THE REDUCTION OF THE DESTRUCTIVE ELEMENTS OF FOREST ROAD CONSTRUCTION PROJECTS

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ABSTRACT

The opening up of forests is an important precondition for sustainable forest management. However, forest roads are often blamed for environmental problems. In this paper the optimum road density and the degree of opening-up is calculated by the use of computer programs. It is also found that the increase of the road gradient and the use of overloaded vehicles accelerate the soil erosion. Finally, the stabilization of forest roads by industrial by-products has proved that natural resources are saved up, the bearing capacity is improved and the forest ecosystem is protected.

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ΜΕΙΩΣΗ ΤΩΝ ΚΑΤΑΣΤΡΕΠΤΙΚΩΝ ΕΠΙΔΡΑΣΕΩΝ ΑΠΟ ΤΗΝ ΚΑΤΑΣΚΕΥΗ ΔΡΟΜΩΝ ΣΕ ΔΑΣΙΚΑ ΟΙΚΟΣΥΣΤΗΜΑΤΑ

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ΠΕΡΙΛΗΨΗ

Το οδικό δίκτυο που διανοίγει μία δασική έκταση, είναι προϋπόθεση για την αειφορική διαχείριση των δασικών οικοσυστημάτων, αλλά όταν δεν σχεδιάζεται φιλοπεριβαλλοντικά, ευθύνεται για την υποβάθμιση του περιβάλλοντος .Σε 5 παραγωγικά δάση, με τη βοήθεια Η/Υ υπολογίστηκε η άριστη διάνοιξή και οδική πυκνότητα τους. Για την αποτροπή της εδαφικής διάβρωσης η έρευνα έδειξε ότι απαιτείται μείωση της εγκάρσιας κλίσης και κυκλοφορία μη υπερφορτωμένων και διαξονικών φορτηγών. Τέλος η χρησιμοποίηση ανακυκλωμένων παραπροϊόντων στη σταθεροποίηση των εδαφών ,αυξάνει τη φέρουσα ικανότητά τους ,εξοικονομεί φυσικούς πόρους και προστατεύει το δασικό Οικοσύστημα.

1. INTRODUCTION

The forest ecosystems are dominant ecosystems in our planet and contribute decisively to the protection of the environment. They filtrate the atmosphere from pollutants, minimize the greenhouse effect, improve the water balance and the quality of life, prevent the desertification of land and maintain the biodiversity .All the above make necessary the application of a policy which would protect but also would lead to the sustainability of the forest ecosystems. Today, their protection is done by biological and technical interventions . The technical side is obtained by: a) Mountain Hydronomics projects and b) Forest Road Construction projects including the construction of forest roads and the infrastructure projects for environmental friendly mechanization and harvesting of forest products[1] .

The Forest Road Construction plays an important role to ensure the potentials for a more systematic management, exploitation, and protection of forests. However, on the other hand, a road project without an environmental planning it may lead to degradation of the forest ecosystem. This degradation results from the excessive felling of forest land, the erosion of soil, the over- use of natural resources and the pollution of the atmosphere[2]. Our research for many years has provided results and conclusions which explain that an environmental-friendly design for the opening-up, construction and operation of a road network project may reduce the above negative effects and protect the forest ecosystems. In this paper are presented the results of our research which, after their classification into unities, were handed out to the State in the form of regulations for the protection of this important ecosystem.

2. MATERIALS AND METHODS

Our research was conducted in Grevena, Aridea, Alexandroupoli, Drama, and Thassos which are the most significant Forest Offices of Greece. Because of the intensive exploitation of forests in these forest offices, every year are taking place fellings and construction of forest roads. Also, in these places there are many biotopes as well as protected natural areas which make necessary that every interference should be done with the greatest care. Such areas are Valia-Kalda, the Black Forest, the Virgin Forest and the Delta of Evros.

The research investigates the manners by which a forest is opened-up and estimates the economic optimum density of forest road network ,the degree of forest opening up and the mean distance of wood translocation .Also, it principally investigates the machinery which must be used[3]. During the construction, the research was focused mainly to the restriction of the use of natural resources, the erosion and the pollution. These are carried out by the calculation of the stresses of various vehicles, the determination of distress on the roads by the overloaded trucks, the construction of strong-wearing road surfacing layers with recyclable by-products, the stabilization of slopes, and the construction of drainage works. During the operation of the road network it was investigated the kind of vehicles used for the transportation of products and was studied their behavior on the ground and on the remaining stand.

3. RESULTS AND DISCUSSION

3.1 Opening-up

Because for the construction of one Kilometer forest road is wasted one ha forest land and a woody volume of 70-120 m^3 , it initially requires a specialized personnel to design the forest road network.Also the computer programs have greatly contributed to the right design of opening-up. Computer packages for road design have an important application to the design of new arterial routes and also for the upgrading of both country roads and forest roads for logging traffic [4].

