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Opening Up and Sustainable Development of Mountainous Regions

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ABSTRACT

In 2009, in Copenhagen found out that while the ices melt interest for the environment "freezes" because of the economic crisis. The sustainable development is the best answer to this bleak outlook. The principal objective of the paper is the evaluation of the opening up of the mountainous forest of Greece.

The calculation of the optimum road density is calculated by the method of internal rate, but is also evaluated empirically.

In mountainous forests of Greece analyse the conditions of opening up-harvesting of wood. The opening up is investigated based on the optimum road density:

- The theoretical optimum (Dth) i.e., when the total costs become minimum.

- The economical optimum (Dec) i.e., when construction costs are equal to the skidding costs.

- The maximum (Dmax) i.e. when not taken into account the construction costs of roads and the loss of land revenue.

- The formulation of the opening up of forest areas is impossible, since each forest area is something special that requires a special handling. The techno-economic opening up of each forest area is achieved after a thorough study of the traffic, the soil and climate, and forest, financial and ecological conditions of the region.

- In productive mountainous forests with technical-economic criteria i.e. when not considering indirect benefits, in terms of opening up (road network) there is a problem of excessive road construction through uneven space distribution of the forest roads in places.

KEYWORDS : optimum road density; environmental management; flexible forest road network

1. Introduction

The development of mountainous regions is associated with the forest opening up. The opening up as an anthropogenic intervention is accompanied with both positive and negative environmental impacts.

The forest opening up is a parameter of the sustainable development of mountainous regions both for indirect utilities e.g. alternative tourism and for the exploitation of biomass.

As a result, in Greece, the forest opening up is a difficult and complicated problem because of its uniqueness.

Since the forest opening-up is inevitable, (Heinimann 1994) in order to achieve their commercialization and at the same time their protection that corresponds to the viable development and the efficient forest fire confrontation, a golden section has to be found. Harvesters are used in many regions of the world to gather a large proportion of the total timber harvest. They can achieve high productivity levels but they are expensive pieces of machinery and therefore have to work very efficiently (Purfürst, Erler 2011).

Harvesters primarily have an influence on the production process; their influence is negligible when simply moving material (Nimz 2002).

According to Greek forest norm has been implemented selective cuts in order to product the growth of the forest and to improve the quality of the logs.

In most industrialized countries, the use of draught animals in forest operations represents a curiosity, rather than a technical necessity. The rapid mechanization of all rural activities has brought animal power to the brink of extinction, despite the staunch resistance of its few loyal supporters (Magagnotti, Spinelli 2011).

Only after forest fires in Greece is a used "clearcuts" method in order to sale the burned logs and construction of barriers against the erosion (Karantzidis et. al 2008).

- The network of forest roads in Greece

The construction rate of the roads during the period 1984-1998 has been above the order of 1000 km per year, whereas since the year 1999 a progressive decline in the construction rate has commenced, so as an order of 151 km in 2006 and 1 km in 2011 is achieved. Nowadays, the total length of the forest road network of the country is measured above 32600 km.

In table 1, the forest roads, which have been opened up, paved and maintained in Greece during the period 1997-2011 and in total, are depicted.

Table 1.
Forest roads, which have been opened up, paved and maintained in Greece during the period 1997-2011 and in total

Years	Opening up (km)				Road pavement (km)		Improvement (km)	Maintenance (km)
	Categories of forest roads			In total	Tarmacadam	Sand-gravel-**macadam**		
	A′	B′	**C′**					
Until 1996	2044	6244	19891	28179	346	4972	9436	334529
1997	13	62	852	927	15	224	477	26914
1998	6	42	605	653	72	245	2926	24744
1999	10	35	505	550	69	367	5012	22601
2000	-	84	299	383	134	250	7790	22608
2001	6	13	195	214	118	555	8836	20597
2002	-	6	222	228	121	622	2962	15125
2003	5	1	109	115	48	39	1828	17464
2004	-	5	106	111	30	64	1265	17477
2005	-	7	23	30	8	80	1311	14723
2006	12	13	126	151	8	37	519	13491
2007	-	6	843	849	20	145	743	34060
2008	-	7	198	205	21	155	976	27545
2009	-	5	62	67	50	370	1373	13848
2010	-	-	1	1	2	10	697	6354
2011	-	-	1	1	8	60	118	3967
In total	2096	6528	24032	32656	1065	7127	51405	586428
Percentage (%)	6	20	74	100	13	87	-	-

In figure 1 the evolution of the construction and the improvement of the forest roads during the period 1950-2011 are depicted.

