Assessment of Forest Opening Up with Multi-criteria Analysis

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Abstract

This paper examines the compatibility of the opening-up forest works with the natural environment of the public forest of Krousion and evaluates the contribution of this method for the sustainable development of this region. To that end, we evaluate several criteria. Similar procedures are called evaluation based on multi-criteria analysis. The Decision Making Support Systems (DMSS) are used to support such problems with varying construction degrees, while they enable the development of decision rules that allow problem definition, while creating alternatives and selecting the best solution. In the case of DMSS, the GIS is used to provide information to decision-makers.

Keywords: Environmental Impact Assessment; intensity; absorbency; GIS; multi-criteria analysis

1. Main text

The development of an integrated forest opening-up method with forest works such as primary haul roads, haul passages and staking grade line harvesting methods (tractor roads, hauling road path) of wood, constitutes an interference to nature. This has to be studied with a very critical mind from the ecological aspect because of the consequences to the natural environment \cite{1, 2}. Since the forest opening-up is inevitable, \cite{3} in order to achieve their commercialization and at the same time their protection that corresponds to the viable development and the

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efficient forest fire confrontation, a golden section has to be found. Contrary to the classical opening-up methods, which are mainly based on financial criteria, a method for the forest roads appreciation including financial, ecological and social criteria has to be developed Doukas [4, 5]. In this case, the straightforward forest opening-up as an independent variable in the model shouldn’t be accepted, but as a part of the whole [6] because of the close connection to the development of the each time area that contributes to the protection of the natural attraction. It is very hard to estimate the forest opening-up consequences with financial extents by using familiar methods such as cost-benefit analysis. In order to estimate these consequences, the compatibility of the opening-up forest works with the natural environment could be used [7, 8]. That requires the use of countable criteria for the intensity of human impact to the forest ecosystem and the forest ecosystem absorption of the opening-up forest works. With the term “compatibility with the natural environment” we mean the definition, the description and the estimation of the impacts of an opening-up forest works to the natural environment as well as to take measures for its protection.

The purpose of this paper is to examine the compatibility of the opening-up forest works with the natural environment of the public forest of Krousion and afterwards to estimate the contribution of this method to the sustainable development of this area.

2. Materials and method

The public forest of Krousion included primary forests of Commences: 1) Kerkini 2) Lithotopou 3) Rodopolis 4) Anatolis, 5) Kastanousas. Located in the central Macedonia in Greece in western part of the prefecture of Serres and dominating N, NW and E slopes of the mountain of Krousion, which is northwest direction at an average distance of about 55 km from the city of Sidirokastro. The altitude ranges from 40 to 1,200 meters and the slope from strong to steep (20-70%). It is a semi mountainous region and has all the typical characteristics of a Greek semi mountain forest with fantastic panoramic landscape. The geographical coordinates are between:

North latitude 41° 7’ and 41° 17’ east longitude 22° 52’ and 23° 14’. The mountain of Krousion has a general direction from NW to SE of Serres. The under study forest has a general aspect that ranges from North up to East. The total extent of the forest is 15,282.50 ha.

For the investigation and the achievement of the research goals that lay down within the scope of this paper were used:

Digital orthophotomap of the research area and the respective digital terrain models DTM that resulted from the photogrammetric process of a pair of aerial photographs in a digital photogrammetric station. So the digitization of the land uses and the forest road network make possible and finally the inference reliable measurements regarding to the accurate estimate of the area for each land use and the length of the existing forest road network.

The last management plan of the forest from which we utilized factors such as harvesting, management form, the already existing forest species, tree age etc.

The method, which would be applied, should be practical, effective and easy to use. For this reason we have been set a number of absorbency and intensity criteria. The absorbency and intensity criteria and their weight came from a questionnaire sent to specialist scientists [9].

The grading of these criteria depends on the following principle:

We accepted a situation as ideal (=100%) for the forest protection. The percentage of deviation from this ideal situation will be subtracted from 100%. The result will be the grading of the criteria.

For the definition of the intensity of the human impact to the natural environment from the existing forest opening-up works and the exploit of the forest, we used respective criteria [10, 11, 3, 8]. At the same time, weight coefficients were set to express the intensity of each criterion based on the opinion of expert scientists.

