1st International Symposium of

Forest Engineering and Technologies

FETEC 2016

"Forest Harvesting and Roading in Environmentally Sensitive Areas"

SYMPOSIUM PROCEEDINGS

2-4 June 2016
Bursa-Turkey

Bursa Technical University
Faculty of Forestry
16330 Bursa, Turkey

fetec2016@btu.edu.tr
http://fetec2016.btu.edu.tr

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Bursa Technical University
Faculty of Forestry
16330 Bursa, Turkey

Tel: +90 (224) 3003426
Fax: +90 (224) 3003429
E-mail: fetec2016@btu.edu.tr
http://fetec2016.btu.edu.tr

INTRODUCTION

An environmentally sensitive area (ESA) can be defined as a sensitive site which needs special protection, strategies, and implementations because of its natural features, ecological functions, wildlife, aesthetic or historical value. ESAs include, but are not limited to, native forests, high quality successional forests, national parks, essential wetlands, riparian areas, water bodies, important watersheds, karst features, wildlife reserves, world heritage areas, sensitive sites with significant natural and cultural values, and areas of high visual value.

The resources management activities can be undertaken in ESAs by considering specific guidelines; however, the principal value is conservation, including the protection of biodiversity, ecosystems, and habitats. On the other hand, designated forestry activities have to be carried out in a manner that protects the identified conservation values in ESAs.

"1st International Symposium of Forest Engineering and Technologies (FETEC 2016): Forest Harvesting and Roading in Environmentally Sensitive Areas" has been organized on 02-04 June 2016 at Bursa Technical University, Faculty of Forestry in the city of Bursa, which is located in such a region that is very rich in terms of forest products, forest resources, and environmentally sensitive areas in particular. The symposium co-organizers included IUFRO Division 3.01.00 and FETEC Platform. V. Forest Enginering and Technologies Workshop will be held during the symposium.

The aim of the symposium was to discuss the most recent scientific researches and professional works related to forest harvesting and roading activities taken place in environmentally sensitive areas with attendance of relevant shareholders, practitioners and international researchers from various regions of the world.

On behalf of the entire organizing committee, I would like to thank all the participants of the symposium and express my best wishes to those who contributed during the preparation and organization stages of the symposium.

Prof.Dr. Abdullah E. AKAY
Symposium Chairman

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ORAL PRESENTATION

POSSIBILITY OF EFFICIENT FOREST MANAGEMENT AND UTILIZATION BY SCM-MODELING CONCEPT AND SUBJECT

Toshio NITAMI
University of Tokyo, Tokyo, JAPAN
nitami@fr.a.u-tokyo.ac.jp

ABSTRACT

The SCM, supply chain management, is commonly used at industrial product manufacturing. Their producing processes and material feedings are finely controlled through the huge fixed system. On the other hand, forest is the huge manufacturing plant itself to produce woods which continues production restlessly, and woods themselves are not uniform and homogenous material. Furthermore, their production processes are also not able to be standardized due to uneven terrain and ground conditions and the complicate operation procedures under natural environments. Here, SCM application is discussed for forest management and utilization. Time axial expansion is required for the long period growing to be the product by itself, and the space axial expansion is also required for the vast area of stands where face much diversity of environment's.

Key words: SCM, management, utilization, time, space

1. INTRODUCTION

It comes common to use the idea and utility of SCM (Supply Chain Management) in many industrial fields. We have scarcely usage in the forestry sector, in spite that in the wood industry and paper industry.

It may mainly because that forestry is processes under the natural environment not easy to manage their conduction definitely and because that which deals long life tree vegetation whose grow stage and matureness are vague. It is advancing to adapt ICT to forestry activities and pushing the harvesting, production and sales management to systemize. This expects SCM-based method applicate to forestry processes.

It is convincing that we are getting involved much with highly mechanized high performance forest operations and which leads to require more efficient and proper for the regional conditions. SCM can be expected to play such functions balancing these two subjects.

2. SCM APPLICATION AND SUBJECT FOR FORESTRY PROCESS

Sales and transportation from forest logging site to market and sawmill factory of log, processed timber, have been systemized as a distribution process of management industry. The upstream part of the timber supply can be divided into two sections, the former is growing standing tree in forest stands applying adequate silvicultural treatments and the latter is tree felling, harvesting and wood processing to logs.

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The former is management for long life living staff and there is no definite time critics besides the necessity for treat management for growing stages, such as pre-commercial thinning for younger and thick stands and tree density control thinning, and finally mature stands are to be clear felled, but each treatment have no definitely scheduled execute time in order to process for a product. These treatments have a certain allowance of execution and can be enough to be conducted in the system with fuzziness.

And also the latter has vagueness for operation system by machine and labor complex under various natural condition. Even if we alter the sequence of operation in a system it may work and achieve to provide same product, and multi process would be merged to a single process when a machine was introduced.

3. EXPANSION OF SCM FOR FORESTRY BUSINESS

SCM for ordinal industry usually models the processes bounded to time definitely, but our agricultural field founded by livestock production requires process modeling considering vegetation growth. So called Sixth industrialization has been promoted in Japan for years which comes from pushing harmonious combination of the first, the second and the third industry, aiming that regional first industry would be active through the regionally integrated natural industry connected chain. It is very initiative to see close the business result and the effect of the operation. The integrated database of the sixth industry can be viewed from the first industry stand point for the row material production, viewed from the second industry stand point for the processing and viewed from the third industry point for the construction (Figure 1) (Yotsukura, 2009).

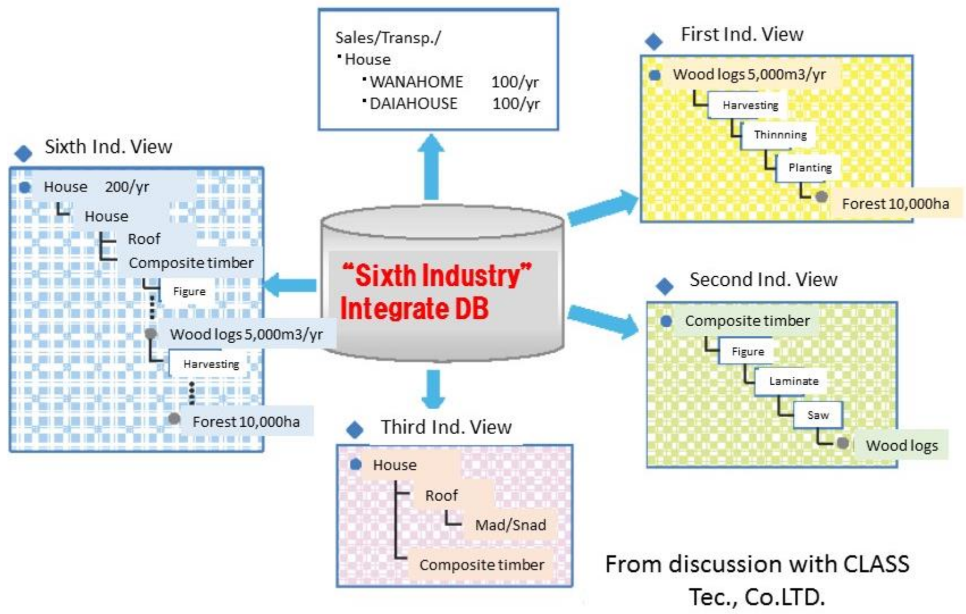

Figure 1. Modeling of expanded SCM for forestry, considering "Sixth Industry"

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Forest management plan requires regional forestry to consider time series of treatment processes. Usually there are no consideration for special optimization on location of harvesting sites. A timber harvesting undertaking would be initialized by a planner staff of a regional forestry enterprise by focusing on a certain size of forest which may promote business area integration, often up to 30ha, but scarcely consider stand volume and quality in numerical way (Figure 2). One can say it is too much to understand and evaluate by a human.

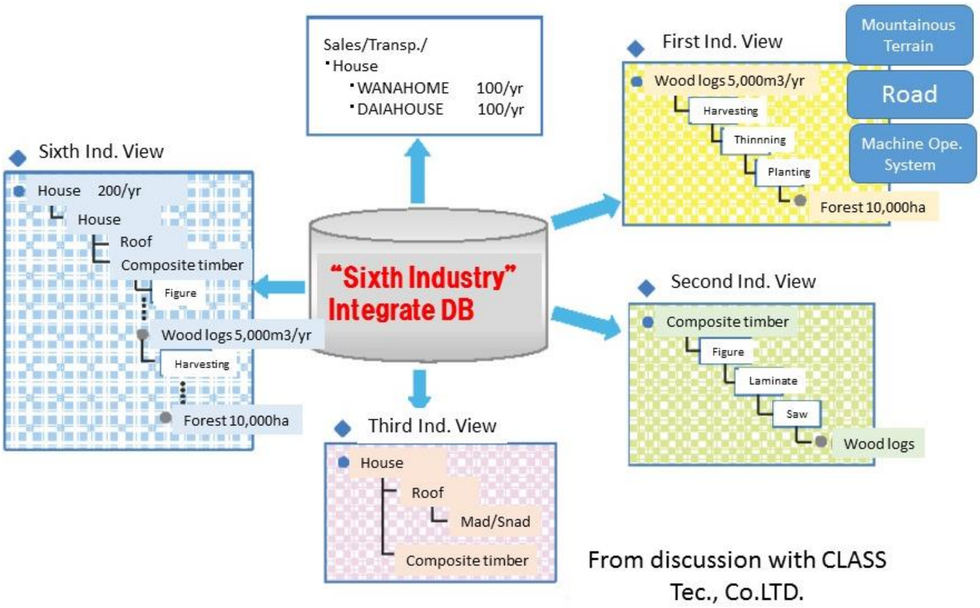

Figure 2. Modeling relationship considering forestry circumstances

Bivalent harmonization between special and horal conditions for forestry and wood harvesting and silviculture are inevitable under natural condition, such as mountainous terrain, by human techniques, such as road equipping and machine operation system (Figure 3).

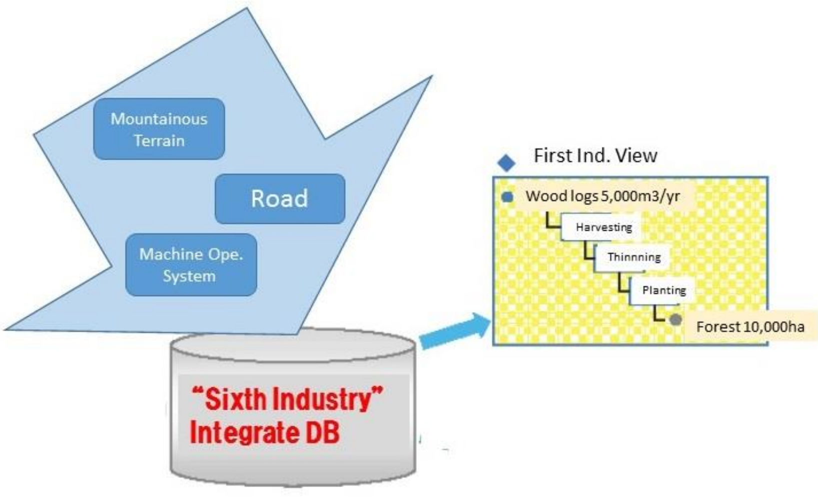

Figure 3. Requirement for DB management considering forestry activities.

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A system for forest resource management and timber production is undertaking as a tool for business integration, promotion and evaluation on a web cloud style as a service, Figure 4, 5, and expanding function for forestry engineering chain management.

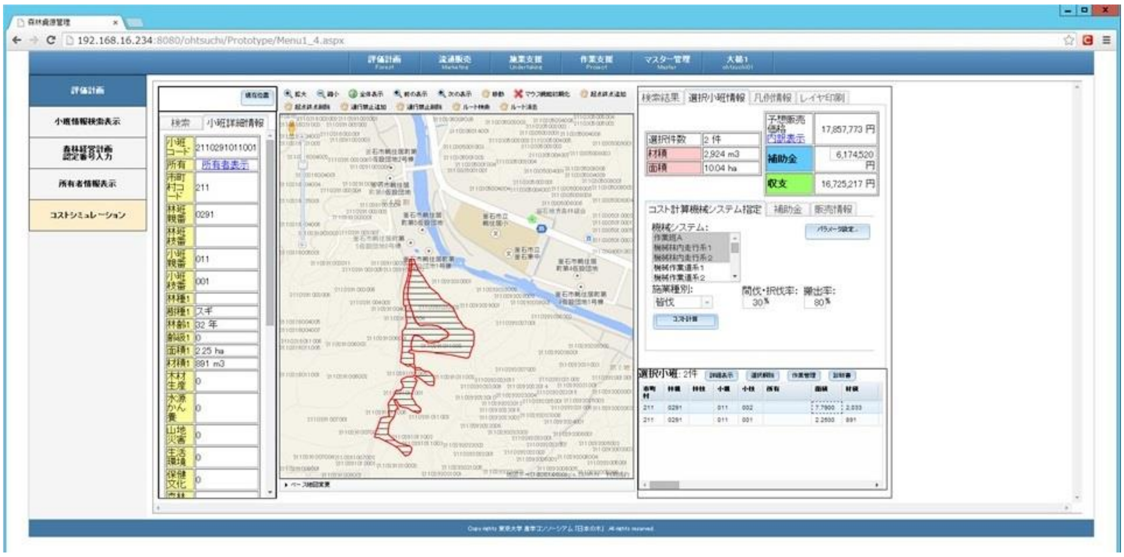

Figure 4. User interface page of Forest and Forestry Management System

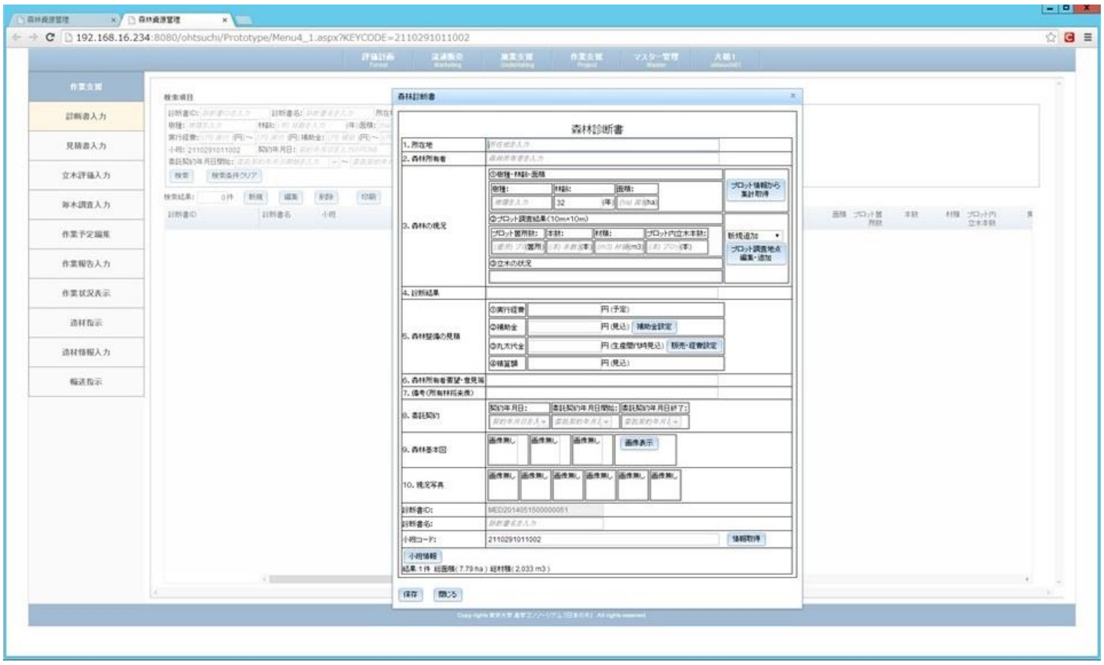

Figure 5. Proposal to forest owner by a simulation result of harvesting business.