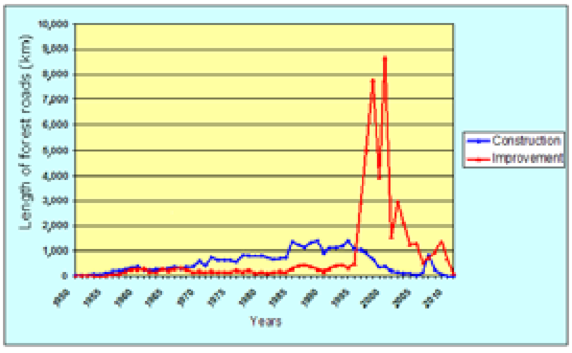


Figure 1. Evolution of the construction and improvement of the forest roads during the period 1950-2011

As far as the density of the roads is concerned, optimization is intended. Optimum density of forest roads in a woodland area is defined as the road density in which the aggregation of the effects in the forest road network is optimum, thus when by the forest exploitation the maximum possible benefit or the minimum possible cost is attained.

Several researchers throughout the world have involved themselves in the calculation of the optimum road density and developed diverse methods therefore (Hasburg-Lothringen 1970; Pestal 1970a, b; Sanktjohanser 1971; Hafner 1971; Kroth 1973; Stergiadis, Stamou 1982). In Greece, there are singularities, as timber harvesting is not the sole criterion of opening up and as a consequence, the common calculation methods are not utterly applicable, whereas the latter ones is the basis of assessment.

The aim is the assessment of the opening up of the mountainous forests in the country (Greece).

2. Methodology

The calculation of the optimum road density is achieved through two methods (Löffler 1974; Dietz et. al 1984) a) the analytical and b) the empirical.

The analytical methods are based on the calculation of the optimum road density with the assistance of mathematical relations. As a result, the road density becomes optimum when the direct expenses (expenses related to the timber skidding) and the indirect expenses (those related to the construction and maintenance of the forest roads) are minimized at the surface unit, thus the benefit is maximized. However, the application of the specific methods displays disadvantages: a) in mountainous regions due to the extreme topographic relief, the extent of the calculated road density is difficult to be accomplished, because the acceptable restrictions in road design on account of the topography are not taken into consideration in the calculations. b) Moreover, when calculating the optimum road density, parameters whose value can be attributed to monetary units are taken into account and as a consequence, a series of other effects cannot be depicted through the relations.

The empirical methods are based on the design of more solutions on the map or the terrain, thus their qualitative assessment is performed and the advantages and disadvantages of the method are become known. The advantages of the method are the following: a) Quantities which are assessed qualitatively and not only in monetary units are taken into consideration. b) Furthermore, combinations of other means of opening up e.g. forest roads-rural roads, forest roads-aerial rope cranes etc. However, the application of the method is costly due to the expenses required for the road design. Furthermore, the results of the application of the method provide limited probative value, because only some of the factors that affect the opening up, such as the construction expenses, maintenance expenses and timber transportation expenses are considered.

Calculation is performed via the method of internal rate (Kroth 1973), and factors are also assessed empirically.

In the following, in representative mountainous forests of the research areas (Figure 2), the opening up-timber harvesting is analyzed. The opening up is investigated on the basis of the optimum road density:

- The theoretical optimum road density (D_{th}) thus when the total expenditure becomes minimum.

- The economical optimum road density (D_{ec}) thus when the construction costs are equal to the skidding costs.

- The maximum road density (D_{max}) thus when the road construction expenses and the loss of territorial revenue are not considered.