In detail, the intensity criteria that were used are:

1. Road Density.

For the optimum forest opening-up firstly we ought to investigate the forest road net according to the Kroth method and calculate as the optimum economical road density $D_{ec}$ and the optimum theoretical road density $D_{th}$ as the maximum road density $D_{max}$ [12, 13, 14, 15, 16, 17]. The $D_{max}$ is calculated for the forest and tractor roads when we do not take under consideration the forest roads construction costs and the loss of the territorial income (revenue). The existing road density $D_{ex}$ is compared with the $D_{th}$ and $D_{ec}$ and is considered with the logging means (animals, tractors, cable winches).
When the animals are used as logging means then the optimum of the opening-up is based on the $D_{th}$, when the mechanical means are used as logging means the optimum of the opening-up is based on the $D_{ec}$, and when we have a combination from animals and mechanical means as logging means and the harvesting is bigger than 2.5 $m^3$ per ha the optimum of the opening-up is based on the $D_{max}$.

The excess percentage of $D_{ec}$ and $D_{max}$ is rated as the reduction of the optimum 100.

1.1. Skidding with draught or load animals. Coefficient weight: 3.
1.2. Skidding with mechanical means or combination from animals and mechanical means. Coefficient weight: 3.
2. Use of tractors in skidding. The percentage of the use of tractors for skidding is rated as the reduction of the optimum 100. Coefficient weight: 2.
3. Opening-up percentage. The percentage of the forest opening-up from forest roads and tractor roads which is <70%, is rated as the reduction of the optimum 100. Coefficient weight: 3.
4. Skidding direction (horses, tractors, cable winches). The skidding direction percentage which is <45° comparing to the vertical to the road skidding, is rated as the reduction of the optimum 100. Coefficient weight: 1.
5. Traffic frequency and vehicle type.
5.1. Exceeding of traffic frequency. The excess percentage of the traffic load, in comparison to the one that is justified from harvesting, is rated as the reduction of the optimum 100. Coefficient weight: 2.
5.2. Overloading of transport vehicles. The excess percentage due to truck overloading of the uniform truck loading according to the rules is rated as the reduction of the optimum 100. Coefficient weight: 2.
6. Forest roads’ categories. A ratio of 40% of main roads (category A’, B’ and C’ of forest roads) and 60% of tractor roads in addition of infrastructure is considered as ideal (100). A deviation from this ratio in favour of the main roads will be evaluated with reduction of the grading on a scale of 100. Coefficient weight: 2.
7. Position of roads: The distance of the forest road from a stream, from the forest borders and from dangerous sites.
7.1. Distance of water flows. The percentage of the forest road that is located on a valley less than 10m from a stream bank reduces the grading on a scale of 100. Coefficient weight: 3.
7.2. Distance of forest boundaries. The percentage of the forest road that is located less than 10m outside the forest borders or less than 20m inside the forest borders, for aesthetic reasons, reduces the grading on a scale of 100. Coefficient weight: 3.
7.3. Problematic (unstable) soils. The percentage of the road passing by a clay ground, large opening streams, unstable soils (landslides), steep slopes (over 50%), rock fall risk areas, etc., reduces the grading on a scale of 100. Coefficient weight: 3.

The next parameter studied was the capacity of the forest ecosystem to absorb the impact of the works. By absorbency, we mean the extent to which the effect will be absorbed by the ecosystem with time, as well as the number of the recipients of the effect [6]. The absorbency criteria evaluated and the respective weight coefficients are the following:

The absorbency criteria are divided into 3 categories:
1st forestry criteria, 2nd topographical criteria and 3rd social criteria. The weights of the criteria are: three (3) for the forestry criteria, two (2) for the topographical criteria and one (1) for the social criteria.

The forestry criteria are the following:
1. The land uses. The forest is graded with excellent 100; a wooded area, depending on the density, with 25-50; and a bare (denuded) area with 15.
2. The forestry species. A mixed forest is graded with excellent 100; a coniferous forest with 70; and a broadleaved forest with 50-80 depending on the season when measurements are performed, that is if trees have leaves or not.
3. The management form. A seedling (high) forest is graded with excellent; a coppice forest is graded with 50 and a dual-form forest is graded with 75 to 100 depending on the seedling-coppice forest rate.
4. Age (forestry form). A group-selective forest is graded with excellent 100; a selection forest with 75 and an even-aged forest with 50.
5. The height of the trees. Tall trees >20m is graded with excellent 100; medium size trees 10-20m with 75 and small trees <10m with 25-50 depending on their height.
6. The site quality. Good (first and second site quality), medium (third and forth site quality) and poor (fifth and sixth site quality). The good land quality is graded with excellent 100; medium with 50 and poor with 25.