A basic step towards the protection of the environment is the definition of the lower road density and the reduction of clearing and road width to save forestland for production purposes and environmental reasons. We found that the economic optimum road density is 25m/ha and the mean distance of wood translocation is 400-500m.

However, in the first phase of opening-up, a dominant role plays the machinery which will produce the least damage on the ecosystem and on the remaining stand. Field studies on five road construction sites have examined the construction of road by use of hydraulic excavators and advanced rock drilling and blasting techniques. The results of this case study show that the environmentally sensitive techniques applied to the five road projects are superior than road construction by the traditional use of bulldozers on steep slopes. There are short-term economic benefits from the use of bulldozers in forest road construction; however, in the long-term, dozer construction in mountainous terrain is likely to create considerable environmental damage. The scale of damage increases as side slopes increase. The advantages of road construction by means of hydraulic excavator and advanced drilling and blasting techniques are listed below: Subgrade width can be kept to the absolute minimum determined by safety and anticipated use. Excellent control can be applied the placement of excavated material .Excavated material can be separated and temporarily stockpiled by the excavator in anticipation of its best use in building the road. Total construction width is minimized since subgrade width and length of ill slope are minimized. The use of a hydraulic hammer results in less need for blasting. Damage to stands along the road is dramatically reduced. Drainage and erosion control can be installed immediately and function satisfactorily during the entire project. Generally: excavators with well trained operators often proved to be a cheaper and much more environmentally sound alternative than bulldozers on forest road construction work[5].

3.2 Construction

The phase of construction starts out by the calculation of the distress of ground from all sorts of traffic vehicles .The research based on the CESAR-LCPC program showed that the biggest damage of the ground is caused by 3-axle semi-trailer trucks while the damage caused by tractors is 6 times less. It was also found that the size of stress is influenced by the radius and the pressure of vehicles's tires. An increase of 20% of this pressure reduces the price of the contact radius per 9,2% and the vehicle's stress on the ground per 3% [6]. The calculation of stresses leads to the right dimensionism of road surfaces a fact which means that the volume of the required aggregates is precisely set out on one hand and the phenomena of soil erosion are prevented on the other.

The protection by the overuse of the aggregates is also obtained by the creation of surface layers with industrial side-products. There have been used fly ash, red mud and slag which were stabilized with lime and cement. The stabilization of forest roads represents an environmentally friendly process since using materials of nature, which are abundant, they provide the basis for improved road constructions, from the biological, technical and economical points of view. The optimal composition and the long-term behavior of these materials are being investigated based on laboratory and field-test results. The compressive strength results of soil treated with varying percentages of cement with 35% fly ash or 50% red mud, after 7 and 28 days curing, are shown on Table 1.

Considering the soils which have been stabilized with cement, only the loamy soils (SC-CL) from flysch and the sandy clay (SC-CL) from granite show unsatisfactory strength results. For this reason they have been stabilized with lime and slag. Soil stabilization with stabilizers has resulted to decreasing of the plasticity, increasing of the strength and increasing of the angle of internal friction and of true cohesion[7,8,9].

TABLE 1. Compressive strength results of soil treated with 35% fly ash or 50% red mud
with 5%, 7%, 9% cement , after 7 and 28 days.

Soil type	Cement content %	Compressive strength (with 35% fly ash),{ 50% red mud } Mpa					
		7 days			28 days		
1. SC-CL loamy	5	1.6	(1.7)	{1.7}	1.9	(2.2)	{2.3}
	7	2.2	(2.4)	{2.3}	2.4	(2.8)	{2.7}
	9	2.7	(3.0)	{3.0}	3.2	(3.5)	{3.6}
2. GC-CL sandy	5	2.2	(2.4)	{2.6}	2.6	(2.9)	{3.0}
	7	2.5	(2.6)	{2.6}	2.8	(3.0)	{3.1}
	9	3.0	(3.1)	{3.3}	3.4	(3.6)	{3.6}
3.GC-CL sandy	5	2.7	(2.9)	{3.2}	3.1	(3.4)	{3.6}
	7	2.9	(3.1)	{3.3}	3.8	(4.0)	{4.2}
	9	3.3	(3.5)	{4.0}	4.9	(5.1)	{5.0}
4. GC-CL sandy	5	2.0	(2.4)	{2.7}	2.6	(2.9)	{3.3}
	7	2.7	(3.0)	{3.4}	3.6	(4.0)	{4.3}
	9	3.2	(3.5)	{3.8}	4.7	(5.0)	{5.2}
5. SC-CL clay	5	1.4	(1.5)	{1.5}	1.5	(1.6)	{1.8}
	7	1.5	(1.6)	{1.7}	1.6	(1.7)	{1.8}
	9	1.5	(1.6)	{1.7}	1.6	(1.7)	{1.8}
6. SM-ML clay	5	1.3	(1.4)	{1.4}	1.6	(1.7)	{1.7}
	7	1.6	(1.7)	{1.8}	1.77	(1.8)	{1.8}
	9	1.75	(1.8)	{1.9}	1.85	(1.9)	{1.8}