The positive impacts created by the construction of roads and not evaluated on money should be co-assessed, such as: a) the protection against fires, b) the development of local and national economy (approach of the exquisitely beautiful forest landscapes, recreational development, approach of agricultural areas, transport of agricultural products, timber supply in the market, transportation improvement through the extension of provincial road network, improvement of the labour markets and creation of new jobs etc.) c) the management of water resources (easy approach to springs, construction of works related to the elimination of torrents), d) the contribution in the defense of the country, e) the contribution in the rangeland science etc.

Figure 2. Research areas

3. Results

A. Pisoderi

With the data of the forest complex in Pisoderi and the processing of information it has been observed that (Figures 3 and 4):

The increment of the forest complex is 6.35 m^3/year/ha.

The harvesting according to the management plan is 2.48 m^3/year/ha, thus only 40 % of added biomass.

The existing road density is: D_{ex} = 26.82 m/ha.

The economical optimum road density is: D_{ec} = 23.83 m/ha.

The theoretical optimum road density is: D_{th} = 17.81 m/ha.

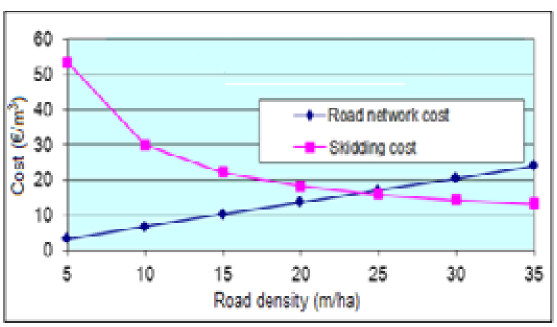
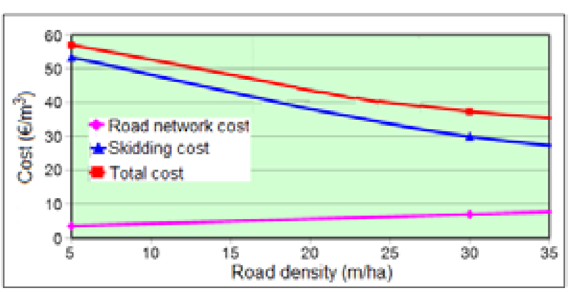


Figure 3. Calculation of the economical optimum road density (section on 23.83 m/ha) with harvesting 2.48 m³/year/ha. (Graphic method of calculating the optimum road density)



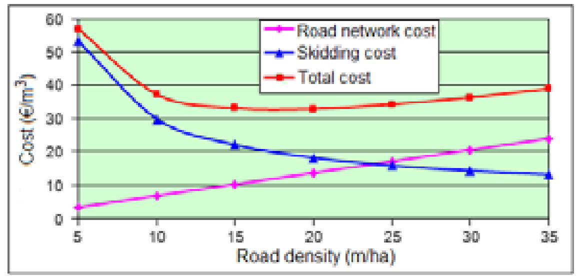


Figure 4. Diagram of calculation of the theoretical optimum road density (minimum in total cost at 17.81 m/ha) with harvesting N = 2.48 m³/year/ha

In future revenues when timber amount received approximates the 3.00 m^3/year/ha, the road density (D) will be formed as following:

Harvesting	2.48m^3/year/ha	3.00m^3/year/ha
D_{ex}	26.82m/ha	26.82m/ha
D_{ec}	23.83m/ha	26.87m/ha
D_{th}	17.81m/ha	19.45m/ha

As a result, the economical optimum road density amounts to 23.83 m/ha and the theoretical optimum one to 17.81 m/ha with harvesting 2.48 m^3/year/ha, whereas for 3 m^3/year/ha, there is a correspondence to 26.87 m/ha και 19.45 m/ha respectively. The existing road density amounts to 26.82 m/ha, which is not sufficient so as opening up percentage greater than 70% - suitable according to Backmund (1996) - is accomplished. The existing road density suffices quantitatively in relation to the theoretical and economical optimum ones, as the means of skidding is the animal load for the time being, but the roads are not correctly space allocated (52.19 % percentage), so as opening up percentage greater than 70% is achieved.

In order to improve the prerequisites for the future inevitable mechanization of works which requires denser road network and better space allocation, the construction of six new forest roads lengthening 13.18 km which are depicted on the forest map is proposed.