7. The productivity of the forest (Harvesting):
Category I (productivity over 3m³/year/ha).
Category II (productivity 1-3m³/year/ha).
Category III (productivity less than 1m³/year/ha).
The forest of category I productivity is graded with excellent 100; forest of category II productivity with 50 and forest of category III productivity with 25.

The topographical criteria are the following:
1. The cross slope of the ground. The gentle slopes < 8% is graded with excellent 100; from medium slopes 8%-20% with 50 and high slopes > 20% with 25 to 5, depending on the slope.
2. The aspect. The percentage of the lands with an altitude less than 1000 m with northern exposure is graded with excellent 100; southern with 50 and eastern-western with 75.
The percentage of the lands with an altitude over 1000 m, with eastern or western exposure is graded with excellent 100 and northern or southern with 70.
3. The terrain relief. The mild relief is graded with excellent 100; a bold (intense) relief with 15 and a various relief with 50.

Social criteria depend on the number of humans affected by the road. Distance plays a major role in impact e.g.
1. Distance from a tourist resort (Since tourism is seasonal and is culminated during the peak season, each kilometer of the distance from the resort increases grading e.g. distance 0-1 km is graded with 0, 1-2km with 10, 2-3km with 30 etc.).
2. Distance from the national and country road network (the same as with the resort).
3. Distance from a railway (it has no direct impact but if one sees the road from the train, he/she might want to visit the forest by car. However, it has impact due to noise).
4. Distance from an archaeological site (the same as with the resort).
5. Distance from an adjacent big city (the same as with the resort).
6. Distance from an adjacent village (the same as with the resort).
7. Distance from a European path. Every time the road crosses the path, its grading is reduced (e.g. if it crosses the path once it is graded with 80, if twice with 60, 3 times with 40 etc.).
8. Distance from a natural or artificial lake or river (the same as with the resort).
The final grading of intensity (I) for each criterion is provided by the product of each criterion value multiplied by its weight coefficient in order to find the barycentric mean. Similarly, the absorbency (A) of the forest ecosystem is calculated by each criterion value multiplied by the respective weight coefficient with a view to find the barycentric mean.
The value (%) that estimates the impact of intensity (I), which is not negative, is multiplied by the respective weight coefficient (W_I) and is divided by the sum of the weight coefficient values so as to extract the barycentric mean:

\[ C_I = \frac{\sum(I \times W_I)}{\sum W_I} \]  \hspace{1cm} (1)

where \( \sum(I \times W_I) \) and \( \sum W_I \) are the sum of the estimate impact of intensity multiplied with the respective weight coefficient (\( W_I \)) and the sum of the weight coefficient values, respectively, for matrix as size %.

Likewise, the absorption (A) of the forest ecosystem is multiplied by respective weight coefficient (\( W_A \)) and is divided by the sum of the weight coefficient values with a view to extract the barycentric mean:

\[ C_A = \frac{\sum(A \times W_A)}{\sum W_A} \]  \hspace{1cm} (2)

where \( \sum(I \times W_A) \) and \( \sum W_A \) are the sum of the absorption’s estimate multiplied with the respective weight coefficient (\( W_A \)) and the sum of the weight coefficient values, respectively, for matrix as size %.
The figures \( C_I \) and \( C_A \) represent the indexes that regard to the degree of compatibility of the forest opening-up works with the natural environment.
3. Results

Grading each criterion of human impact (intensity) to the natural environment:

1. Road density: For the definition of the existing road density we applied the software AutoCAD Civil 3D 2009 (definition of topology, road length measurement) from the digitized map of the study area that derived from the respective orthophotomap. For the determination of the mean vertical skidding distance, the mean inclined skidding distance and the curvature coefficient we applied the software GIS taking under consideration the logging means (tractors, two-sided skidding and animals one-sided skidding). The values that were rated are: \( D_{\text{ex}} = 12.93 \text{ m/ha} \) (\( D_{\text{ex}} \): existing road density), \( D_{\text{ec}} = 13.06 \text{ m/ha} \) \( D_{\text{thex}} = 9.81 \text{ m/ha} \) (\( D_{\text{ec}} \): optimum economical road density, \( D_{\text{thex}} \): theoretical existing road density). The excess percentage of the \( D_{\text{ec}} = 13.06 \text{ m/ha} \) from the \( D_{\text{ex}} = 12.93 \text{ m/ha} \), is 0.13 m/ha, so the value of the criterion is 100 – 0.13 = 99.87%.

