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DEFINING THE SLOPE STABILITY AREAS OF FOREST ROADS

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Abstract: *Forest roads provide access for people to study, enjoy or contemplate natural ecosystems. The materials that slip or bowl under the fill slope during or after the construction of the forest roads harm the ecosystem very badly. The slipping and the rolling of the materials go on after the construction of forest roads. To hold the harmed areas by the slipping or rolling of the filling materials on the lowest level, the filling area should be stabilized by physical barriers or plantation.*

In this study, the fill slope area and the area effected by the rolling filling material of a forest road that is planned to be constructed by a Forest district has been tried to be modeled.

1. Introduction

Despite the ecological problems they cause, forest roads have an indispensable infrastructure function in sustainable management of forest resources. Forest roads planned and constructed within the forest ecosystem, which is a natural environment, must be planned, projected and constructed carefully. Determination of forest road alignments represents the most important and difficult phase of forest road planning efforts. An erroneous alignment determination that can be done during planning stage can generate technical and economic problems as well as maintenance and environment difficulties in the future (Aricak and Acar, 2005). Forestry agencies have to plan and construct new forest roads which are acceptable to the public and which will give minimum harm to the environment (Heinimann, 1998).

In order to construct 1 km new road in a forest area, 0,6 – 1,0 hectares of forest area is opened directly and 400-3500 trees are cut depending on stand age. As a result of downstream flow of dug material, trees suffer from breaking, injury and damage and harmful pests are attracted. Supporting structure of slopes is broken which causes landslide (OGM, 1984). According to Spellerberg (1998), direct losses occur in habitat during road construction and negative impacts are created on hydrological structure nearby the construction site. Once the construction is completed, microclimate balances of the area are affected.

Use of heavy construction machinery for road construction causes degradation in the soil structure and quality of water resources as well as distortion of the natural scenery and zone loss (Sever, 2000; Hayrinen, 2007). Tunay and Melemez (2004) argued that, once road construction is over, visual distortion results from filling slope exposition along the road and the talus caused by rolling of stones and other materials downstream the road. Öztürk and Ayberk (2005) stated that abundance of digging extracts in forest roads with highly-slopped terrain and disposal to the surrounding of the part of this material which was not used in filling causes considerable damage to the stand.

With this study, areal destruction and the impact range of this destruction caused by road construction will be predicted. Criteria for calculating the forest road filling area and rolling range of filling material have been determined in the study. The objective is that, with the help of this model which is developed from sample area, filling area and the impact range of the material rolling outside the construction zone can be predicted beforehand for future forest roads at the planning stage. If the destruction exceeds acceptable range, alignment can be changed, too. Therefore minimizing negative environmental impact will bring about technical-economic benefits.

2. Material and Method

Forest road with 126 code number with a length of 3+081 km which is located in Kürtün district of Gümüşhane province has been chosen as the study area. Road construction took place between September 2005 and August 2006. Road alignment passes through intra-forest clearance, stands with low closure and intense forest areas with high closure.

Once the forest road construction was completed, measurements shown in Figure 1 were made on cross section with some 20 meters intervals and these data were recorded in the prepared land report. Total number of points measured is 148.

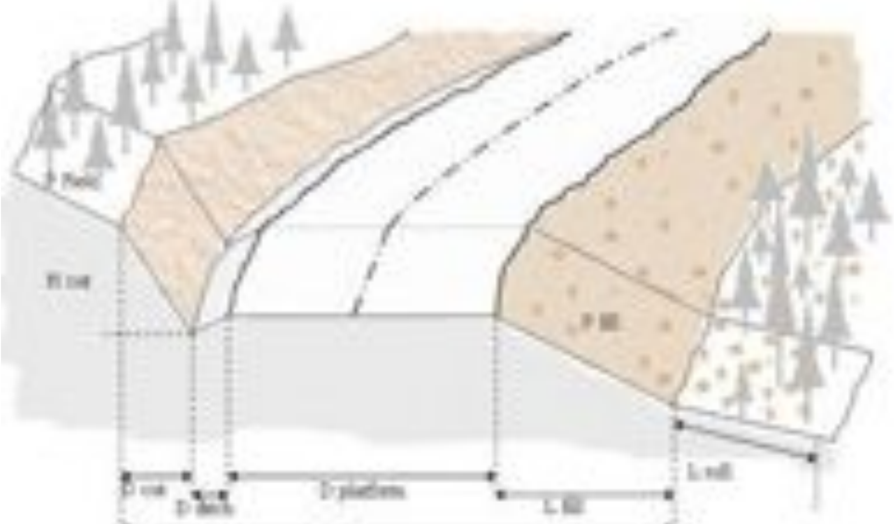

Figure 1. Measurements made on road cross section in the terrain

Land types have been categorized as three different types of land within this study. These categories are (i) areas with no forest cover but forest soil and arable agricultural areas (OT-Z), (ii) highly degraded areas with one closure and thin forest cover (CB-S), and (iii) areas with intense forest cover which have two and more closure (ORM). Stand types in the stand map are also classified according to these three categories.

