria to achieve a decision according to a specific objective [6]. In the last fifteen years, much work has been directed toward integrating Geographic Information Systems (GIS) and the MCE methods in the context of spatial decision support systems for planning, retail and services locations, land-based project selection, and environmental management [15], [16]. In this paper, we focus on the environmental impacts' intensity criteria evaluation and more specifically on the forest road density, the road spacing and the forest opening-up percentage evaluation. For the MCE method, the assessment of the above criteria is crucial for the optimal forest road network spatial planning. The rest of the intensity and absorption criteria evaluation of our research are still in progress and they will be published in a following paper.

II. MATERIALS AND METHODS

At the orientation map (Fig. 1) the study area, is presented. As study area, we chose the Greek Island of Thassos. Specifically, the study area is located at 40.5495 and 40.8351 Northern Latitude and between 24.4808 until 24.797 Western Longitude. The study area is about 38682.86 ha.

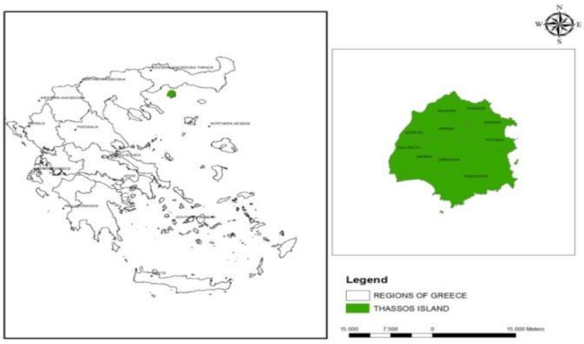

Fig. 1. Location of the study area, Thassos Island

For the needs of the research we used: The QGIS software, the digital orthophotomaps of the area and the respective Digital Elevation Models (DEM). Thus, the land use and the forest roads' network were digitized. We also used the forest management plan for the Island of Thassos for the years 2011-2020.

Initially, the optimal spatial planning technique includes the Multi-Criteria Evaluation of the environmental impacts' intensity criteria which are [5], [11], [17]:

1) The forest road density and the forests' protection percentage,

2) The applied skidding means (with either the use of tractors or the cable logging systems in wood skidding),

3) The timber skidding direction (draught animals, cable logging systems),

4) The traffic load and truck type,

5) The forest roads' location (the distance between forest roads and streams, the distance between forest roads and the forest boundaries and if the forest roads come through unstable soils).

Each criterion is rated with a Weighting factor (based on experts' agreements) that represents the intensity value.

We agreed on the optimal ecosystem forest protection status to be the 100%.

The average of the environmental impacts' intensity evaluation (ΣI), is equal to the sum of the products $\Sigma(I \times W_I)$ divided by the sum of the Weighting factors (ΣW_I).

$\Sigma I = \Sigma(I \times W_I)/\Sigma W_I$ Where: I= the criterion value assessment (%) that evaluates the impacts' intensity which is not negative,

W_I= the Weighting factor of each intensity criterion

ΣW_I= the sum of the Weighting values of each intensity criterion .

Hence, the criterion evaluation of the road density and the forests' protection percentage is: the percentage of the excess or the reduction of the values D=12.5-15m/ha, for roads spacing S=800m and the forests' protection percentage which is < 85%, is rated totally as the reduction of the optimum 100. *Weighting factor: 3*

III. RESULTS AND DISCUSSION

The rate for the road density and forests' protection percentage criterion is evaluated below.

We digitized the forest road network (Fig. 2) and the land uses (Fig. 3) and successively we created attribute tables with the forest roads' length as well as the land uses' area (ha).