4. CONCLUSION

Information utilization for forest management is useful and getting inevitable when consider the scale of space and time. Getting operation data and share them with conjuncts is efficient for promote the business. Connecting parts of a forestry business through ICT offers smart forestry which integrates whole forestry activities and pull in the timber market into the forest domain as a market-in business instead of product-out business.

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A laser based forest stand measuring system is operating (Figure 6, 7) and expecting efficient forest stand survey. And it also enables accurate grasp of not only tree volume but also the location and shape. And it founds flexible forestry managing system with accurate stand information.

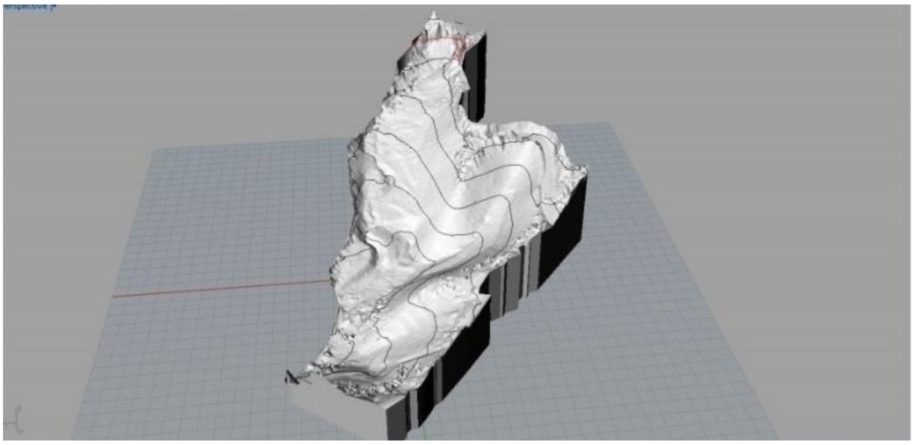

Figure 6. Easy and precise mountainous terrain understanding at sites

Figure 7. Digitalized forest stand view – useful for Virtual Reality treatments

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INFRASTRUCTURE LAYOUT AT FOREST ECOSYSTEMS MANAGEMENT

Selcuk GUMUS

Karadeniz Technical University, Faculty of Forestry, Forest Engineering Department, 61080 Trabzon, Turkey Tel: +90 462 3772861 Fax: +90 462 3772861 E-mail: sgumus@ktu.edu.tr

ABSTRACT

Forest land access is primarily provided by forest roads in the conditions of Turkey. Road infrastructures are one of the most important factors at adequate planning and managing of forest ecosystems. The stages of evaluating and determining the adequacy of forest roads, although very important, are usually ignored at ecosystem planning studies in the current applications. The planning of the forest road network has been individually done by considering general planning approaches such as road amount, road interval, and some technical limitation, somehow distinct from other ecosystem planning activities, according to the Turkey official legislation. The forest road networks are planned in accordance with the Principles of Road Communique No: 202, which was first published by General Directorate of Forestry in 1984. Today, it continues with the Communique No: 292 renewed in 2008 according to the changing conditions and approaches. At the current planning applications, the amount of road has definitely been restricted. It was stated that the total of road construction area could not exceed %1 of the total forest area (20 m/ha). Turkey is located on a large geography where generally business shapes the structure of the. Therefore, it should not be any absolute and general restriction. It is known that Austria, with similar characteristics with the conditions of Turkey, has higher road density value (45 m/ha) than the limit specified for forested areas in Turkey. This study was aimed to discuss the restriction of the road density of Turkish forests. The forest road network planning should be made as a part of strategical scale harvest planning. By this way, forest structure and functions, topographical features, soil properties, wildlife ecology, transport systems and road needs can be taken into account in determining road density.

Key words: Forest Infrastructure, Forest Road, Road Density, Infrastructure Layout, Forest Ecosystems Management.

1. INTRODUCTION

Forests are the one of the common renewable natural sources widespread in the Earth. Forests offer many services besides the wood that is the used wide range of human life. Sustainable management of forest ecosystems are depend on well balanced protection and usage policy. The forest harmless utilization can be realized with the appreciate infrastructure layout. Roads is the most important forest infrastructure. The forest road network consist of access and secondary hillside roads segments for serving appropriately every kind of forestry service and transportation of each type of product obtained from forest communities.

Roads, in particular, are physical manifestations of the social connections and the economic and political decisions that lead to land use change. Their existence depends on social structures, and their physical characteristics depend partly on landscape structure. Ecological

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road network theory, which is comprised of basic principles of land use, transportation, network theory and ecology, provides a framework to interpret the ecological effects of road networks (Coffin, 2007).

Traditionally, road analysis has been narrowly focused both geographically and ecologically. Roads can be analyzed as ecosystems using environmental gradient analysis to distinguish between road segments in different sectors of the landscape or across latitudes and elevation. (Lugo and Gucinski, 2000) (Figure 1).

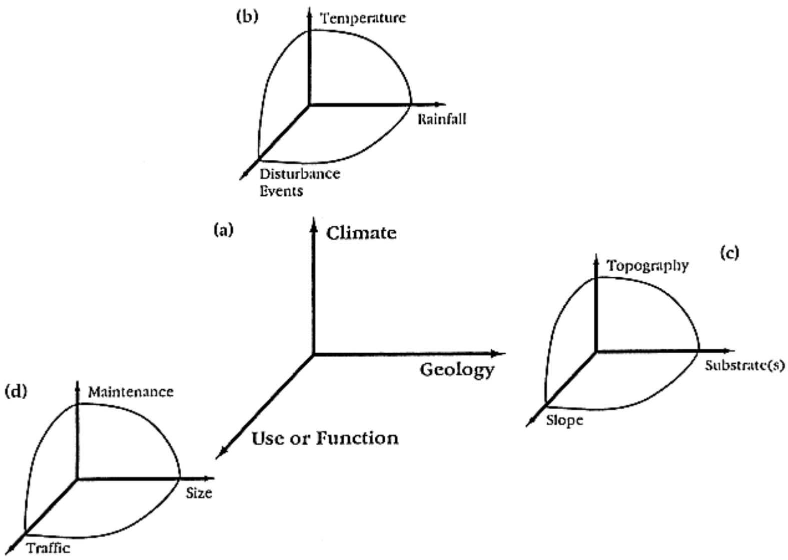

Figure 1. Axes of the parameters that define the ecological space or the environmental gradients within which roads function. The main gradients are shown in (a) and each (climate, geology, and use/function) are further subdivided into component factors in (b), (c), and (d), respectively. (Lugo and Gucinski, 2000)

Many authors consider that fragmentation of habitats by roads may be the most important of the ecological effects of roads and their traffic. The direct and indirect influences of roads on ecological processes vary widely from plant community to landscape level. On a large scale, these influences are multiplied by the density of road networks and mainly result in landscape pattern change in the road effect zone. Road development is a primary cause of habitat fragmentation, as construction removes original land cover, thus creating edge habitat. (Liu, et al., 2008; Spellerberg, 1998). Fragmentation included road density, housing density, lake perimeter, lake area, and grassland, coniferous forest, and barren area. Deciduous forest, wetland, public land area, and percent volume of poor subgrade soils were negatively correlated with fragmentation (Hawbaker, et al. 2005).

Subjects such as roadkills and local erosion are familiar, whereas traffic noise effects, subdivided populations, and interrupted or enhanced horizontal ecological flows are real frontiers (Forman, 1998). There was an indication that roads in the direct surroundings of a reproduction site (250 m) affect the population size negatively. This is in accordance with the expected extra mortality on roads (Vos and Chardon, 1998).

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Effects are evident for faunal movement, population fragmentation, human access, hydrology, aquatic ecosystems, and fire patterns. A road density of approx. 6 m/ha appears to be the maximum for a naturally functioning landscape containing sustained populations of large predators, such as wolves and mountain lions (Felis concolor). Moose (Alces), bear (Ursus) (brown, black, and grizzly), and certain other populations also decrease with increasing road density. These species are differentially sensitive to the roadkill, road-avoidance, and human access dimensions of road density. Species that move along, rather than across, roads presumably are benefitted by higher road density (Forman and Alexander, 1998).

Dutch policy has focused on the open roadside vegetation, road-kills, animal movement patterns, and nature restoration. US transportation policy largely ignores biodiversity loss, habitat fragmentation, disruption of horizontal natural processes, natural stream and wetland hydrology, stream water chemistry and reduction of fish populations, a range of ecological issues highlighted in the transportation community in 1997. The Netherlands and Australia are world leaders with different approaches in road ecology. In The Netherlands, the density of main roads alone is 15 m/ha, with traffic density of generally between 10,000 and 50,000 vehicles per commuter day. Australia has nearly 900,000 km of roads for 18 million people. In the United States, 6.2 million km of public roads are used by 200 million vehicles. Ten percent of the road length is in national forests, and one percent is interstate highways. The road density is 12 m/ha, and Americans drive their cars for about 1 h/day. Road density is increasing slowly, while vehicle kilometers (miles) traveled is growing rapidly (Forman and Alexander, 1998).

Road construction causes a destruction on forest ecosystems. Road removal creates a short-term disturbance which may temporarily increase sediment loss. However, long-term monitoring and initial research have shown that road removal reduces chronic erosion and the risk of landslides (Figure 2) (Switalski et al. 2004). For this; forest road amount is as important as its layout in forest area.

Figure 2. Forest acces road and forwarder usage to extraction of woods (Phillips, et al. 2004)

Road network should be carefully design as well as calculate road amount. There is a relation between road density and space. Figure 3 shows the relation parabola (Picman, and Pentek, 1998). Road density decreases cause increases on road interval space.

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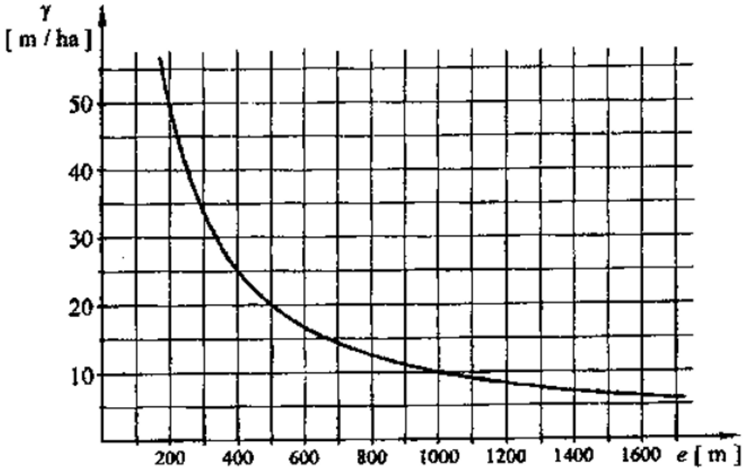

Figure 3. Road density and spare relation

Because it is very difficult digitalize the environment and ecosystem factors, road density calculations are made according to total transportation cost taking into environmental considerations. Total cost does not significantly change for slight deviations away from the optimum density (Figure 4). It is therefore acceptable to deviate away from optimum values by up to 15% (Phillips et al. 2004).

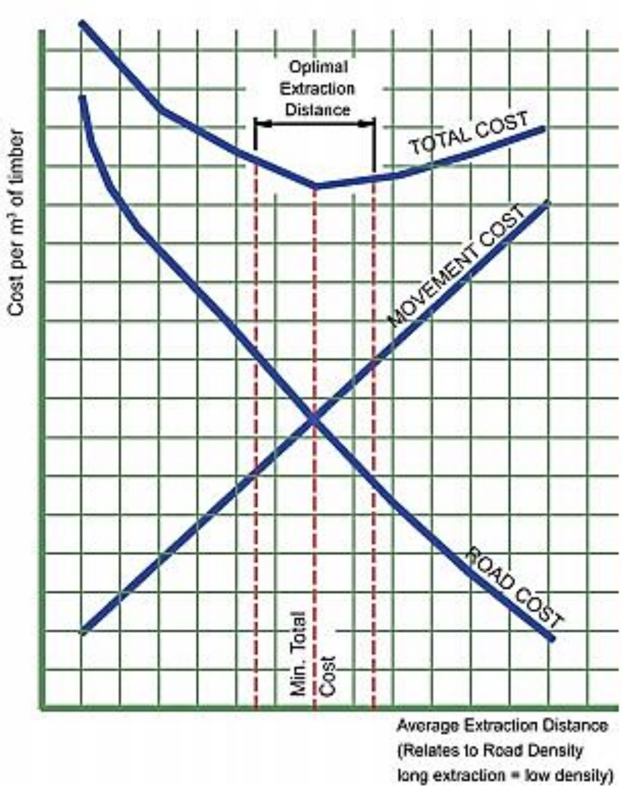

Figure 4. The cost effects of road density (Phillips, et al. 2004).