2. Percentage of tractors’ use in skidding: At the study area, are used tractors in skidding, therefore the criterion value is 10%.

3. Opening-up percentage: The opening-up percentage was calculated by creating on the digitized map, a zone of width twice as the mean horizontal skidding distance in both sides of the forest roads in the study area. The opening-up percentage is 67.27%, therefore the reduction percentage which is below 70% is 2.73% and the criterion value is 97.27%.

4. Skidding direction: The skidding direction is always >45º if tractors are used as skidding mean. Therefore, the criterion value is 100%.

5. Traffic load and truck type: a) The excess percentage of the traffic load: At the study area we observed excess of the traffic load (30 tractors) comparing to the admissible from harvesting, number of tractors (26). Therefore, the excess percentage is 13.33% and the criterion value is 86.76%. b) The excess percentage due to truck overloading: We observed excess of the truck loading, 35tn rather than 32tn. Therefore, the excess percentage is 8.57% and the criterion value is 91.43%.

6. Forest roads’ categories. The criterion value is 0% because there are very few tractor roads compare with the main forest roads.

7. Position of roads:
   7.1. Distance of water flows. The criterion value is 60%.
   7.2. Distance of forest boundaries. The criterion value is 80%.
   7.3. Problematic (unstable) soils. The criterion value is 70% because of the percentage of the road passing by unstable soils (landslides).

Grading the absorption ability of the skidding consequences from the forest ecosystem:

1. Forestry criteria.

1. From the digitized map of land uses is clear that the 66.70% of the study area is covered by forest, the 10.70% from wooded area, the 22.60% has no vegetation or agricultural area. The value of the criterion is 75.44%.

2. Likewise, the study area is covered by broad-leaved forests. So the value of the criterion is 80%.

3. The forest management form is a dual-form forest with criterion value 91.6%.

4. The forest age is between a selection forest and an even-aged forest with criterion value 65%.

5. The mean tree height, is >20m, therefore the value for this criterion is 75%.

6. The site quality is medium (third and forth site quality) and poor (fifth and sixth site quality), therefore the value of the criterion is 40%.

7. The forest productivity (Harvesting) is 2.14 m³/year×ha, according to the last forest management plan, which is between 1-3 m³/year×ha, so, the criterion value is 50%.

2. Topographical criteria.

For the extraction of the absorption values we created slope and exposure maps, applying the software AutoCAD Civil 3D 2009 and the digital terrain models D.T.M. of the area.

1. The cross slope of the ground ranging from strong to steep. The criterion value is 20%.

2. The aspect to the horizon ranges from North up to East. The criterion value is 85%.

3. The terrain relief is described as intense with value 15%.

3. Social criteria.

1. The study area is not a tourist resort. The value of the criterion is 100%.
2. There are two provincial roads that crosses the forest, thus the criterion value is 0%.
3. There is no railway net passing through the study area, thus the criterion value is 100%.
4. There is no any archaeological area in the study area, thus the criterion is valued with 100%.
5. There is no any adjacent big city, since the closest town is Sidirokastro in a road distance of 55 Km. The criterion value is 100%.
6. There are five villages nearby the study area. The criterion value is 50%.
7. There is no any European pathway in the study area thus the criterion value is 100%.
8. The study area is by the lake Kerkini, therefore, the value is 60%.

In the following table 1 are presented the percentages of the intensity and absorption criteria as well as the respective rates $C_i$ and $C_A$.