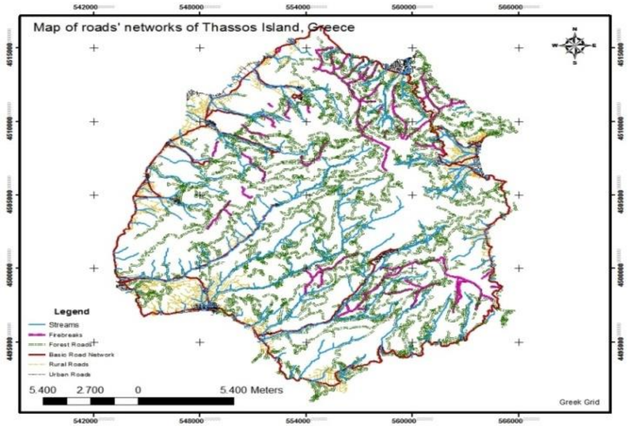

Fig. 2. Map of roads' network in Thassos Island

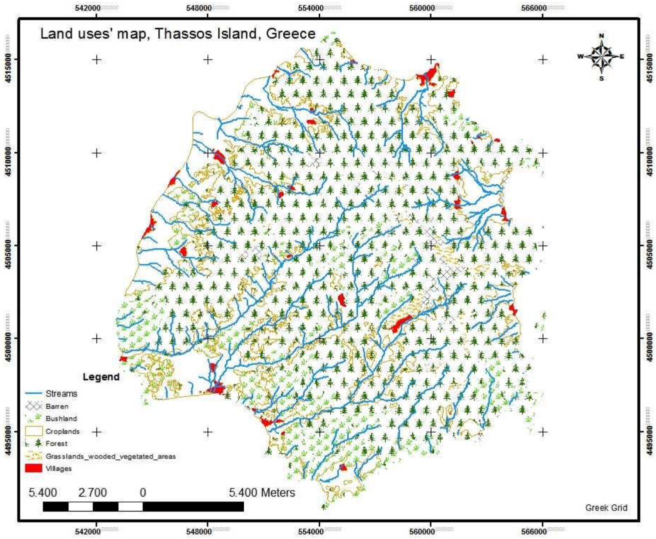

Fig. 3. Map of Land Uses in Thassos Island

From Fig. 2 and 3 and the data procession by using QGIS, the following graphs in Fig. 4 and 5 are the results.

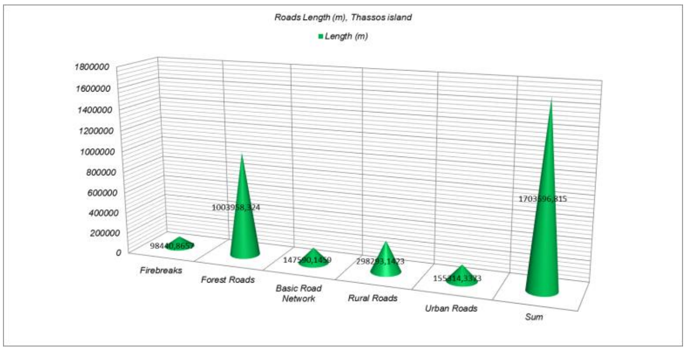

Fig. 4. Graph of the roads' length (m) in Thassos I

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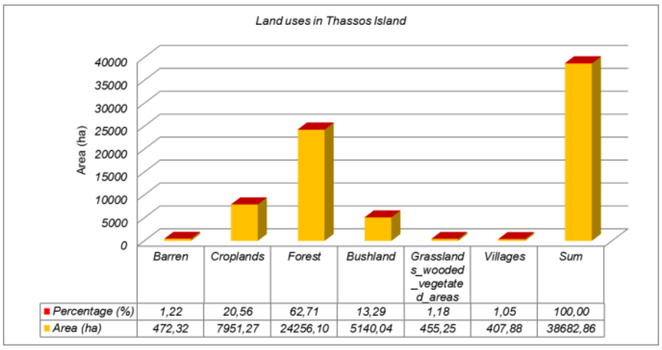

Fig. 5. Graph of the land uses' area (ha) in Thassos Island

From the forest roads' length (Fig. 2) and the land uses' area (Fig. 3) of the study area, we can evaluate the existing forest road density (m/ha):

$D_{ex}=\frac{L}{F}$

L: forest roads' length (m),

F: land uses area (ha).

In the table below, various forest road density values are given because of the forest roads' values and the land uses diversity.

Table I. Forest road density values, in Thassos Island

Roads and Land Uses	Forest Road Density (m/ha)
Roads Length Sum/Land Use Sum	44.0401
Firebreaks+ForestRoads+Rural Roads/Sum Land Uses-Villages	36.5955
ForestRoads/Forests	41.3899
Forest Roads/Forests+Barren+Bushland	33.6127
Forest Roads/Forests+Barren+Bushland+Grasslands_wooded_vegetated_areas	33.1080
ForestRoads+Firebreaks/Forests	45.4483
Forest Roads+Firebreaks/Forests+Barren+Bushland	36.9085
Forest Roads+Firebraks/Forests+Barren+Bushland+Grasslands_wooded_vegetated_areas	36.3544
Roads Length Sum-Urban Roads/Land Use Sum-Villages	40.4516

From the various forest road density values that are given, we chose as best for our research the value D_{ex}=36.5955m/ha. For the evaluation of this value we took under consideration the forest roads, the rural roads and the firebreaks that were related directly to the forest. These types of roads are used for the forest protection as well. Additionally, the Forest Service of Thassos was responsible for their construction study.

The existing forest road density D_{ex}=36.5955m/ha (Table I) of the study area, has been evaluated according to the forest roads' networks data that were given up to the present.