It is assumed that the effective factors in costs can be determined by using the mathematical models, as well as by the help of graphical model, less costs of skidding and road construction can be obtained; therefore, optimal road density can be evaluated. Harvesting methods, different types of roads, the ratio of each road to the whole network, stand per hectare, slope, geological conditions, presence of sand mine for constructing surface of roads, capital interest rate, wood extraction costs, type of skidding or yarding machinery, routes, type and number of load, allowable winching distance, brush and underbrush, condition of the roots, silvicultural methods (cutting form), regional soil, regional height, direction of the slope and morphology of the forest are factors which have been mentioned in this research as affecting determination of roads network density (Lotfalian et al., 2008).

Although those common knowledge worldwide there are different forest road density value between countries. Each country has forest road length according to their social, economic and ecosystems sensitivities. In Turkey, at the current planning process, that form the basis of Road Communique-No:292, the amount of road has definitely been restricted. It is stated that the total of road construction area could not exceed %1 of the total forest area (20 m/ha).

This study was aimed for discussing the restriction of road density in Turkish forests. The common literature investigated and evaluated for Turkish Forest roads planning process. Google Earth was used understanding some relations between different road networks, forest lands and topographical features.

2. RESULTS AND DISCUSSION

Road density studies can be grouped in two aspects one of ecosystem effectives and the other wood transportation economics. There are many approach for determining optimal road density and the evaluation of the ecosystem effects such as fragmentation and wildlife harmful.

A study have been made for Middle Atlantic Coastal Forest, data ranges used to determine ordinal ranking for each selected fragmentation metric given Table 1. Road density determined a range of 2.8 to 64.18 m/ha in this report (Heilman et. al, 2002).

Table 1. Road density values according to the fragmentation metric.

Fragmentation metric	Ordinal score data range				
	1	2	3	4	5
Road density (km/km^2)	3.583 – 6.418	2.318 – 3.582	1.740 – 2.317	1.301 – 1.739	0.208 – 1.300
Class area (ha)	153 – 5099	5099 – 11855	11855 – 22977	22977 – 42416	42416 – 77981
Percentage of landscape	7.37 – 31.66	31.67 – 46.41	46.42 – 58.78	58.79 – 71.51	71.52 – 92.78
Total core area index (%)	7.13 – 31.13	31.14 – 43.93	43.94 – 54.08	54.09 – 64.28	64.29 – 86.66
Mean nearest neighbor (m)	145.57 – 285.55	89.46 – 145.56	63.00 – 89.45	45.76 – 62.99	30.00 – 45.75

The best range for road density was 0-8 m/ha and included the majority of the ecoregion. In comparison, conservation planners in charge of the eastern red wolf (Canis rufus) recovery effort, which is centered in and around the Alligator River National Wildlife Refuge could be concerned about the impact of roads on recovery efforts. Although there has been some variability based reports an approximate road density threshold of 5 m/ha for long-term persistence of wolves on species and geographic location, the scientific literature (Heilman et. al, 2002)

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The road density threshold described by other studies applies most directly to areas not adjacent to large reservoirs of occupied wolf range, and that relatively small areas of high road densities can sustain wolves so long as suitable roadless reservoirs are nearby (Mech, 1989). According to Lyon 1983, habitat effectiveness for elk at road densities up 37.27 m/ha (Lyon, 1983). At Nested Ecological Units in Northern Great Lakes Region, USA, road density ranged from 1.6 to 20.7 m/ha that highest densities were in the Keweenaw Peninsula (an area with relatively low population) (Saunders, et al. 2002).

In a study, the cable systems analyzed for optimal road spacing in Austria. The roading, yarding and installation cost per cubic meter were computed for different yarding distances and graphed as a function of road spacing. The minimum total cost and ORS were 42.88 Euro/m^3 and 261 m, respectively for one-way yarding. For two-way yarding, the minimum estimated total cost, ORS and optimal road density would be 38.48 Euro/m^3, 373 m and 26.8 m/ha, respectively. The results showed increasing harvested volume decreases ORS and that increased roading cost increases ORS. (Ghaffariyan et al., 2010). Generally, under Austrian conditions road spacing varies from 200 m to 400 m depending on steepness, forest ownership and available skidding equipment. The mean road density is 45 m/ha in commercial forests and 9 m/ha in protection forests including effective public roads (Sedlak, 1996).

Under European conditions road densities for ground skidding are about 25 m of road per hectare of forest. Expressed in terms of the volume of timber extracted, this corresponds to an effective density of roughly 100 m of road per 1000 m^3 of extracted roundwood. In a mixed broad-leaved tropical forest under conditions typical of West Africa, where harvest volumes average about 10 m^3 per hectare, an effective density of 100 m of road per 1000 m^3 of extracted roundwood would imply only 1 m of road per hectare of forest. This is many times lower than actual road densities commonly encountered in tropical forests, suggesting that effective road densities may be higher in some tropical forests than in temperate forests in industrialized countries (Dykstra and Heinrich, 1996). The optimal density for forest road network in low-lying stands was calculated on the terrain according to minimum total cost model and found 14.71 m/ha in Croatia. The mean extraction distance (ds) would decrease to 170 m (Picman and Pentek, 1998). Phillips and friends studied on optimum road density according to road construction and timber extraction costs for Irish forests. They developed a matrix for road density (Table 2) (Phillips, et al. 2004).

It can be seen that the road density varies from 13.61 m/ha to 22.59 m/ha. Demir 2007 was examined the road density and space in some European countries. It was observed that every country has adopted implementations differing according to that country’s geography and social conditions (Demir, 2007). In Korea, optimal road densities were calculated from 7.7 to 29 m/ha according to stands volume per ha for skidders (Lotfalian et al., 2008). A study have been made in Iran Hyrcanian zone, optimum road density was 3-5 m/ha for forwarders according to minimizing sum of skidding and roading costs (Rafiei et al., 2009). Any other study made for evaluation of performance road density calculated as 10.6 m/ha in Iran (Amiri et al., 2012).

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Table 2. Matrix for road density vs timber movement cost and road construction cost

	Optimum Road Density (m/ha)								
Timber Move. Cost (€/m³/100m)	Road Construction Cost (€/m)								
	24.00	25.25	26.50	27.75	29.00	30.25	31.50	32.75	34.00
0.80	15.97	15.61	15.27	14.95	14.65	14.37	14.10	13.85	13.61
0.88	16.75	16.37	16.01	15.68	15.37	15.07	14.79	14.53	14.28
0.96	17.50	17.10	16.73	16.38	16.05	15.74	15.45	15.17	14.91
1.04	18.21	17.80	17.41	17.05	16.71	16.38	16.08	15.79	15.52
1.12	18.90	18.47	18.07	17.69	17.34	17.00	16.69	16.39	16.11
1.20	19.56	19.12	18.70	18.31	17.94	17.60	17.27	16.96	16.67
1.28	20.20	19.74	19.31	18.91	18.53	18.18	17.84	17.52	17.22
1.36	20.82	20.35	19.91	19.49	19.10	18.74	18.39	18.06	17.75
1.44	21.43	20.94	20.48	20.06	19.66	19.28	18.92	18.58	18.26
1.52	22.01	21.51	21.05	20.61	20.20	19.81	19.44	19.09	18.76
1.60	22.59	22.07	21.59	21.14	20.72	20.32	19.95	19.59	19.25

Heinimann developed a normalized cost model as a function of road density and slope gradient for skidder and yarder-based extraction systems. Above 42% the model prefers cable-based extraction systems, extraction is limited to road densities approximately below 25 m/ha because of limited line length. Difference between total cost of skidder and cable based extraction at optimal road spacing at 30% slope, and 60% slope respectively (Heinimann, 1998). A necessary condition for minimum cost is that variable yarding costs equal road costs (Peters, 1978).

The average animal power (sulkies) skidding distance was measured to be 71 m while average skidding production was estimated to be 1.21 m³/man-hour. An optimal road spacing which minimizes the overall total costs was found to be 137 m. at forest plantations in Tanzania (Abeli and Magomu, 1993). A Japanese study was reported from 5 to 50 m/ha road density of total forest road system according to terrain gradients and logging systems (Table 3).

Table 3. Standard Forest Road Density Suggested (Kato, 1967).

Terrain	Type of Logging	Standard Density
Class I Even	Type I Truck hauling type	30-50
Class II Hilly	Type II Tractor hauling type	20-30
Class III	Type ill Medium distance	10-20
Class IV very	Type IV Long distance	5-15

The planning of forest road networks were start according to the principles of Road Communique-No:202 that were first published General Directorate of Forestry in 1984. Today, it continues with the of Road Communique-No: 292 renewed in 2008 according to the changing conditions and approaches. The planning of the forest road network studies have being individually made considering general planning approaches such as road amount, road interval and some technical limitation, somehow distinct from other ecosystem planning activities, according to the Turkey official legislation.

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At the current planning codes the amount of road has definitely been restricted. It is stated that the total of road construction area could not exceed %1 of the total forest area (20 m/ha). In this code, the harmfully effects of forest road constructions were described, but there is not any approach to optimizing of the road density. High forest road density and existing road network can be ecologically affect the spatial structure of forest functioning patches, compartments, and also forest stands, in the long run. (Eker and Coban, 2010). These cases wanted to collaborate for development the knowledge the susceptibility of environmental damage in forestland, and the importance of planning the wood harvesting and timber hauling and the proposition of measures were want minimize the this harms, and perhaps develop the wood harvesting practical code considering the environmental weakness associated with economical aspects (Corrêa and Bognola, 2010).

3. CONCLUSIONS

It concluded that the road density values varies from county to continents according to its effects on forest access relating with transportation techniques and costs components as well as ecosystems priorities. Generally, road density is optimized by total cost minimization studies. This studies are based on skidding, forwarding, yarding and road construction costs. Selection one of these logging systems depends on the general terrain slope. Terrain slope is also an important effect on road construction costs and ecological aspects.

The forest road network planning should be made a part of strategical scale harvest planning. By this way, forest structure and functions topographical features, soil properties, wildlife ecology, transport systems and road needs should be taking into account and road density can be optimized for sustainable forest ecosystem management.

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EFFECTS OF COMPACTION IN LOGGING ROADS ON SOME TOPSOIL PROPERTIES IN A FORESTED CATCHMENT[1]

Ceyhun GÖL*, Ender BUĞDAY, Semih EDİŞ, İlker ERCANLI

Çankırı Karatekin University, Forest Faculty, Depart of Forest Engineering, Çankırı, Turkey.
Tel: +90 376 2122757 Fax: +90 376 2136983 E-mail: drceyhungol@gmail.com*

ABSTRACT

Many studies have been conducted on the ecological and hydrological effects of different types of terrain use in catchments. However, there have been few studies on the effects of forestry activities and especially logging roads on catchment hydrology. Forest roads are very important in terms of providing access to forestry products and to satify human needs. However, building forest roads or roads adjoining forests can have certain ecological and hydrological effects. This study aims to present the hydrological effects of forest roads in the Gökçay Catchment, located in the southern slopes of Ilgaz Mountain. Geographic Information Systems/Remote Sensing (GIS/RS) techniques were used to identify the road network of the catchment, and sampling spots were determined from roads with different soil characteristics. Catchment roads were classified into Transport Roads (TR), Tractor Logging Roads (TLR), Human/Animal Power Logging Roads (HAPLR), and Asphalt Roads (AR). The road density of all the roads in the catchment was 2.5 km km^{-2}, and the ratio of road surface to total catchment area was 2%. The highest level of compaction was measured in TLR soil (0-10 cm) with 6.50 MPa, and the lowest level of compaction was measured in HAPLR soil with 0.25 MPa. The highest level of topsoil bulk density (1.87 gr cm^{-3}) and the lowest level of topsoil hydraulic conductivity (0.69 cm hr^{-1}) were measured in TLR soil. In natural forest soil, compaction varied between 0.1 MPa as the lowest and 2.64 MPa as the highest, bulk density was 0.95 gr cm^{-3}, and hydraulic conductivity was 35.49 cm hr^{-1}. Infiltration values were 0 cm hr^{-1} in TLR soil and 7.21 cm hr^{-1} in natural forest soil. There were statistically significant differences between the compaction values of different roads. Forest roads, in general, were observed to have poor hydrological characteristics, and low levels of hydraulic conductivity. Particularly during heavy or prolonged rainfall, surface runoff on the roads is a distinct possibility. Controlled transfer of this water to the catchment drainage system is very important for catchment hydrology, and to control floods and overflows.

Keywords: Forest harvesting, forest road, soil penetration, catchment

1. INTRODUCTION

Forestry production consists of three distinct stages: felling and preparation (harvesting), initial transportation (skidding or extraction), and main transportation (transportation over regular roads) (Öztürk, 2009). In Turkey, forest roads are classified on the basis of the amount of wood to be transported in a year, and the purpose of construction (GDF, 1984). Criteria used in the design and planning of forest roads are the technology to be used, stand characteristics, terrain conditions (geology, hydrology, etc.), cost, and ownership status

[1] Note: This paper has been partly presented in Symposium on Precision Forestry in Forest Operations (Turkey)

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(Erdaş, 1987). Many factors play a role in the construction of forest roads. The constructor plays a significant role in the prioritization of these factors. When the practice is examined, stand characteristics and cost appear to be most important factors. According to Tan (1992), the most important factor in the construction of forest roads is the transportation of forestry products at low costs. Ecological and hydrological factors are usually not prioritized in forest road construction.

Road density refers to the ratio of road length to a given area, and road spacing refers to the direct distance between the roads in a forest road network. For Turkey, the ideal road density was calculated as 20 km/ha, and the ideal road spacing as 500m (Erdaş, 1987). Ideal road density and road spacing values for a multi-functional forestry approach have not yet been established. Road density and road spacing values need to be re-calculated on the basis of functional characteristics of forests. Besides operation and economic concerns, ecological and hydrological criteria should also be seriously taken into consideration. Especially in catchments where water production takes place, road design and road planning should be part of catchment-wide planning.

In the historical development of forestry production activities in Turkey, there is a tendency towards a heavier use of machine power instead of human and animal power. However, in extraction works, human and animal power is still widely used, due to rural employment conditions and topographical features. Environmental concerns, on the other hand, usually take a backseat in logging activities. Transportation for logging in Turkey is historically done using human and animal power (Acar, 2004). Extraction is done using primitive methods 95% of the time, which lowers the quality and amount of transported wood, damages saplings and trees in the vicinity of the work area, requires heavy manual work, and sometimes results in fatal work accidents. Thus, there is an acute need to improve methods used during extraction, which is an important stage in forestry production (Erdaş, 1987; Acar and Eroğlu, 2003).