As a result, the total road density will rise to 64.33+13.18 km/2410 ha = 31m/ha, a condition which will exceed 15-30% the optimum one and the opening up percentage according to Backmund (1996) is satisfied.

The suggested roads need to be constructed gradually, so as the emerging lack of animals for the skidding and the gradual mechanization of works is covered, as it already happens in all countries of EU.

Both the maximum improvement of reaction time in cases of emergency and the facilitation of the guarding vehicles in the sensitive area through dangers which threaten both the forest ecosystem and the national interests in general are achieved through the construction of the proposed roads.

B. Metsovo

It is a purely mountainous region whose forest displays all the characteristics of a typical mountainous forest in Greece.

Just as previously, the following values have been calculated (Tambekis 2010)

α) D_{ex} = 28.31 m/ha,

β) D_{th} = 12.50 m/ha,

γ) D_{ec} = 13.75 m/ha and

δ) D_{max} = 36.10 m/ha.

It is observed that the existing road density for the constructed forest road network (D_{ex} = 28.31 m/ha) is greater than both the economical optimum road density (D_{ec} = 13.75 m/ha) and the theoretical optimum road density (D_{th} = 12.50 m/ha), but lesser than D_{max}. D_{max} is calculated based on the data regarding:

a) the timber skidding expenses,
b) the annual yield and

c) the annual expenses for the maintenance of the road network

and relates to forest roads and rural roads.

The use of tractors for the skidding (harvesting) has created a tendency of excessive opening up in the region.

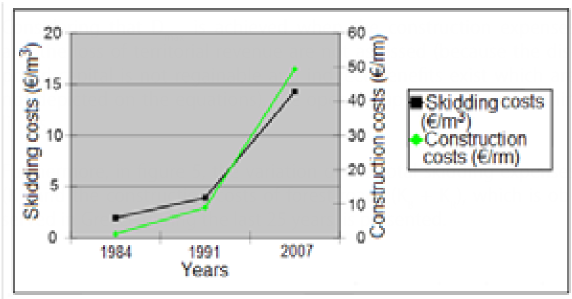


Figure 5. Variation of the total skidding costs and the construction costs of forest roads during the last 25 years.

The total construction expenses of forest roads equals to the loss of territorial revenue (K_B) and the annual annuity of the construction expenses of forest roads (K_R). It is observed that the rate of increase in construction costs is greater than the increase in timber skidding costs, because through the late years the construction cost of forest roads has risen. This rise is not proportionate to the observed increase in the timber skidding expenses (Tambekis 2010). As a result, lesser economically optimal density is accomplished.

Moreover, the excess on the right of the curve, thus from the point of D_{th} to D_{ec} smaller increase in expenses for the skidded timber is observed than on the left of the curve from D_{th}. As a result, the excess is considered as justified. However, with only economic (calculated revenues and costs) criteria, it is excessively opened up.

C. West Nestos

- Road network and existing road density

The basic opening up of the forest complex of West Nestos is accomplished with the construction of road network (rural and forest roads), whose length and existing road density are presented on table 3.

Table 3.
Length of road network and existing road density of the forest complex of West Nestos

Forest office	Length of road network (m)			Total area (ha)	Existing road density (m/ha)
	Rural	Forest	Total		
Drama	254589	554123	808712	48597.92	16.64
K. Neurokopi	45676	158985	204661	18546.01	11.03
Total of forest complex	300265	713108	1013373	67143.93	15.09

- Optimum road density

From the calculations of the optimum road density the following have been observed:

a. The economical optimum road density D_{ec} = 21.90 m/ha
b. The theoretical optimum road density D_{th} = 17.21 m/ha

In figure 6 the graphic method of calculating the economical and theoretical optimum road density is depicted.