For the strength estimation we have used the “Benkelman beam” in experimental surface with CBR=3, and estimated a deflection D $=580 \cdot 10^{-2}$ mm. After the stabilization with sand-gravel we have found that for the layer thickness 20 cm, the Benkelman beam deflection has been reduced to dm$=528 \cdot 10^{-2}$ mm. For the same layer thickness, but with 50% red mud, we have estimated dm=480 · 10^{-2} mm., while with 7% lime and 30% fly ash the deflection is dm=349 · 10^{-2} mm. For the same sample with 7% cement, we have estimated dm=240 · 10^{-2} mm, while by adding 20% fly ash, we have dm=200 · 10^{-2} mm. Finally, for the same layer thickness with 30% blast furnace slag, we have dm=400 · 10^{-2} mm. For the research purpose was required the calculation of the strength layer coefficients for each sample. It was found that : a=0.1, a=0.11, a=0.14, a=0.2, a=0.21, a=0.12, respectively. We have realized that a layer with cement and fly ash shows a deflection 2.6 times smaller than the same layer of sand-gravel, 1.7 times smaller than a layer with lime and fly ash and 2 times smaller than a layer with blast furnace slag.

However, besides the increase of strength and the economical construction by the use of side-products, we also have a saving of energy but also a restriction of the environment pollution from $C0_2$ and $S0_2$.It is known that Road Construction is responsible for the 7% of the total pollutants of $C0_2$ and $S0_2$ on the planet. Our research has shown that during the use of side-products we must take care to prevent any penetration of heavy metals into the acquifers.

Special care, during road construction, should be given to the cross-gradients, the cross-section grading patterns the drainage works and the stabilization slopes as well. The most effective way to prevent watershed disturbance and increased soil erosion rates is to minimize the total length of roads. It has to be kept in mind that even the best developed drainage system established during the road construction process will only reduce rather than avoid impacts on natural watersheds. Some of the most common drainage-related problems are: inadequately sized stream crossings, culverts; inadequate road surface drainage; poor drainage of skid trails joining roads; lack of road maintenance after logging operations, hauling activities or erosion caused by thunderstorms resulting to improper work of ditches and culverts. Following environmentally sound construction practices, the measures stated below are considered obligatory to provide satisfactory water drainage and consequently to prevent erosion:

- the road fitted as closely as possible to the terrain and to be restricted in width to the absolute minimum for safety and anticipated use;
- soil disturbance and surfaces exposed to erosion are to be minimized by balance of cuts and fills;
- gravel should be applied on the running surface not only for more convenient use by vehicles but also to provide a more weather resistant sealing surface;
- surface water from joining skid trails should be prevented from flowing on to the road
- culvert locations are to be spaced not only at certain distances but are to be installed where are actually needed
- culverts are to be protected from plugging by using sediment catch basins and debris racks
- outlets of culverts are to be armoured with rock boulders to prevent emerging water from eroding the fill slope
- individual drainage facilities are to be inspected periodically for the need of maintenance
- damage to road features should be avoided by effective road-use management which includes access control in general as well as road closure during wet seasons.

- road gradients should be varied to reduce concentrated flow on road surfaces, in ditches, in culverts and on fill slopes;
- ditch gradients should be adjusted to the specific soil condition at the construction site to keep collected waters moving to culverts and preventing sediment deposition and ditch erosion.

Road gradient is the main effect of road surface erosion processes followed by cross-section grading patterns. Using a camber significantly reduces the occurrence of erosion gullies. The relevant effects grow with increasing road gradient. Canopy closure also has a significant influence.
Also we have developed a road deterioration model that quantified the role of road slope. This model shows that when the road gradient increases by 2% to 8% the vulnerability index increases too. This finding agrees quite well with the model configurations " horizontal grading without canopy protection". Also we found that that erosions problems already occurred on gradients over 7 percent. We have the opinion that gradients on forest roads should not generally exceed 12 percent because of drainage and environmental reasons . The maximum gradient could be increased, if an overall evaluation of alternatives demonstrates that this had the least impact. The need for an adequate drainage system in steep terrain was emphasized.