Many studies have been conducted on the ecological and economic impacts of forestry production. These studies can be grouped into those focusing on forest soil (Bettinger and Kellogg, 1993; Smidt and Blinn, 1995; Marshall, 2000; Pinard et al., 2000; Makineci et al., 2007), residual trees (Froehlich et al., 1981; Krzic et al., 2003), young trees (Rushton et al., 2003; Eroğlu et al., 2007) and the products transported (Eroğlu, 2007). One conclusion that clearly emerges from these studies is that forestry production has many negative consequences. On the other hand, forestry production is a must in order to meet the needs of human societies. Thus, forestry production activities should strive to develop and adopt methods with minimal harm to the ecosystem, to the products, and to human health, in other words methods that are economically efficient as well as environmentally sustainable.

This study comparatively examines the effects of human-power based, animal-power based, and machine-power based techniques used in the extraction stage of wood production in Turkey, on the topsoil compaction and hydrophysical characteristics of soil. The study aims to measure the impact of forestry production activities in Gökçay Catchment on catchment hydrology.

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2. MATERIAL AND METHOD

2.1. Study Area

Gökdere Catchment, the site of this study, is located within the Ilgaz district of Çankırı province, in the Middle Kızılırmak section of the Central Anatolia region of Turkey. Gökdere Catchment, which is 20 km northeast of the district and on the southern slopes of Ilgaz Mountain, is situated between the latitudes 40º 59´-41º 04´ North, and longitudes 33º 42´-33º 51´ East (Figure 1) (Göl et al., 2010; Göl et al., 2011).

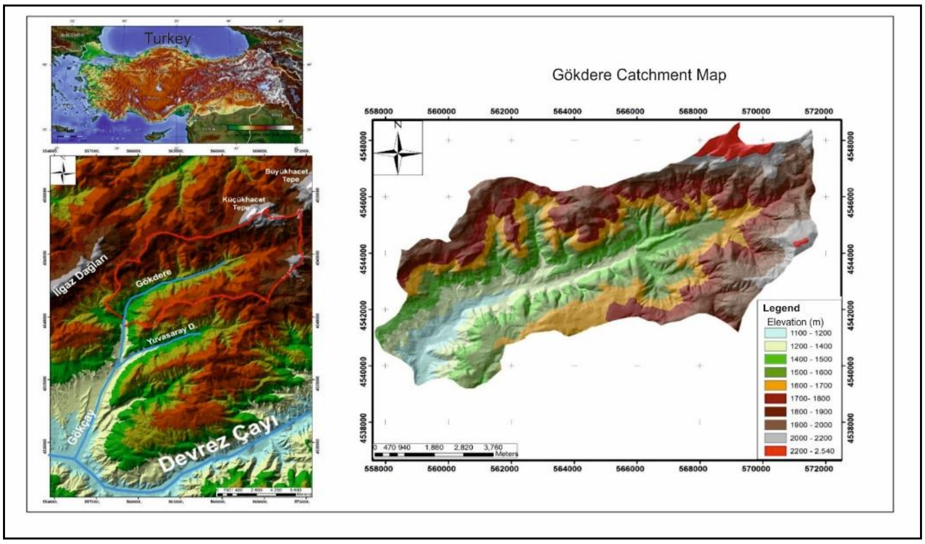

Figure 1. Location and DEM map of Gökdere catchment

The average annual temperature at the site of the study is 10.2°C, and annual rainfall is 484 mm. The climate of the site is described as 'arid-subhumid, mesothermal, with medium levels of surplus water during winter, and close to the effects of maritime climate.' The catchment is located on the transition zone between the humid climate of the Black Sea region and the continental climate of the Central Anatolian region (Göl et al., 2011).

The geology of the catchment contains schists, phyllites, marble, limestone, sandy limestone, and limestone clay. There are Brown Forest Soil (M), Colluvial soil (C) and Alluvial soil (A) in the catchment. Soils in the catchment are classified as entisol and inceptisol (Göl et al., 2011).

Coniferous trees that are dominant in the region are *Pinus nigra* Arnold (Black pine), *Pinus sylvestris* L. (Scots pine), and *Abies bornmülleriana* Mattf. (Uludağ fir). These species form pure and mixed stands in the catchment (Öner, 2001). The dominant tree in the site of the study is Scots pine. In addition, juniper species *Juniperus communis subsp. Nana* L. (Common juniper) and *Juniperus oxycedrus* L. (Prickly juniper) are also seen in the region, in small numbers and in a dispersed manner (Anonymous, 2006). 76.6% of the catchment is covered by forests, 12.7% by forest gaps, and 10.8% is used as residential and agricultural land.

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The total area of the catchment is 6798.7 ha and the average slope is 38%; about 70% of the catchment is covered by very steep slopes, mean elevation is 1702m, max. catchment point is 2545m , min. catchment point 1090m. There are a total of 223 streams, with drainage density of 0.76 The mainstream slope, calculated using Benson's method is 4.6% The drainage pattern of the catchment is dendritic.

Transportation roads, logging roads and other roads in the catchment have a total length of 263 km. In terms of their usage and construction characteristics, unpaved forest road makes up 129.1 km of these roads (Surface area= 0,71 km^2 = 71 hectares), unpaved village transportation road through or adjoining forests makes up 23.0 km (Surface area= 0,184 km^2 =18 hectares), and paved village transportation road makes up 14.1 km (Surface area= 0,141 km^2 = 14 hectares). Skid trails, on the other hand, which are not shown on the maps and used temporarily during logging, have a total length of 96.5 km (Surface area= 0.197 km^2 = 19.7 hectares). The total surface area of all the roads built in the catchment by clearing forest is 123 hectares. Road density in the catchment is 2.5 km/km^2. The ratio of total surface area of the roads to total catchment area is 123 ha/6798.7 ha = 0.02 = 2% (Figure 2).

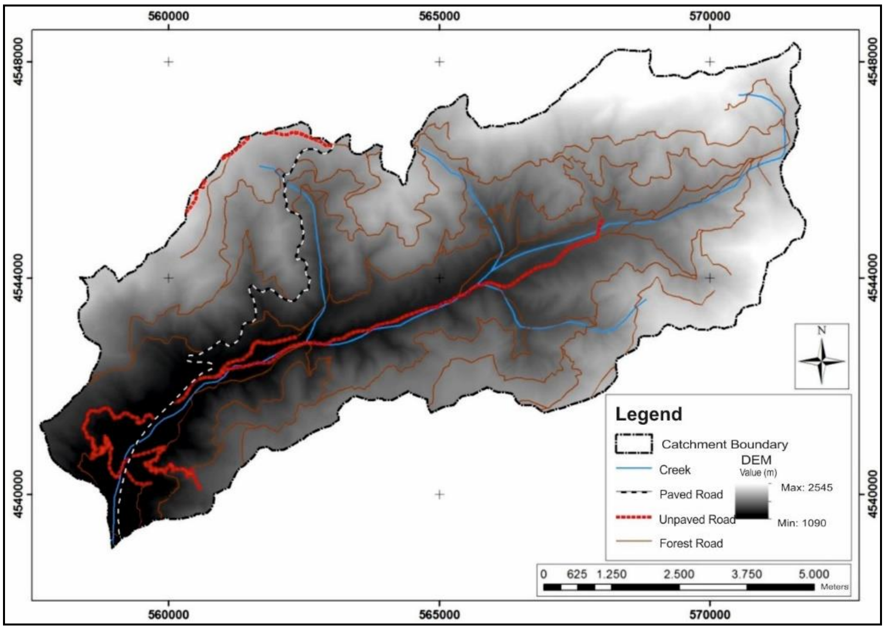

Figure 2. Gökdere catchment DEM and current forest roads network

2.2. Method

Using the Digital Elevation Model (DEM) (Figure 1), climate, a topographical map, a geological map, and aerial photography data were collected. To examine the road system of the catchment, forest stand map, topographical map, aerial photos and ground measurements were used. Geographic Information Systems/Remote Sensing (GIS/RS) techniques were used to identify the road network of the catchment, and sampling spots for ground measurements were selected from roads with different characteristics. In addition, coordinates of the roads not found on the maps but actively used were identified using a GPS device, and added to the maps. Catchment roads used in forestry production were classified as Transport Roads (TR), Tractor Logging Roads (TLR), Human/Animal Power Logging Roads (HAPLR), and Asphalt Roads (AR).

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Transect sampling was conducted over transect lines (perpendicular to the road) on sampling spots, selected from different roads with similar physiographic, soil, vegetation and other characteristics. Soil samples were taken and compaction measurements were made along 30 transect lines each spaced three meters apart. Samples were taken from the side slopes, tire tracks and mid-road, and compaction measurements were made for the topsoil (0-5 cm) and subsoil (5-10 cm). In addition, for comparison purposes, samples were taken from non-disturbed soils in forest (15-20 m from the side slope of road) on the roadside, along each transect. Compaction measurements were made using a 30˚ manual cone penetrometer.

To identify the general soil properties of the sampling spots in the catchment, soil pits (10m away from the road) were dug for each road type. From these soil pits, disturbed and undisturbed cylindrical soil samples (400 cm^3 and 100 cm^3) were taken, one from each horizon (Özyuvacı, 1976).

Texture (Bouyoucous, 1951), field capacity, permanent wilting point and available water capasity (Cassel and Nielsen, 1986), pH (U.S. Salinity Laboratory Staff, 1954), EC and salinity (Rhoades, 1996), lime($CaCO_3$) (Richard and Donald, 1996), soil organic matter (Nelson and Sommers, 1996), and bulk density (Blake and Hartge, 1986) analyses were conducted on the soil samples collected.

3. RESULTS and DISCUSSION

3.1. Soil Properties

The solum depth of the forest soils of the catchment was observed to vary between 30 - 50 cm. Measurements conducted at the study area showed that the soils were shallow. Texture classes were identified as SCL (Sandy clay loam), CL (Clay loam) and L (Loam). Sand content varied between 30-51%. The highest field capacity was measured in A_h horizon of soils, with 45.31%, and the lowest field capacity in C_v horizon of soils, with 15.98%. The highest soil bulk density was 1.17 gr cm^{-3} at 0-10 cm depth, and 1.33 gr.cm^{-3} at 10-20 cm depth. The fact that soil at 10-20 cm depth has a higher level of bulk density can be explained with compaction, lower levels of organic matter content, and lower levels of root and soil fauna activity. Aggregate stability of soils varied between 24.51% and 72.37%. The average of aggregates stability in topsoil (0-10 cm depth) was 64.93%. Infiltration rate of the soil samples varied between 7.21-10.94 cm.h^{-1}, infiltration rate at the end of 20 minutes was 2.11 cm h^{-1}, and final infiltration was 1.98 cm h^{-1} Hydraulic conductivity (percolation) varied between 13.01-22.91 cm h^{-1}.

pH of the soils was defined to be moderately acidic. In general, the soil samples did not have a problem with salinity. Lime content of the soil samples was low (0.52-0.82%). Organic matter made up 0.69% to 16.81% of the samples. Topsoil samples were rich or very rich in terms of their organic matter content. Total nitrogen amounts varied in proportion to the amount of organic matter.

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3.2. Effects of Forest Roads and Harvesting Activities on Soil

The skidding of the logs on the forest ground causes soil compaction, which according to (Greacen and Sands, 1980) lowers soil porosity on the forest ground, and affects water infiltration, soil moisture, soil aeration, and root volume. Landsberg (2003) found that trail depth on the forest ground following skidding varies between 15 and 25 cm, and the average soil density is 500kP and above. According to Vidrine et al. (1999) following a thinning harvest, 11% of the harvest area was disturbed, bulk density was increased by up to 21%, and 70% of the harvest trail was covered by logging slash (Acar and Ünver, 2004). Soil compaction is a physical factor that prevents plant growth. Studies conducted show that soil compaction above 80 kPa prevents root development in plants (Bowen and Coble, 1967; Okursoy, 2000). Godwin (1990) found that, although there is some variation between plants, shear strength values of 0.9-1.5 MPa usually hinder root development.

It was found that roads built inside or in the vicinity of forests have different effects on the physical and chemical characteristics of the soil. Road construction and forestry activities did not have a great impact on soil texture classes. Organic matter content of the roads varied significantly, with the highest levels (2.55%) observed in HAPLR soil, and lowest levels (0.52%) observed in TR soil. Critical moisture tension levels varied significantly by road type, and the lowest beneficial water levels (4.67%) were observed in TR soil. Bulk density values were higher in all road types compared with natural forest soil, and the highest value (1.98 $gr.cm^3$) was observed in TR soil. Highest levels of topsoil compaction were observed in TR soil, with a compaction value of 14.0MPa.

In terms of catchment hydrology, it was found that roads have the biggest impact on infiltration rate, hydraulic conductivity, bulk density, and aggregate stability characteristics of the soil. The stability of the aggregates and the pores between them affects the movement and storage of water, aeration, erosion, biological activity. Soil samples taken from the forest roads had poor hydro-physical characteristics. In TR soil and TLR soil, infiltration values were measured as 0 cm h^{-1}, which indicates that during rainfall, these roads would be impermeable. During heavy rainfall, in particular, there is a distinct possibility of surface run-off on these roads. Considering the total surface area covered by roads in the catchment, and the total impermeable surface area this creates, it should be expected that very high volumes of water would be transferred to the catchment drainage system.

Different compaction values were observed, depending upon the type of production activity, frequency of road use, type of transport, and pavement status. Rural area transport roads (TR), in particular, have very high levels of compaction (12.36-14.01MPa). In the HAPLR roads, compaction values were close to the compaction values of natural forest soil. Compaction values were found to be higher in those sections where log skidding takes place. In TLR roads, which were built for forestry production purposes and usually used for tractor transportation, soil compaction values varied between 4.86-9.24 MPa. When average values of soil compaction at different soil depths were compared, it was found that 5-10 cm depths of the TR and TLR roads had higher levels of compaction. Average compaction values were highest under the tire-track sections of the TR and TLR roads (Figure 3).