After the standard topographical maps and stand map of the area were transferred into GIS database, filling range of road alignment and impact range of rolled material were determined depending on the characteristics of terrain cover and terrain features. Based on the data obtained from the terrain, construction zone which was formed during road construction in the zone and rolling range of the filling material have been determined.

Relations of the data obtained through topographic methods from the area have been searched with SPSS software. Regression analysis has been conducted for determination of the regression equations which would help estimating the rolling horizontal distance of filling materials and filling horizontal distance for each terrain type. In order to determine the success level of successful regression equations, 35 control data for land slope figure, filling distance and rolling distance of filling material for each terrain type have been collected. With these collected data, filling distance and rolling range of filling material which were calculated with regression equations formed for each terrain type have been compared based on "matched samples t test" method and success rate of the models have been determined.

Determined filling distance and rolling range of filling materials have been created as buffer zone in ArcMap 9.2 software. Areas which showed the filling distance and rolling range of filling material have been calculated and evaluated. Filling area data calculated based on the data obtained from the terrain and usage of the created regression analysis equation have been compared and results have been discussed.

3. Findings and Discussion

When a forest road is being planned, 10 m digging area and 10 m slope area vertical to the road alignment is accepted as the construction area of the road. The area calculated by taking this buffer zone into consideration constitutes the "estimated construction area" before the road construction. Estimated construction area for the road which is subject to this study was calculated as 60.894,5 m^2.

As a result of statistical analysis conducted using the data obtained from the terrain with topographic methods, the following equation has been found as successful for all terrain types in order to determine the regression equations which would help estimate the filling distance based on the terrain slope variable for each terrain type (OT-Z, CB-S and ORM):

$$y=e\ (b0+b1X)$$
$$(\text{or in linear terms } \ln y = b0+b1x)$$

where y is filling distance (m) and x is terrain slope (%). Equation parameters estimated for each terrain type, coefficient of determination (R^2) figures and p figures for these parameters are given in Table 1.

Table 1. Filling distance equation R^2 and chart of coefficients

FD	R^2	b_0	b_1	p
Y_{OT-Z}	0,805	1,655	2,123	0,000
Y_{CB-S}	0,898	1,421	2,384	0,000
Y_{ORM}	0,726	1,046	2,434	0,000

FD: Filling Distance

In addition, according to the results of the Regression Analysis conducted for determination of the regression equations which would help estimate the rolling distance of filling material using terrain slope variable, the following exponential equation has been found successful:

$$y=e\ (b0+b1X)$$
$$\text{(or in linear terms } \ln y = b0+b1x)$$

where y is filling material rolling range and x is terrain slope (%). Coefficient of determination (R^2) figures and p figures for each terrain type are given in Table 2.

Table 2. Chart for rolling range equation R^2 and its coefficients

RR	R^2	b_0	b_1	p
Y_{OT-Z}	0,879	1,885	2,429	0,000
Y_{CB-S}	0,912	1,708	2,546	0,000
Y_{ORM}	0,841	1,249	2,776	0,000

RR: Rolling Range

Equations which provide the filling distance and rolling range of filling material of a road alignment depending on the obtained equation and coefficients are shown in Table 3.

Table 3. Equations which will be used in estimation of filling distance and rolling range

Land Types	Filling Distance	Rolling Range
OT-Z	$\ln Y_{OTZ}=1{,}655+2{,}123x$ ($R^2=0{,}805$)	$\ln Y_{OTZ}=1{,}885+2{,}429x$ ($R^2=0{,}879$)
CB-S	$\ln Y_{CB-S}=1{,}421+2{,}384x$ ($R^2=0{,}898$)	$\ln Y_{CB-S}=1{,}708+2{,}546x$ ($R^2=0{,}912$)
ORM	$\ln Y_{ORM}=1{,}046+2{,}434x$ ($R^2=0{,}726$)	$\ln Y_{ORM}=1{,}249+2{,}776x$ ($R^2=0{,}841$)

With the help of the control data collected independently from the data used in generating regression model, regression models related to the filling and rolling ranges for each terrain type have been compared based on “matched samples t test”. As a result of such comparison, all models were found as valid for independent control data group as well, which means that no statistically significant difference have been detected at 95% reliability level between the estimated figures obtained with these models and the real figures obtained as a result of terrain studies.

In Table 4, construction site calculated with the data obtained from the terrain, estimated construction site which was accepted as 20 m, and construction site calculated with the developed model were provided as well as the deviation rates compared to real construction site.