If the spatial planning of the forest roads was as the theoretical model defines, where the forest roads are parallel to one another and in equal distance to the roads' spacing (S), then the mean of the skidding distance REm, for the study area, is evaluated according to the existing forest road density D_{ex}=36.5955m/ha:

1. For one-sided skidding direction:

$$REm=\frac{S}{2}=\frac{10000}{2D}=\frac{5000}{36.5955}=136.63 \text{ m.}$$

2. For double-sided skidding direction:

$$REm=\frac{S}{4}=\frac{10000}{4D}=\frac{2500}{36.5955}=68.32 \text{ m.}$$

The assessment of the forest road density for the island of Thassos is D_{ex}=36.5955m/ha. For the forest protection percentage evaluation we took under consideration that the forest roads can be used by the firefighting vehicles for the forest protection due to their direct access to the wildfires' fighting. The firefighting vehicles that the Greek Fire Service uses, are small pickup trucks (4x4) equipped with water tanks, piping and pumps that have the ability to drain water with pressure at 300m uphill and 500m downhill from forest roads. Thus, the forest opening-up percentage can be used as the forest protection percentage as well, due to fact that the firefighting vehicles can be utilized for the wildfires' prevention and suppression. With the QGIS software we create Buffers (300m uphill and 500m downhill from forest roads) and as a result we have the forest protection map (Fig. 7) and the geodatabase.

In Fig. 6 and 7, we evaluate the percentage of forest protection (Buffer zones 300m uphill and 500m downhill from forest roads), which is E=70.39%.

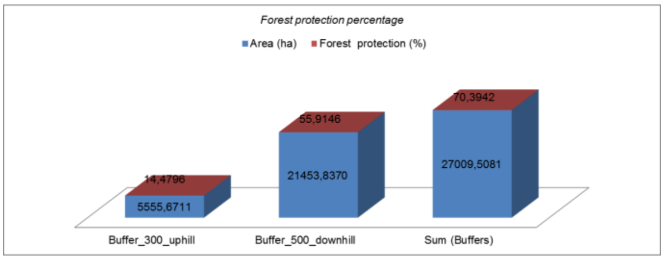

Fig. 6. Forest protection percentage evaluation

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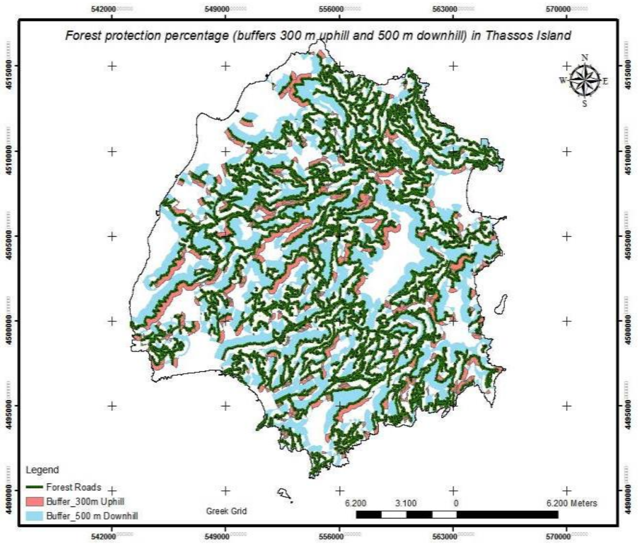

Fig. 7. Forest protection percentage

So, the excess from the road density values (D=12.5 - 15m/ha), is 36.5955-12.5=24.0955m/ha and 36.5955-15=21.5955m/ha.

The excess percentage is 100*24.0955/36.5955=65.84% and 100*21.5955/36.5955=59.01%.

Their average is $\frac{65.84+59.51}{2}$=*62.425%.*

The reduction percentage from the forest protection percentage which is smaller than 85%, is 85-70.39=*14.61%.*

Finally, the sum of the average forest road density excess percentage and the reduction percentage of the forest protection percentage is 62.425+14.61=*77.035%*.This percentage is totally rated as the reduction percentage from the optimum 100.

Concluding, the value of the criterion is evaluated100-77.035=*22.965%. Weighting factor: 3*

IV. CONCLUSION

From the road density (Dex=36.5955m/ha) and the forest protection percentage (E=70.39%) evaluation, we can deduce that in the study area there have been opened a lot of forest roads. Nevertheless, with the integration of the intensity and the absorption criteria evaluation we can deduce whether the existing forest roads in the study area have been designed with the optimal spatial planning. Consequently, with the application of the optimal spatial planning technique we will ensure the best protection and at the same time the sustainable exploitation of the forest resources. Additionally, it will be valued if there are any impacts to the natural environment and if some of the forest roads had been constructed legally or not according to the guidelines. By applying this method, the average of the environmental impacts' intensity can be evaluated due the forest roads' construction at the island of Thassos. Also, with the development and the application of the MCE method we can evaluate the spatial planning for the optimum forest roads' network as well as the environmental impacts that are caused. A new innovative tool is now created. This method plays a crucial role in the optimum solution selection (spatial, financial, forest, topographical, social and environmental) for the forest roads' planning. Additionally, this method constitutes the basis for a new decision support system (DSS) for the forest managers. It can also be customizedto each areas' particularities and to be applied for the creation of a new integratedDSS.

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