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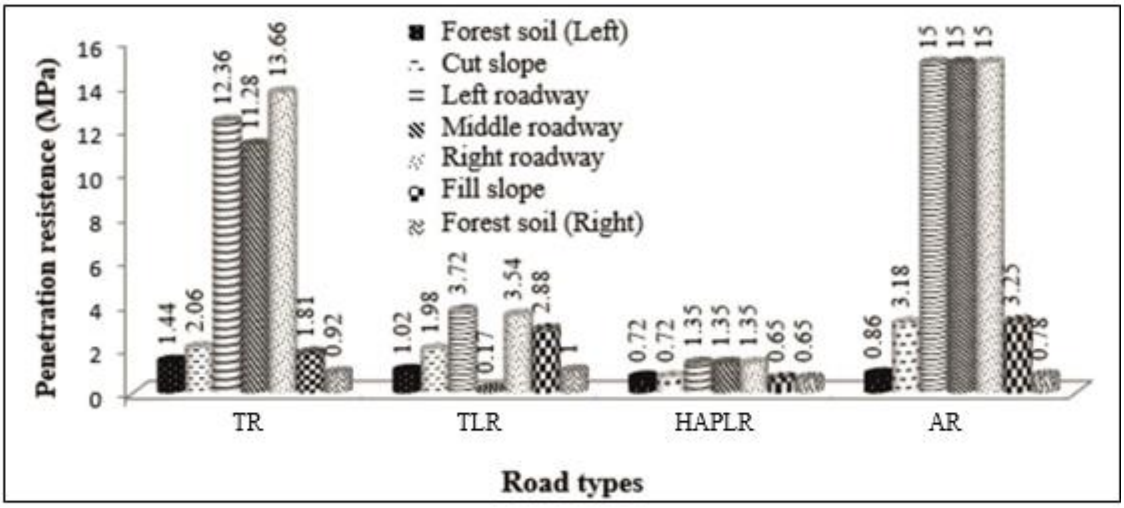

Figure 3. Penetration values according to road types

Statistics concerning the compaction values of different road types, built inside and in the vicinity of forests, are reported below.

Statistically significant differences were found between the compaction values measured along transect lines on different road types. The difference between the compaction values of natural forest soil on the one hand, and compaction values of all types of road soil on the other, is statistically significant (F: 30.603, $p<0.05$). When compaction values along tire tracks and skid trails were compared, statistically significant differences were found between HAPLR soil and TLR soil, as well as between TR soil and TLR soil (F: 3100.186, $p<0.05$).

Statistically significant differences were found between the compaction values measured along transect lines on different road types. The difference between the compaction values of natural forest soil on the one hand, and compaction values of all types of road soil on the other, is statistically significant (F: 27.455, $p<0.05$). When compaction values along tire tracks and skid trails were compared, statistically significant differences were found between HAPLR soil and TLR soil, as well as between TR soil and TLR soil (F: 2641.193, $p<0.05$).

3.3. Catchment Hydrology and Forestry Activities

Forest roads, built with different purposes, have multiple effects on the environment. These effects can be ecological, hydrological, or recreational. Roads also have detrimental effects in terms of erosion, surface runoff, amount of groundwater, and water quality. Soil compaction decreases infiltration, and thus leads to an increase in surface runoff. Surface runoff damages road surfaces, and lowers the quality of stream water with the sediments it carries. During heavy rainfall, it can cause erosion, landslides, and at high altitudes even avalanches. Surface runoff is faster on road surfaces and roadside slopes, and the water is transferred to streams faster. Road construction increases the risk of landslides (Görcelioğlu, 2004). Road construction collects and strengthens the otherwise dispersed movement of runoff water down the slopes. Riparian zones can be damaged by road construction and logging activities. In regions with steep gradients, cutting slopes interrupt both surface runoff and shallow underground runoff. Materials from erosion on road surfaces and roadside ditches, and from collapses in cutting slopes increase the volume of sediment carried to stream beds

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(Görcelioğlu, 2004). In catchments where water production takes place, and in forests with a hydrological function, protecting the hydrological structure should be the first priority in road construction.

Roadside ditches are a part of the surface drainage system, and increase the water drainage capacity of the drainage system to the river. In the past, felling and transportation (production, harvest) methods were based on very intense road networks. Horel (1996) argued that in catchments, surface area of permanent forest roads and landing sites together should not exceed 5% of the total surface area of the forest cover. This ratio is suitable for extraction via suspended cables and helicopters. In addition, this ratio can help minimize the effects of roads on hydrology and sediment transport. For forests that have a hydrological function, a road density threshold value of 2.0 km km^{-2} is recommended (Kartaloğlu, 2011). In Turkey, the total length of forest roads is 125 000 km. For a 4-meter wide road built in a steep mountainous region, 20 m^2 of forest area is destroyed. Multiplying this number with the total length of forest roads, it could be argued that 250 000 ha of forest area are destroyed for road construction. In a study conducted in Artvin, it was found that the construction of a 2 km road in a terrain with 60% slope by using a dozer resulted in the destruction of 3.8 ha of forest area. In ecological and hydrological terms, this area can no longer be classified as natural forest, and has direct effects on the hydrological characteristics of its catchment. Forest roads are also highly vulnerable to erosion because they are sloped, unpaved, and lack vegetation.

Further studies and efforts are needed to develop more effective methods for the protection of natural hydrologic regimes. The first priority should be protection and the development of measures to mitigate the damage done by forest roads to hydrologic structure. In addition, failure to keep proper maintenance results in the deterioration of the drainage system of the roads, and causes floods and overflows. Extra sediment load carried from the roads causes blockages in the catchment’s stream system and exacerbates floods and overflows (Görecelioğlu, 2004).

The most commonly used routes for forest road construction in Turkey are those tracing ridges and riverbeds. Roads built along riverbeds, in particular, have detrimental effects on catchment hydrology and aquatic system. These include the narrowing of the riverbed, failure to build sufficient drainage infrastructure in river crossings, large amounts of sediment carried to water, and floods and overflows due to blockages. Roads built along the streams increase the carving of the sides and trigger channel erosion. Destruction of the riparian zone vegetation eliminates their shadowing effect. Organic matter intake, which is crucial for aquatic life, is hindered. Riparian zone system, the feeding ground and habitat of numerous animals, is destroyed. Extra sediment intake from the road changes the physical and chemical characteristics of the water, with negative effects on the wildlife. In addition, the faster transfer of surface water to streams causes dramatic changes in water temperatures, another factor with detrimental effects on aquatic life.

4. CONCLUSION

Roads are inevitable for the transportation of forest products to human societies. In current practice, the volume of production and economic concerns are given the priority. Yet, ecological and hydrological criteria should also be taken into account. Road planning should

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take the functional uses of the forest into consideration, and in the case of some special ecosystems, should be avoided altogether. Catchments where water production takes place and forests with hydrologic functions require special road planning. In these areas, hydrology should be the main criterion. In the selection of routes, waterways, crosses, and hydro-ecological structure should be taken into account. Road drainage systems should have sufficient capacity and be properly maintained. Measures to prevent or mitigate sedimentation should be taken both in primary production areas and on the roads.

The most important factors that affect soil compaction are soil moisture, texture, structure, and the organic matter content of the soil (Jones, 1995; Özdemir, 1998; Stiegler, 2001). In dry soil and in sandy and granular soil, levels of compaction are higher. Organic matter content of the soil mitigates harmful effects of compaction. Forestry production should be timed to coincide with moisture levels that minimize soil compaction, and avoided in high moisture conditions (Lavoir et al., 1984; Meek et al., 1992). Machinery should be operated with proper tire pressure. Low-pressure tractor tires minimize topsoil compaction (Okursoy, 2000). Drainage on road surfaces and roadside slopes should be improved. Springtime rainfall and melting snow dampen road topsoil, and soil degeneration and compaction are faster in this season.

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ORAL PRESENTATION

DETERMINATION OF PHYSICAL DAMAGES ON LOGS ARISE FROM FOREST HARVESTING OPERATIONS IN ARTVIN REGION

Habip EROĞLU[1*], Yaşar ERMİŞ[2]

[1]Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, 61080 Trabzon, Turkey. Tel: +90 462 3773497 Fax: +90 462 3257499
E-mail: habip@ktu.edu.tr*
[2]Borçka Forest Enterprise, Gündoğdu Mah., Borçka, Artvin

ABSTRACT

In this study, physical damages of logs caused from forest harvesting operations were determined on the mountainous terrain in Artvin region. For this purpose, 400 logs were measured before stack in 3 forest selling storages. Maximum damage depth and length on the logs were measured. Also damage level of logs was determined. Physical damages of logs were examined according to tree species, log diameter and length. As a result; end damage, crack, fracture, slit and smash were verified on the logs. No damage was observed in 50% of logs. In addition, the average damage length, depth and levels of damage were measures as 19.90 cm, 16.75 mm and 0.62 respectively. Considering logs for damaged level, 59% of logs were undamaged, 24% of logs were light damaged, 13% of logs were middle damaged and 4% of logs were heavy damaged.

Key words: Harvesting, log, damage, Artvin

1. INTRODUCTION

Logging operations which are performed inside forest area are time and power-consuming and they are performed with diverse primitive and/or modern methods. Usage of modern methods is closely related to such issues as high technology, abundance of products to be transported, funding opportunities and employment of qualified employees (Eker and Acar, 2005). Logging is, in the simplest terms, conducted in three ways: by manpower, animal power and machine power (Bayoğlu, 2001). In Turkey logging operations are mostly performed by manpower and animal power. Production mechanization rate in developed countries is much higher compared to our country (Acar, 1998).

Wood raw material harvesting operations result damages in various shapes and levels on the product which is manufactured, forest soil, residual trees and saplings (Erdaş, 1986; Dykstra and Heinrich, 1992; Bettinger and Kellog, 1993). Studies conducted for the solution of this problem worldwide display negative impacts of harvesting and compare logging operations based on traditional techniques and Reduced Impact Logging (RIL) and some recommendations are being developed for minimizing the damages (Costa and Tay, 1996; Johns et al., 1997; Bertault and Sist, 1997; FAO, 1998; Elias, 1998; Sist et al, 2002; Eroğlu, 2007; Sist and Ferreira, 2007; Putz et al., 2008).

Depending on the usage of proper techniques during wood extraction, quality and quantity losses are witnessed in the products (Gürtan, 1975; Erdaş, 1986; Holmes et al., 2002: Eroğlu

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et. al., 2009), in addition, as a result of harvesting performed without planning, it is stated that insurance, compensation and transportation costs increase and the forest soil and residual stand suffer from some damages (Dykstra and Heinrich, 1996). Careful and planned performance of logging operations can preserve wood value, seedling and residual trees, and with the resulting increase in value, it might be possible to cover logging costs.

In this paper, it was determined that wood raw material harvesting performed in Artvin area, which has a mountainous terrain, causes physical damages on the transported products and general evaluations are made on the economic dimensions of these damages.

2. MATERIAL AND METHODS

2.1. Study area

Artvin locality, which is chosen as study area, stands out with its steep terrain conditions due to the slope and roughness of forest areas and several negative impacts on wood raw material under these conditions (Eroğlu et al., 2013). Studies were conducted in Hamamlı (20), Ormanlı (120) and Düzhanlar (260) forest storages of Artvin OBM. The distribution according to tree species of the 400 logs measured in these storages is given in Table 1.

Table 1. Number of measured logs according to tree species

Tree species	Sample number
Spruce	162
Scotch pine	44
Beech	105
Chestnut	69
Black alder	20
Total	400

2.2. Methods

In this study the physical damages suffered by wood-related harvesting in the forest until their stockpiling in forest storages are identified. First of all, types of damages occurring in felling, branching, delimbing, debarking, logging, loading and transportation stages were identified. Cracks or damages at the end of the log during skidding were classified using such criteria as the average length and depth of the damage. In the classification of damage level, the following grouping was used depending on the production damage level. As a result, pre-stockpiling damage in logs was determined based on the species of trees (Table 2).

Table 2. The criteria used for the level of damage

Damage level of logs		
0	No damage	
1	Ligth damage	Log damage < 10%
2	Middle damage	Log damage % 10-30
3	Heavy damage	Log damage >%30

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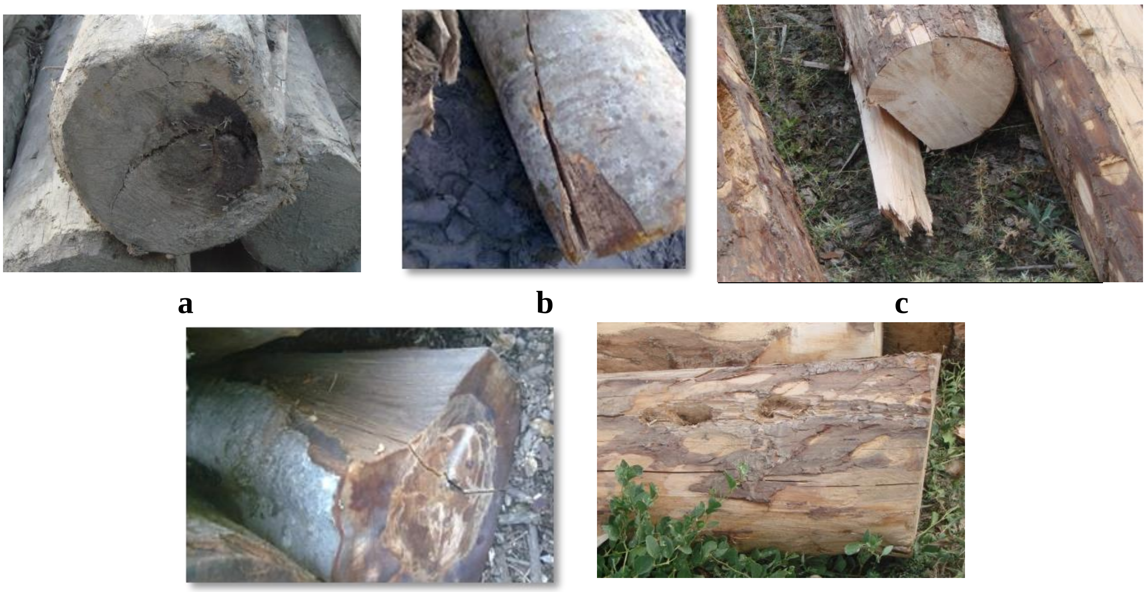
As can be seen in table 2, the damages in logs are graded as 0 (no damage) if there were no damages, 1 (light damage) if the damage was lower than 10 percent, 2 (middle damage) if the damage was between 10 and 30 percent, and 3 (heavy damage) if the damage was higher than 30 percent.