Table 4. Real, estimated and determined-with-the-model construction sites and deviation rates

	Construction Sites (m^2)	Deviation rates compared to real construction site. (%)
construction site calculated with the data obtained from the terrain	75.127,5	-
estimated construction site which was accepted as 20 m	60.894,5	-18,95
construction site calculated with the developed model	69.528,8	-7,45

According to Table 4, it has been determined that estimated construction site which was accepted as 20 m was 18,95% smaller than the real construction site, and the construction site calculated with the developed model was 7,45% smaller than the real construction site.

In Table 5, the inventory of rolling range of filling material calculated with the help of developed model and rolling range of the filling material calculated with obtained data as well as deviation rate of real filling material according to the rolling range are given.

Table 5. (i) Areas affected by rolling of real filling material and rolling material determined with model, and (ii) deviation rates thereof

Hesaplanan Dolgu Materyalinin Yuvarlanarak Etki Ettiği Alanlar	Area (m^2)	Deviation rate of real filling material according to the rolling range are given. (%)
Rolling range of the filling material calculated with obtained data	95.236,2	-
The inventory of rolling range of filling material calculated with the help of developed model	102.661,2	+7,80

According to Table 5, it has been found out that the construction site calculated with developed model is 7,80% larger than the real construction site.

4. Conclusions

With the help of the developed model, it is now possible to know beforehand depending on the terrain class and slope figure of the terrain the road platform area which constitutes the construction site of a forest road that will be constructed in a forest area and the area which will be affected by the rolling of filling material.

For three different terrain categories that have been determined (OT-Z, CB-S, ORM), regression equations which will help estimate the filling distance of forest road and rolling range of filling material by using terrain slope variable have been determined. As a result of the comparison, it has been found out that all models are valid for independent control data group, too. Using these regression equations, a base table (Table 6) has been prepared which gives the filling distance and rolling impact range of filling material for each 10% terrain slope figure.

Table 6. Filling distance and impact range of filling material according to slope figures of terrain categories

	OT-Z		CB-S		ORM	
Terrain Slope (%)	Filling Distance (m)	impact range of filling material (m)	Filling Distance (m)	impact range of filling material (m)	Filling Distance (m)	impact range of filling material (m)
1	5,35	6,75	4,24	5,66	2,92	3,59
10	6,47	8,40	5,26	7,12	3,63	4,60
20	8,00	10,71	6,67	9,18	4,63	6,08
30	9,89	13,65	8,47	11,84	5,91	8,02
40	12,23	17,40	10,75	15,28	7,54	10,58
50	15,13	22,19	13,64	19,71	9,61	13,97
60	18,71	28,29	17,31	25,42	12,26	18,44
70	23,13	36,06	21,97	32,79	15,64	24,34
80	28,60	45,98	27,89	42,30	19,95	32,13
90	35,36	58,62	35,40	54,57	25,45	42,41
100	43,73	74,74	44,93	70,39	32,46	55,98

According to Table 6, as terrain slope increases, so does filling distance and rolling range of filling material in all terrain categories. For any terrain slope, the filling distance in OT-Z areas which have no forest cover is more than the one in CB-S and ORM areas which have forest cover. As closure of forest cover increases, filling distance decreases proportionally at the same terrain slope figure. For this reason, filling distance in CB-S areas is longer than the one in ORM areas. Rolling range of filling material in OT-Z areas is larger than the one in CB-S and ORM areas which have forest cover. In areas with identical terrain slope value rolling range of filling material decreases as closure of forest cover increases, for which reason rolling range of filling material in CB-S areas is larger than the one in ORM areas. This case indicates that, as closure of forest cover increases, filling distance and rolling range of filling materials decrease as trees keep filling material.

Using this research methodology, a method has been developed for estimating the rolling range of filling material and filling distance without going to the field and depending on the characteristics of the area where road will be constructed. With this method, it has been ensured that construction sites of forest roads which will be constructed in the future and the areas from which construction will be affected can be identified in advance. Hereby, choosing the alignment alternative which is most suitable for the environment can be ensured. Physical measures can also be taken in the necessary locations so that forest road construction causes minimum destruction and impact to the terrain.

In the light of evaluated data, planning criteria have been presented taking into consideration the topographic and stand characteristics of the road where forest road alignment is located. With this method, identifying in advance the filling and construction impact area in determination of the route of forest road provides some technical and environmental advantages; in addition, in the short or long run, economic road planning can also be realized (Arıcak, 2008).

Forest road construction efforts have several negative impacts on the environment. Keeping these negativities at minimum level is a requirement of modern and environmentally-conscious forest management. For this reason, when planning forest road networks and alignments, it is essential that the area which will be destroyed is determined beforehand and kept at its minimum level.

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