Some of the measures which are usually undertaken to stabilize slopes and to prevent erosion from exposed surfaces, will already be performed in each single work cycle as they are inherent features of proper road construction technique by excavator. In particular, these measures are the following:
A fill slope cover which provides immediate erosion control will be continuously performed during the phase of topsoil removal from the construction area in each single work cycle of the road construction process. Finally, shaped, smoothed, and compacted cuts performed in each single work cycle ensure that the loose material is removed from slope surfaces which would otherwise be exposed to erosion. Inlet and outlet protection structures of culverts as well as retaining walls for slope stabilization will be built up by the excavator using the boulders which have been separated from other excavated materials during construction operations; The fill slope will be revegetated by turf where a grass layer is coveringcovered the soil at the construction site[10].

3.3.Functionality
As concerns the machinery used for environmentally friendly harvesting, we see that excavators are very useful for a wide variety of forest harvesting tasks. Large volumes are moved from the stump to roadside by an environmentally friendly and cost effective loader logging system. However, the mechanization can be friendly with the environment when it incorporatesmodern technology. The use of modern technology makes it possible not only to operate efficiently in the forest but also to live up to the environmental requirements of the future. A walking machine is the next step in this direction. Walking technology enables operation in difficult terrain. On steep slopes, for example, where conventional methods failed or caused expensive damage, this technology can be applied. It is also an environmentally friendly way of operation in thinnings and young stands.The strong points of walking technology in forest applications are**:** Spot contact with ground, no continuous tracks left behind, minimum risk of soil erosion on steep slopes , optimum distribution of ground

pressure, minimum damage on tree roots, high variable ground clearance and good maneuverability in difficult terrain without damaging the ground

Other modern technology method is the use of training simulators to train forest machinery operators at basic and advanced levels. Here, belong the mechanical crane harvester simulator developed by using miniature elements on a one-to-ten scale. Also, the harvester controls, work techniques and ways to maximize the quality of the timber produced.

The last part of research was the one which sets out the kinds of trucks which will transport bigger amounts and charge the soil less. First, we measured that for the same amount of transported wood, 50% of trucks on forest roads are overloaded in a percentage 15-20% over the permitted gross weight. The consequence of this load increase implies the increase of equivalent standard axle load at 18%, the total increase of pavement thickness about 15% and the appearance of surface damages as well as the reduction of duration of road pavement at 16%. This reduction along with the construction of strengthened pavement will automatically increase the construction cost as well as the negative impacts on the forest ecosystem due to the soil erosion and the over-consumption of natural resources (aggregates and energy)[11].

Finally, the research about the distribution of the load on the trucks to obtain maximum load with minimum effect on the truck and on the forest roads showed that in the aggregate surfaced forest roads the damaging effects on the 3-axle, 4-axle, 5-axle tractor semi-trailers trucks, are smaller than is often assumed. The study also shows that 1 m^3 is transported by 0.22 – 0.27 ESAL (2-axles), by 0.11 – 0.17 (3-axle) and by 0.12 – 0.14 (5-axle). Also, it was estimated that 9.7 m^3 are transported from 1 ESAL (3-axle) and 3.7 m^3 from 1 ESAL (2-axle). Four-axle trucks with two tandem axles and five-axle tractor semi-trailers using two single-axle and one trindem, have a very favorable stress distribution on the aggregate pavement. The use of such trucks on forest roads is economically, ecologically, and technically, suitable[12].

4.CONCLUSIONS

In this paper the research results in five of the most productive Forest Offices of Greece, are presented.The research has focused on the replacement of the traditional and without environmental design construction methods of forest roads by new ones which will not degrade the forest ecosystem.To bring the above objective into success we must act towards the following directions:

- Using computer programs for the optimist design of opening – up and pre-harvest road net and skid trial planning.
- Shortening the total length of roads and trails for a lower and sufficient density of roads network (opening up-system).
- Reducing clearing and road width to save forestland for production purposes and environmental reasons.
- Reducing the size of cutting and filling slopes. Revegetation of slopes and re-establishing vegetation on roads and landings that are no longer needed.
- Respecting cultural or religious places or habitats of rare plants and animals.
- Using excavators instead of bulldozers in steep terrain. Advanced drilling and blasting techniques.

- Adequate compaction of the road surface.
- Establishing ditches and a raining system, reducing the maximum road gradient to minimize erosion,
- Improving road maintenance.
- Introducing central deflating and inflating tire pressure systems for trucks and tractors,avoiding the use of overloaded vehicles, and
- Using and stabilizing of forest roads with industrial by-products to recycle industrial wastes and to save natural resources. Recycled building materials and industrial by-products must be environmentally compatimble.

Also, the most effective way to reduce the negative impacts of forest roads on forest ecosystems is to train road planners, supervisors, machinery operators and others in the workforce how to design, construct and maintain environmentally friendly forest roads for the total of country's forests.

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