While determining the types of damages, the physical damages which occurred on logs were classified as end damage, crack, fracture, slit and smash. Figure 1 provides examples of these types of damages. End damage is the skull formation due to dragging the logs on ground.



a b c

d e

Figure 1. Damage types on logs (a- end damage, b- crack, c- fracture, d- slit, e-smash)

Crack is the cleavage caused by impacts during cutting-toppling, loading-unloading stages. Fracture is the breaks caused by impacts with hitting hard surfaces during cutting-toppling or unloading. Slit is the situation caused by slitting of logs during delimbing or logging operations. Smash is the situation which occurs due to hitting trees or rocks during tying according to logging methods during wood extraction or hooks of loading machines compressing the logs.

While measuring the length of damage in logs, if there is more than one damage on the log, the longest one is accepted as the length of damage for each log and recorded in cm. In addition, the depth of damage was also measured on the logs. This value is determined by recording the deepest physical damage determined on the log in mm (Figure 2).

3. RESULTS

The summary of data obtained as a result of observation and measurements made on 400 logs in three different forest storages is given in Table 3. As can be seen from the table, measurements were made on 5 different types of logs the average length of measured logs were found as 3.38 m and average diameters were found as 47.88 cm.

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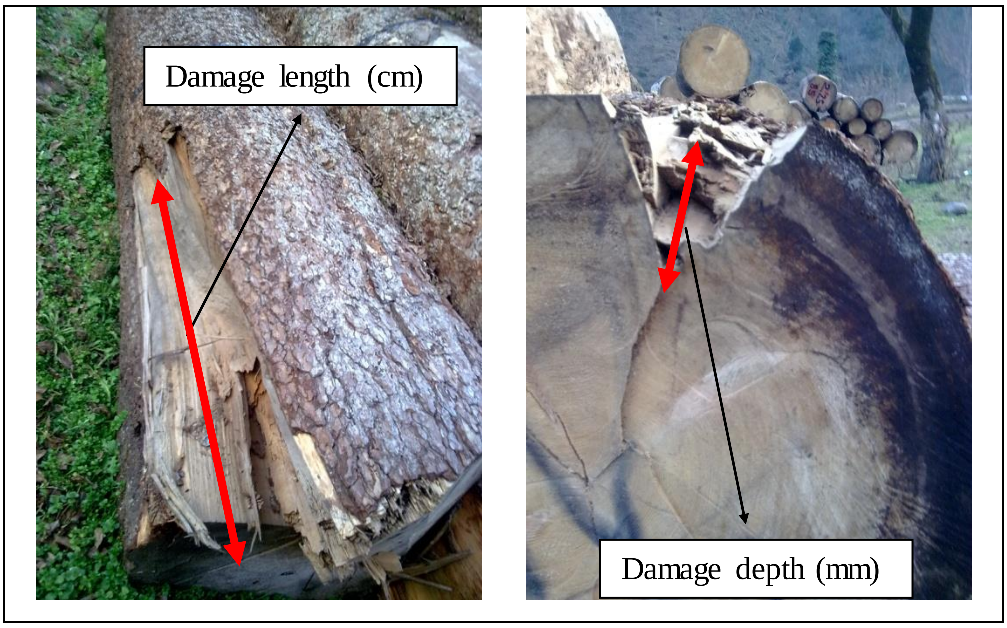

Figure 2. Damage length and depth

Table 3. Number of logs according to tree species and forest storage

Tree species	Number	Average length, m	Average diameter, cm	Average damage length, cm	Average damage depth, mm	Average damage level
Spruce	162	3.81	52.27	18.77	18.86	0.65
Scotch pine	44	4.16	40.45	12.27	15.93	0.57
Beech	105	2.88	51.53	15.22	11.98	0.59
Chestnut	69	2.93	39.95	38.74	24.16	0.77
Black alder	20	2.43	36.95	5.40	0.88	0.15
	400	3.38	47.88	19.90	16.75	0.62

Depending on tree species, the longest damage was found in chestnut logs, followed by spruce, beech, scotch pine and black alder species of trees. The ranking from large to smallest of damage depth was chestnut, spruce, scotch pine, beech and black alder. The ranking as regards level of damage was chestnut, spruce, beech, scotch pine and black alder. In general, the average damage length was found as 19.90 cm, average damage depth was found as 16.75 mm and average level of damage was found as 0.62.

As can be seen in Figure 3, the most common physical damage in logs is end damage, followed by crack, slit, smash and fracture damages. No damages were identified in 196 logs. The main explanation of non-damaged logs can be attributed to the fact that the share of machined logging in wood extraction is high.

General classification of level of damage on logs showed that most logs (59%) fall in the non-damaged group (Figure 4). Light damage, middle damage and heavy damage found in the logs was represented by 24%, 13% and 4% shares, respectively.

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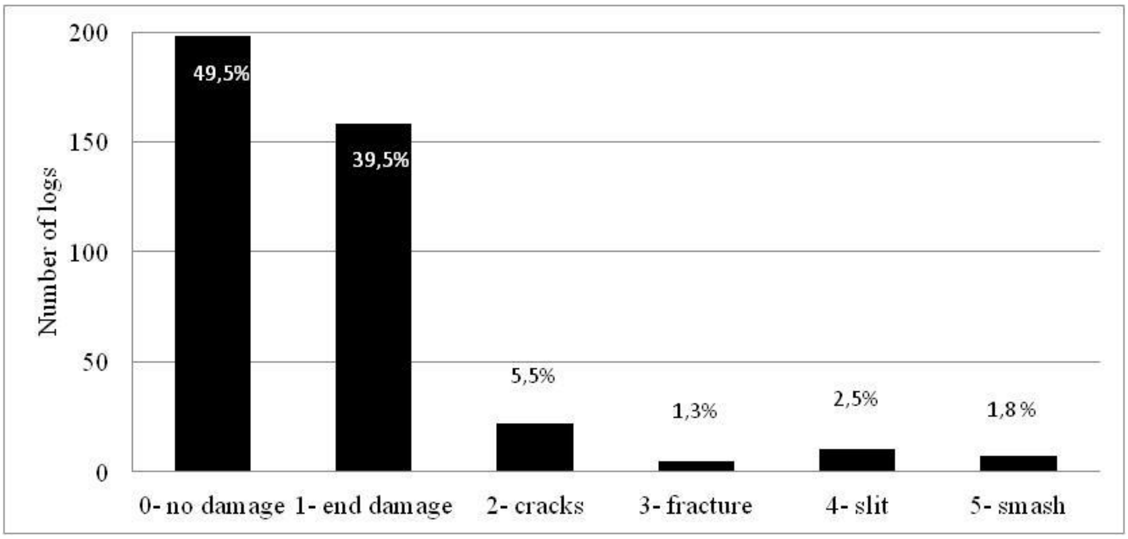

Figure 3. Ratio of the damge types of logs

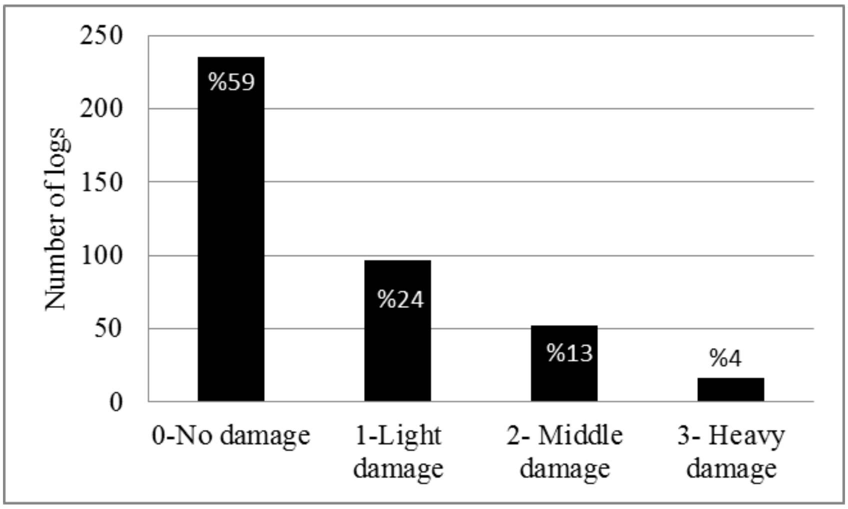

Figure 4. Ratio of the damage level of logs

Figure 5 provides the distribution of damages according to tree species in determination of damages on logs. When the total 162 spruce logs are examined, all types of physical damages determined in the study are encountered. No damage was found in 45% of spruce logs, whereas 46% was found with end damage, 3% with cracks, 1% with fractures and 2% with slits. 25% of scotch fir logs displayed no damages, whereas 75% were found to have end damages. It is believed that the reason for which end damage is higher compared to spruce logs is that scotch fir logs are dragged on the ground with manpower and wood extraction is applied. Of the 105 beech logs which were measured, 53% had no physical damages, 33% had end damage, 10% had cracks and 3% had fractures. There are no physical damages in 61% of chestnut logs, whereas 16% suffered from end damages, 9% from cracks, 10% from slits and 4% from smash. No physical damage was found in 80% of the measured black alder logs whereas 20% suffered from end damage.

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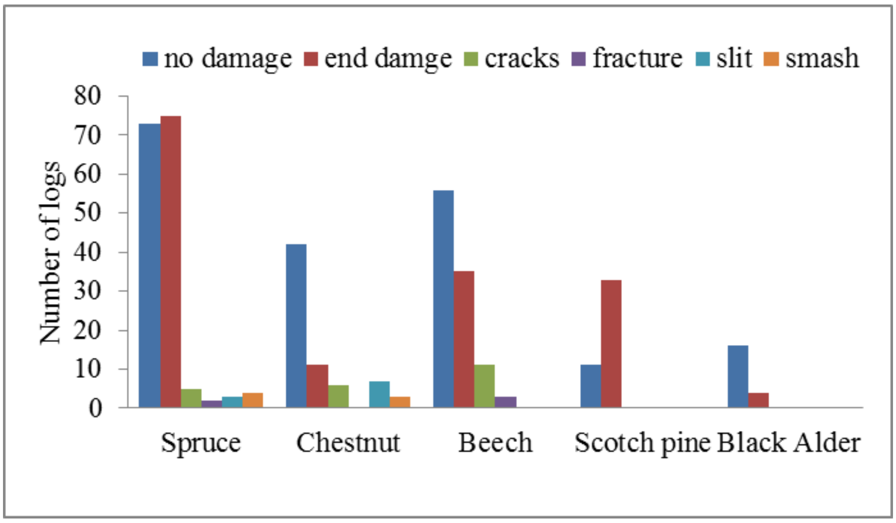

Figure 5. Ratio of the damages types of logs according to tree species

In Figure 6, the levels of damage identified in logs are given according to tree species. 57% of spruce logs are in the non-damages group, whereas 23% are light-damaged, 17% are middle-damaged and 2% are heavy-damages logs. As for scotch fir logs, middle and heavy damage was not identified; 757% of these logs are non-damaged and 47% are light-damaged. As for beech logs, 59% are classified as non-damaged, 25% as light-damaged, 14% as middle-damaged and 2% as light-damaged. Of chestnut logs, 65% are non-damaged, 7% are light-damaged, 13% are middle-damaged and 14% are heavy-damaged. As for black alder logs, no middle and heavy damage was found, and 85% of these logs were classified as non-damaged and 15% were classified as light-damaged.