<table>
<thead>
<tr>
<th>INTENSITY</th>
<th>Criteria Grad %</th>
<th>Weights</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Road density</td>
<td>Skidding with draught or load animals - It does not exist in the area.</td>
<td>99.87</td>
<td>3</td>
</tr>
<tr>
<td>1.2. Skidding with mechanical means or combination from animals and mechanical means</td>
<td>97.27</td>
<td>3</td>
<td>291.81</td>
</tr>
<tr>
<td>2 Percentage of tractors’ use in skidding</td>
<td>10</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3 Percentage of opening up</td>
<td>97.27</td>
<td>3</td>
<td>291.81</td>
</tr>
<tr>
<td>4 Skidding direction</td>
<td>100</td>
<td>1</td>
<td>100.00</td>
</tr>
<tr>
<td>5 Traffic frequency and motor vehicle types</td>
<td>Exceeding percentage of traffic frequency</td>
<td>86.76</td>
<td>2</td>
</tr>
<tr>
<td>5.2 Exceeding percentage due overloading</td>
<td>91.43</td>
<td>2</td>
<td>182.86</td>
</tr>
<tr>
<td>6 Forest roads’ categories</td>
<td>100</td>
<td>1</td>
<td>100.00</td>
</tr>
<tr>
<td>7 Position of roads</td>
<td>Distance of water flows</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>7.2 Distance of forest boundaries</td>
<td>80</td>
<td>3</td>
<td>240.00</td>
</tr>
<tr>
<td>7.3 Problematic (unstable) soils</td>
<td>70</td>
<td>3</td>
<td>210.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>24</td>
</tr>
</tbody>
</table>

Average value $C_i = \Sigma H \times W_i / \Sigma W_i = 1697.80 / 24 = 70.742\%$

<table>
<thead>
<tr>
<th>ABSORBENCY</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Land uses</td>
<td>75.44</td>
</tr>
<tr>
<td>2 Forest species</td>
<td>80</td>
</tr>
<tr>
<td>3 Forest management form</td>
<td>91.6</td>
</tr>
<tr>
<td>4 Forest age</td>
<td>65</td>
</tr>
<tr>
<td>5 Tree height</td>
<td>75</td>
</tr>
<tr>
<td>6 Site quality</td>
<td>40</td>
</tr>
<tr>
<td>7 Forest productivity (Harvesting)</td>
<td>50</td>
</tr>
</tbody>
</table>

**Topographical criteria**

| 1 Slope of ground | 20 | 2 | 40 |
| 2 Aspect | 85 | 2 | 170 |
| 3 Terrain Relief | 15.00 | 2 | 30.00 |

**Social criteria**

| Distance from |
| 1 Tourist recreation area | 100 | 1 | 100.00 |
| 2 National or provisional road network | 0 | 1 | 0.00 |
3 Railway 100 1 100.00
4 Archaeological site 100 1 100.00
5 Adjacent big city 100 1 100.00
6 Adjacent village 50 1 50.00
7 European path 100 1 100.00
8 Natural or artificial lake or river 60 1 60.00

Total 35 2281.12

Average value $C_A = \frac{\sum(A \times W_a)}{\sum W_a}$

$2281.12 / 35 = 65.175\%$

4. Conclusions

The average of the positive intensity of the impact that carries out from the study (CI = 70.742%), represents that the existing forest opening-up works were constructed in a compatible for the environment way. It is confirmed from the absorption average which was calculated (CA = 65.175%), that the specific forest ecosystem has absorbed the negative consequences that came from the forest opening-up works.

The said values are based on objective and measurable figures, the indices of environmental impact whose study ensures the reliability of the method used. Its application is necessary not only for the evaluation of the current opening up works in a forest, but also before the construction of new ones in order to examine their impact on the environment and to promote the best solution.

It is an undisputed fact that forests everywhere and always are a source of joy and health as the harmony of nature with its unique insurmountable beauty excites the visitor and so the forest of Krousion is not an exception, but all the above.

Here you can add the importance of forests as habitat Krousion. The forest spread the edge of Kerkini, declared habitat of particular significance under the Treaty RAMSAR, the best breeding site, but an excellent hiding place for any game species animals and birds living or wintering in the area.

In forest complex of Krousion there is no infrastructure for forest tourism. Apart from an old amusement park that was created in the 70s there has been no further response to forest tourism infrastructure. Taking into account the fact that Krousia bordering Lake Kerkini which brings together a large number of visitors, it is essential to creating views that will foster the emergence of the beauty of the landscape and serve the needs of visitors.

The positions where up view reveals a panoramic landscape. There, visitors can stop to rest and enjoy the scenery. These positions are part of the sight of a wide range of facilities alike. The choice of suitable sites is difficult because they often relied on their own and is almost always higher positions observer. The distinctive feature of places of sight is that large numbers of visitors. For this reason, these places should be set so as to ensure convenient and safe movement and residence.

The roads in the forests should be while serving the transport needs of forest products and the various operations to satisfy the requirements of the browser-visitor. It is multi-use paths, as is the function of forests.

References