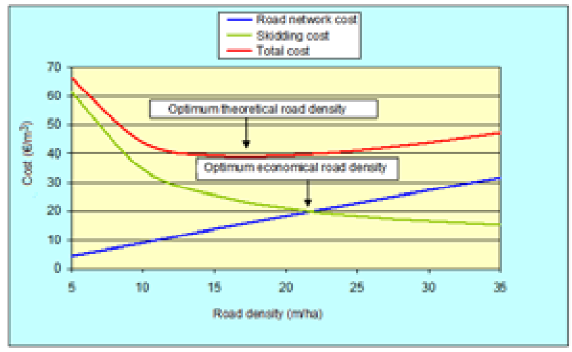


Figure 6. Graphic method of calculating of the economical optimum (21.90 m/ha) and the theoretical optimum road density (17.21 m/ha)

In table 4 D_{max} is calculated, thus the forest and rural roads up to 63.25 m/ha. As a result, roads should be increased up to D_{ec} for the forest roads and D_{max} for the total of roads, rural roads and rope-roads, so as the opening up rate is raised and the mechanization of works is performed.

Table 4.
Maximum theoretical road density D_{max} (when the construction expenses and loss of territorial revenue are not taken into account) in relation to the variation of the maintenance cost of forest roads

Maintenance cost of forest roads (€/m)	Maximum theoretical road density (m/ha)
0.20	89.45
0.40	63.25
0.60	51.64
0.80	44.72

D. Taxiarchis - Vrastama

The existing road density of the university forest in Taxiarchis-Vrastama has been estimated as D_{ex} = 33.10 m/ha. Via the method of amortization, the economical optimum road density has been estimated to be D_{ec} = 23.84 m/ha, whereas the theoretical optimum road density D_{th} = 17.87 m/ha (Figure 7). Based on the above result, it is shown that the existing road density is greater than both the theoretical optimum road density and the economical optimum one.

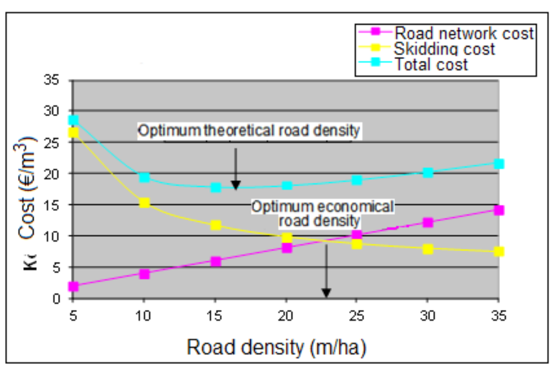


Figure 7. Graphic calculation of the economical (23.84) and the theoretical optimum (17.87) road density

Double opening up in areas (27%) is observed, whereas the single one applies only for 33%. This phenomenon is attributed to provincial and rural roads for the service of fir-fields, having as a result the uneven space allocation. At the same time, the forest protection is serviced, because it lies on a touristic and hot and dry zone in Chalkidiki, vulnerable to fires. Improvement of space allocation for better protection, especially towards the eastern section of the forest of Taxiarchis-Vrastama is required.

4. Conclusions

- The standardization of the opening up of the forest areas is non-feasible, since every forest area is unique and requires special management. The economical-technical opening up of every forest area is accomplished via thorough study of the traffic, soil-climatic, forest-economic and ecological conditions of the region.
- There is a problem of excessive opening up due to uneven space allocation of forest roads in places (Pisoderi) as far as the opening up (road network) is concerned, at productive mountainous forests with economic-technical criteria, thus when the indirect benefits are not considered.
- The emerging mechanization of the projects in the future justifies the excessive opening up, such as e.g. in Metsovo there is an exceedance of the economical optimum opening up of roads and rural roads because of the transportation through mechanized means only.
- In West Nestos region that corresponds to forests of Central Europe (Timber productive with production of 4.2 m^3/year/ha) there is gradual increase in the existing opening up to the economical optimum one for the roads and the D_{max} for the total of roads, rural roads and rope-roads.
- The fire protection is a significant design factor of the opening up in fire-endangered forests, such as the university forest of Taxiarchis-Vrastama. The excessive opening up is justified because of both this reason and the cultivation of fir-fields.
- The opening up requires improvements in space allocations of the roads up to 500 m. road distance, so as the requisite road density is reduced and local excessive opening ups are avoided. As a result, there are better soil protection, working and employment conditions and optimum economic-technical results.
- For the case of Greece, the criterion of harvesting is not efficient by itself, because the indirect ecological forest benefits which preserve "our heavy industry"; the tourism are more significant the direct ones related to timber harvesting. On the contrary, in

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