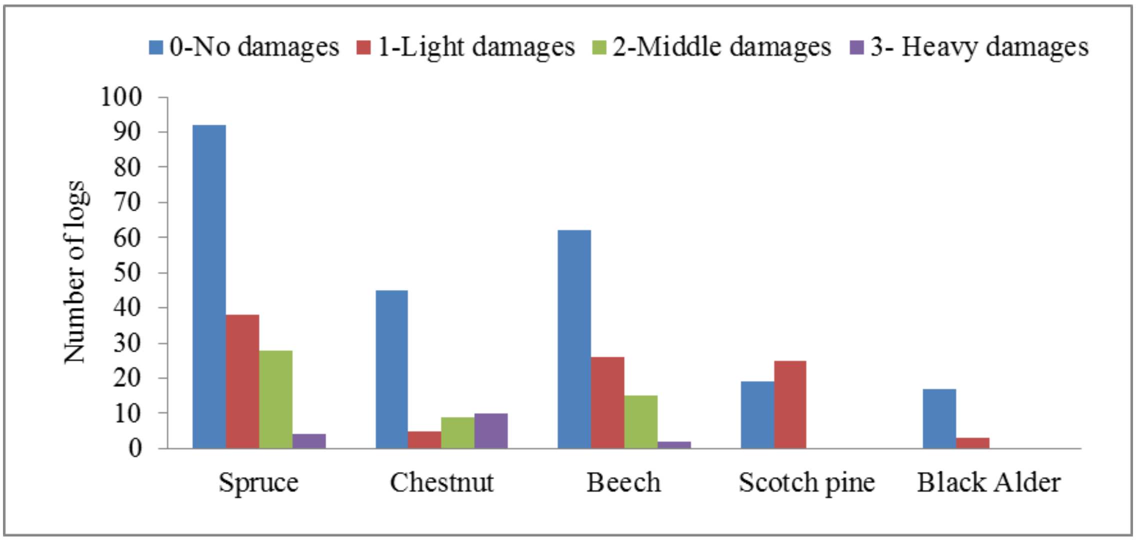

Figure 6. Ratio of damages levels according to tree species

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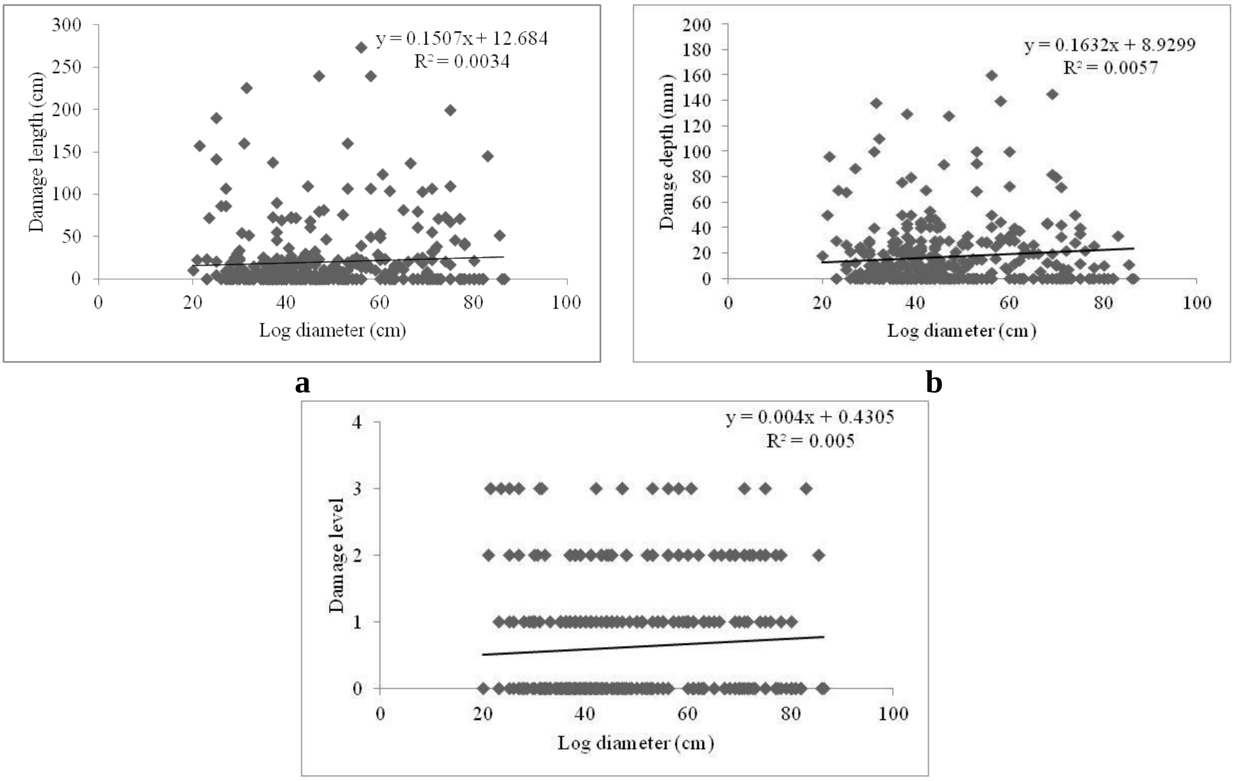
As a result of the performed examination, no significant relation was determined between middle diameters of logs and the length, depth and level of damage. Nevertheless, as diameter values increase, all three damage parameters showed a slight increase. The graphs, equation and R^2 values showing relations between average diameters and the length, depth and level of damage is given in Figure 7.



c

Figure 7. Relation between log diameter and damage length (a), depth (b) and level (c)

As a result of the examination, no significant relation was found between lengths of logs and the length, depth and level of damage. Nevertheless, as length values increase, all three damage parameters showed a slight increase. The graphs, equation and R^2 values showing relations between average length and the length, depth and level of damage is given in Figure 8.

4. CONCLUSION

At the end of this study, it was concluded that in Artvin locality which is located in a mountainous area, with highly sloped, rocky and steep terrain, physical damages occurred which cannot be accepted as high in the products which are transported to the storage during wood raw material production activities.

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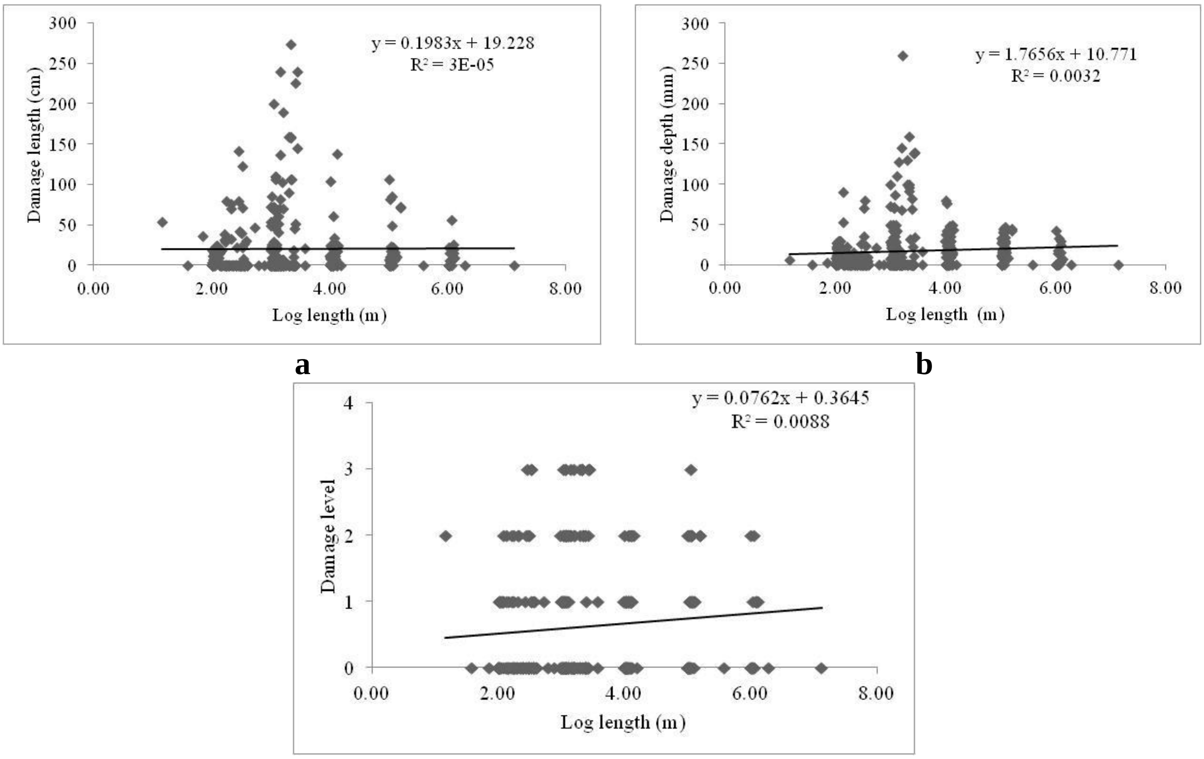

c

Figure 81. Relation between log length and damage length (a) depth (b) and level (c)

Forests, which are renewable natural assets, are formed by coming together of several living and non-living elements. However, this formation is not a haphazard batch, but it is in the form of a whole, a system. Forest ecosystem is processed for a number of purposes, during when the structure of the forest must not be compromised. For this effect, forests must be managed according to forestry technique. This means that certain rules and techniques must be observed in order to minimize the damages given to the products during production and transportation of forestry products. Logging operations by machines suffer from high costs and logging by manpower result in excessive damage; for this reason, in both cases, a good transportation plan and work organization is needed.

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ORAL PRESENTATION

VISUAL QUALITY ASSESSMENT ALONG ROAD CORRIDOR INSIDE AND AT THE SIDE OF SOME FOREST HABITATS UNDER PROTECTION: THE CASE OF DÜZCE

Engin EROĞLU[1], Habip EROĞLU[2*], Sertaç KAYA[1]

[1]Duzce University, Faculty of Forestry, Department of Landscape Architecture 81620 Duzce, Turkey.
[2]Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering 61080 Trabzon, Turkey. Tel: +90 462 3773497 Fax: +90 462 3257499
E-mail: habip@ktu.edu.tr*

ABSTRACT

Basic elements of the landscape are expressed as patch-matrix-corridor. The road corridor inside and at the side of forest is a very important corridor in terms of perception of the landscape on which people wander. Road corridor plays an important role in determination of the visual impact of natural and cultural values that landscaping possesses; they are also essential components that express ecological transitions and borders. In this study a visual evaluation has been performed on the habitats and species that are scattered especially inside or at the side of forests in Düzce province. Within this purpose, phenological observations and visual photographing was performed between June and October in order to determine the visual potential displayed by *Bublero falcato-Pinetum sylvestris*, *Centaureo yaltirikii*, *Seselio resinosii* and *Eleocharietum quinqueflorae* habitats at the side of roads. These photographs including tree images for each habitat were then assessed by users and non-users so as to determine their meaning in terms of visual quality parameters. As a result, a visual quality value as regards all three areas under protection status and their perceptive implications were identified.

Keywords: protected areas, visual potential, phenological observation.

1. INTRODUCTION

Generally landscape is defined as a whole consisting of patch-matrix-corridor basic components. It is true that an essential part of this whole is represented by corridors which ensure interrelation between different landscapes. Corridors not only provide this interrelatedness, but they also represent the prominent characteristics with their different landscapes and habitats (Forman, 1983; 1995). Natural and different corridor structures such as road, stream, and valley represent different situations of landscape. Although corridors are witnessed with natural structures, roads are essential corridor structures which lead the fragmentation of the landscape.

Forests are the most important components of landscape. Forest roads are the most important components in perception and definition of forest landscapes. Forest road corridors contribute to the formation of a new habitat style as well as fragmentation of the habitat (Sayer and Maginnis, 2005).

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There are several protection areas with different statuses inside forest habitats. Protection statuses directed especially towards fauna bring with it efforts for protecting the habitat which host the species. Forest ecosystems host a variety of habitat species such as rocky, water bank, space in and around forest, halophilous, and aquatic also stand out with the different types of vegetation that they accommodate.

In recent years visual evaluations are gaining importance especially in defining natural and cultural areas. A lot of studies in the research on environmental psychology have identified some dimensions (Khew et al., 2014) in relation to how nature is perceived and refer to an individual's perceptions of nature to the value of responsibility users feel towards conservation (Schultz, 2000; Clayton, 2003; Fischer and Young, 2007; Bruni and Schultz, 2010).

In line with such information the basic purposes of the study can be listed as follows:

- Determination of the visual situations of protection-priority habitats around forest roads which pass through rocky areas and forest spaces in Düzce province
- Displaying the regard and usage will for such areas in addition to the impacts created on humans by visual material belonging to different habitat species

2. MATERIAL AND METHODS

2.1. Study area

The study was carried out in the forest rodsides including *Bublero falcato-Pinetum sylvestris, Centaureo yaltirikii, Seselio resinosii* and *Eleocharietum quinqueflorae* habitats of Düzce provinence. The province Düzce, which is the research field and is located between the 400 40′ – 400 47′ north altitude and 310 21′ – 310 26′ east longitudes, is situated in the North West part of Turkiye and in the Blacksea region (Figure 1).

2.2. Material

The main materials of the study are *Bublero falcato-Pinetum sylvestris, Centaureo yaltirikii, Seselio resinosii* and *Eleocharietum quinqueflorae* habitats and their visual situations.

2.3. Methods

In the first step of the study, *Bublero falcato-Pinetum sylvestris, Centaureo yaltirikii, Seselio resinosii* and *Eleocharietum quinqueflorae* habitats were observed as phonological (Eroğlu and Demir, 2016). In this term, plants and habitats were also taken photos.To understand visual potentials of road corridor inside and at the side of forest of some habitats under protection, questionnaire was carried out by using their photos (Eroğlu et al., 2012; Acar et al., 2007; Müderrisoğlu et al., 2006; Müderrisoğlu and Eroğlu, 2006; Wolf, 2003). To identify the most visual effect of the habitats were evaluated in the survey according to their visual situations (Eroğlu, 2004) (Figure 2).

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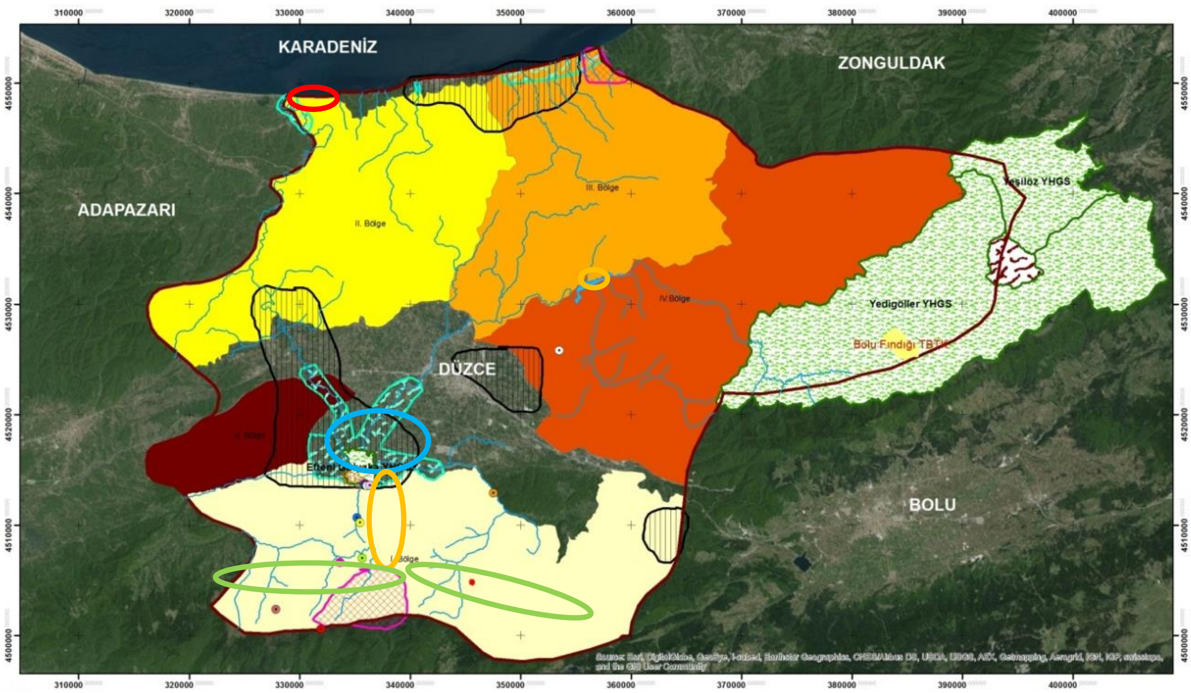

Seselio resinosii, Centaureo yaltirikii, Bublero falcato-Pinetum sylvestris,

Eleocharietum quinqueflorae

Figure 1. Study area

Habitats:

- 1 and 2; *Seselio resinosii;*
- 3, 4, 5, 6, 9 and 10; *Bublero falcato-Pinetum sylvestris*
- 7 and 8; *Centaureo yaltirikii*
- 11 and 12; *Eleocharietum quinqueflorae*

Figure 2. Habitat images used in the questionnaire

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In the questionnaires, the determined questions were asked to the subjects for visual evaluation of the habitats besides to determine participant' demographic features (Acar et al. 2003). These questions were selected in a way to show the relations habitats and visual perceptions. They were indicated in table 1. Finally we asked the participant "*If you want to visit the habitat or not?*" to understand their using tendency of the natural or protected areas (Table 1).

Table 1. Using questions in survey for visual values of the habitats

Questions / Commends	**Scores (from negative to positive)**
This image includes *naturalness* effects	From 1 to 5
The elements in the image are *perceptible*	From 1 to 5
The elements in the image (mountain, plants, roads, water etc.) have *continuity* among themselves	From 1 to 5
This image has a *different attractive* element	From 1 to 5
This image include a *mystery* and I wonder	From 1 to 5
This image includes a lot of elements so it has a *complexity* effect.	From 1 to 5
There are different elements reflected *diversity* in the image	From 1 to 5
The elements are *compatible* with each other in this image	From 1 to 5
I *like* the views in the image	From 1 to 5
I want to *visit* to the landscape in this image	From 1 to 5

In the statistical analysis, SPSS 22 was used to analyze the visual perceptions of the habitats. So this subject, correlation analysis was used in the evaluation of the adjectives and in the determination of the socio-economic differentiation. In addition to this descriptive statistics were done to determine demographic and using values of the road according to habitat photos.

3. RESULTS

3.1. Habitat Features

In this study, *Bublero falcato-Pinetum sylvestris*, *Centaureo yaltirikii*, *Seselio resinosii* and *Eleocharietum quinqueflorae* habitats were observed as phonological during the 2015 (Figure 3). In this term, some floristic and morphological features were determined in Table 2.

3.2. Visual Potentials of the Habitats

In Table 3, the evaluation codes of the data gathered were shown. According to this, 67,6% of the participants were male, 32.4% female, were the ages <20 2.7% 20-30, 43.2% 30-40 24.3%, 40-50 29.7% and +50 0.1%. In addition, their education levels; Elementary school is 2.7%, High school is 10.8% and College or faculty graduate is 86.5%. Their work situation are also Officer (24.3 %), Academicians (70.3%) and Student (5.4%).

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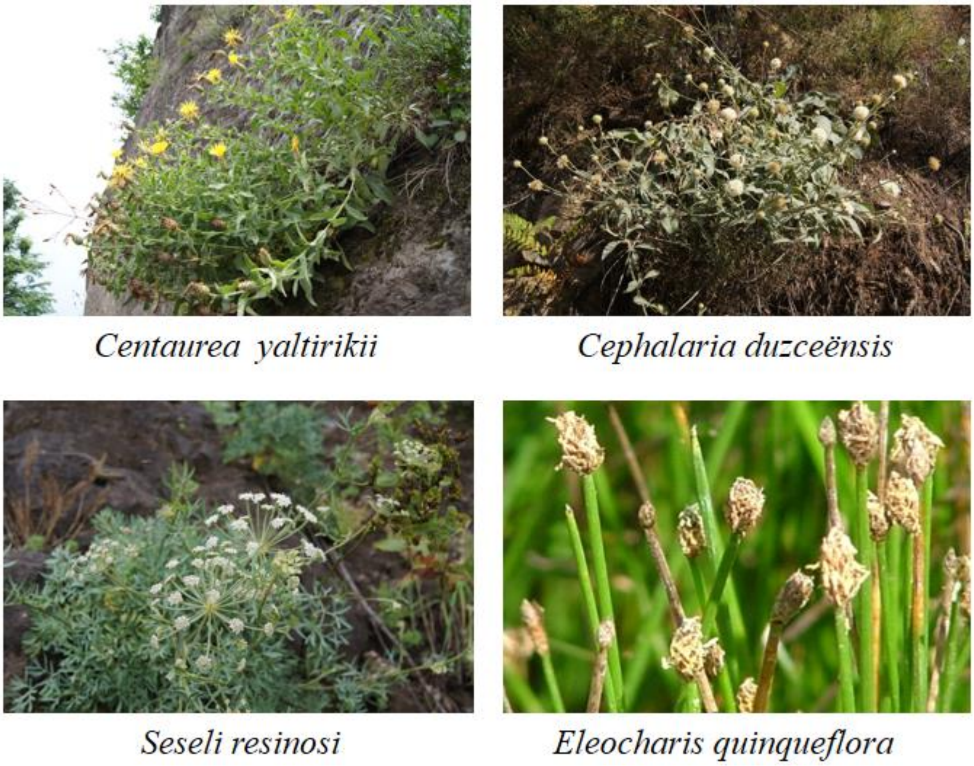

Figure 3. Some photos of the characteristic plants of the habitats

Table 2. Some floristic and morphological features of the habitats

Habitat	**Characteristic plant species**	**Region in Düzce**	**Plant Features**	**Floristic Features (Indicator species and their distribution)**
Seselio resinosii	*Seseli resinosi*	Hasanlar Dam and Elmacık Mountain	White flowers and grey-blue leaves (Figure 3)	*Cover class:* 4-5 *Cover ratio:* % 51-75 *Sociability:* patch, ball, track and small colonies
Centaureo yaltirikii	*Centaurea yaltirikii*	Elmacık Mountain	Dark green leaves and yellow flowers (Figure 3)	*Cover class:* 4 *Cover ratio:* % 55-70 *Sociability:* ball, track and small colonies
Bublero falcato-Pinetum sylvestris	*Cephalaria duzceënsis*	The South Side of Elmacık Mountain	White flowers and grey-green leaves (Figure 3)	*Cover class:* 4-5 *Cover ratio:* % 55-65 *Sociability:* ball, track and small colonies
Eleocharietum quinqueflorae	*Eleocharis quinqueflora*	The South Side Plateaus in Duzce	Calligraphic light green leaves (Figure 3)	*Cover class:* 5 *Cover ratio:* % 75-100 *Sociability:* patch, part, large belts and a small colony

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Table 3. Descriptive statistics for demographic structures of participants

Gender	**(%)**
Male	67.6
Female	32.4
Age	
<20	2.7
20-30	43.2
30-40	24.3
40-50	29.7
50>	0.1
Education	
Elementary school	2.7
High school	10.8
College or faculty graduate	86.5
Work	
Officer	24.3
Academician	70.3
Student	5.4

As shown the Table 4, there are the high and low scores of the habitat images. In this direction, image number 11 was found the most effective aspect of naturalness, perceptible, continuity, attractive, mystery and compatible. In addition this image is to be the most like and visit. On the other hand image 4 was found the most complexity and has the lowest scores of the visual parameters. The most diversity effect was found image 3 by the participant.

Table 4. Arithmetic means of the visual scores of the habitats

Image number	**Naturalness**	**Perceptible**	**Continuity**	**Different-Attractive**	**Mystery**	**Complexity**	**Diversity**	**Compatible**	**Like**	**Visit**
1	3.9	3.8	3.4	3.6	3.8	2.4	3.0	3.5	3.4	3.4
2	4.1	3.8	3.8	3.5	3.3	2.4	3.4	3.5	3.8	3.7
3	4.2	4.1	3.7	3.4	3.4	2.8	**3.7**	3.7	3.8	3.7
4	2.1	3.1	2.1	3.2	2.4	**3.0**	2.5	2.1	1.7	1.7
5	3.9	3.8	3.6	3.2	3.2	2.6	3.4	3.6	3.6	3.2
6	4.1	4.1	3.9	3.1	3.2	2.6	3.5	3.8	3.8	3.4
7	3.8	3.5	3.1	3.4	3.9	2.8	3.0	3.3	3.2	3.1
8	3.6	3.6	3.5	2.9	2.7	2.7	3.1	3.3	3.0	2.8
9	3.8	4.0	3.5	3.3	3.3	2.8	3.2	3.4	3.5	3.3
10	2.8	3.0	2.6	3.1	2.5	2.9	2.9	2.5	2.3	2.3
11	**4.6**	**4.5**	**4.5**	**3.9**	**4.2**	2.4	3.5	**4.4**	**4.5**	**4.5**
12	4.1	4.3	4.0	3.6	3.6	2.5	3.2	3.8	3.9	4.0

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According to correlation analysis (p<0.01 and p<0.05) between demographic structure and visual parameters of the habitats in Table 5, education level and working are negatively related to visual parameters. Gender and age also are related to the parameters. As shown the Table 5, males find the habitats less complex and compatible than females (p<0.01). As education levels of the participant increase, visual values of the habitats decrease. The admiration of the visiting the habitats decrease as well. Participants are younger has higher scores of visual values of the habitats than older.

Table 5. Correlation between demographic situation and visual parameters

		Naturalness	Perceptible	Continuity	Different-Attractive	Mystery	Complexity	Diversity	Compatible	Like	Visit
Gender	P.Corre.	.032	.090	.016	-.141**	.073	-.159**	.014	.141**	.089	.124**
	Sig.	.501	.058	.742	.003	.125	.001	.770	.003	.062	.009
	N	443	443	444	440	444	443	442	441	442	444
Age	P.Corre.	-.106*	-.208**	-.108*	.003	-.087	-.041	-.127**	-.189**	-.144**	-.121*
	Sig.	.025	.000	.023	.948	.067	.392	.008	.000	.002	.010
	N	443	443	444	440	444	443	442	441	442	444
Education	P.Corre.	-.156**	-.126**	-.203**	.026	-.148**	-.142**	-.074	-.183**	-.227**	-.213**
	Sig.	.001	.008	.000	.589	.002	.003	.121	.000	.000	.000
	N	443	443	444	440	444	443	442	441	442	444
Work	P.Corre.	-.035	-.008	-.056	.075	-.138**	.103*	-.073	-.222**	-.174**	-.185**
	Sig.	.462	.862	.236	.115	.003	.031	.126	.000	.000	.000
	N	443	443	444	440	444	443	442	441	442	444

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed).

In Table 6, according to correlation analysis, liking the habitats of the participant is related to naturalness, perceptible, continuity, attractiveness, mystery, diversity and compatible but not complexity. In addition, the admirations to visit the habitats are positively related to visual parameters except complexity. It is clear both Table 5 and Table 6 that visual features of the habitats under protection are related to participant features, habitat features and visual components.

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Table 6. Correlation between visual parameters and admirations for the habitats

		Naturalness	Perceptible	Continuity	Different-Attractive	Mystery	Complexity	Diversity	Compatible
	P.Corre.	.626**	.493**	.647**	.144**	.495**	-.075	.373**	.748**
Like	Sig.	.000	.000	.000	.003	.000	.115	.000	.000
	N	441	441	442	438	442	441	440	439
	P.Corre.	.548**	.452**	.576**	.183**	.560**	-.020	.413**	.666**
Visit	Sig.	.000	.000	.000	.000	.000	.672	.000	.000
	N	443	443	444	440	444	443	442	441

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed).

4. CONCLUSIONS

When considered that this study is aimed to identify the visual effect of the habitats under protection in roadside in the forests is the based on the work to be realized in this context. Following results obtained from the study;

- Demographic structure is an important determining element in the visual perception of habitats under protection in forest road.
- To understand and determine visual preferences and qualities of the habitats under protection in forest road, visual properties of plant species and their environment can be used as effective components of the visual landscape.
- Naturalness, perceptible, continuity, attractiveness, mystery and diversity are the main visual elements to identify what is the visual values of the habitat under protection in forest landscapes.
- *Bublero falcato-Pinetum sylvestris*, *Centaureo yaltirikii*, *Seselio resinosii* and *Eleocharietum quinqueflorae* habitats have different visual characteristic to use them in landscape such as flower and leave features (texture, size, colour and form).
- The habitats under protection in forest landscape in Duzce city have different visual values respectively *Eleocharietum quinqueflorae, Bublero falcato-Pinetum sylvestris, Seselio resinosii* and *Centaureo yaltirikii.*
- According to visual values of the habitats under protection, the most visual effective and admirable to visit habitat is *Eleocharietum quinqueflorae* constructed coniferous trees and large grasses in the south part plateaus of Düzce.

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ORAL PRESENTATION

THE ROLE OF IMPERVIOUS SURFACES IN TRANSFORMATION FROM PRECIPITATION TO FLOODS: THE CASE OF ARTVIN-HOPA

Ayhan USTA*, Murat YILMAZ, Habip EROĞLU

Blacksea Technical University, Faculty of Forestry, Department of Forestry Engineering, 61080 Trabzon, Turkey. Tel: +90 462 3774122 Fax: +90 462 3257499
E-mail: austa@ktu.edu.tr

ABSTRACT

Impervious land covers which are known as impervious surface express every surface where water cannot enter. Impervious surfaces are surfaces which increase the surface flow by means of decreasing or preventing the permeability of surface. All kinds of roads (forest and village roads, highways etc.), buildings in settlement areas, impervious concrete surfaces are examples of such surfaces. Impervious and indirectly impervious surfaces damage the quality of water and in some settlement areas it can turn into flood depending on the level of precipitation, which results in loss of lives and property. With short-term high precipitation, stream and river surfaces are other surfaces that can cause and increase in the flow rate of stream waters. In an area where floods and landslides are witnessed, impervious surfaces are ignored for some reason. In this paper the aim is to examine floods, overflows and landslides which led to loss of lives and property in and around Artvin-Hopa on 24.08.2015 in ecological terms. In the study the focus was on impervious surfaces which are effective in transformation of rain waters to floods and overflows. For this purpose, the watersheds where Hopa central, Sugören and Yoldere villages are located, which experienced the flood and overflow to the highest extent, were evaluated separately. Forest management plan belonging to Hopa Forest Management Office, meteorological measurements, satellite and radar images were used to perform this study. At the end of the study it was observed that especially impervious surfaces (forest road, village road, highway etc.) and stream surfaces were effective in leading to flood and overflow.

Keywords: Flood, impervious surfaces, Artvin-Hopa, precipitation

1. INTRODUCTION

Impervious/impermeable surfaces correspond to anything that water cannot infiltrate. Ranging from house roofs, patios and village roads, commercial buildings and parking lots, impervious cover prevents rainfall from absorbing into the ground, turning it into stormwater runoff. Impervious surface changes the quantity of runoff, eroding and changing the physical structure of streams. Because water runs more quickly from an impervious area, flooding becomes both more common and more intense downstream. Meanwhile, because less water is soaking into the ground, water tables can drop and streams and wells fed by groundwater begin to dry up (Flinker and Miller, 2010). Under natural forested circumstances, only approximately 10% of precipitation runs off the surface of the site, 50% soaks into the ground, and an amazing 40% is taken up by vegetation cover and sent back into the atmosphere through the process of evapotranspiration (Figure 1).

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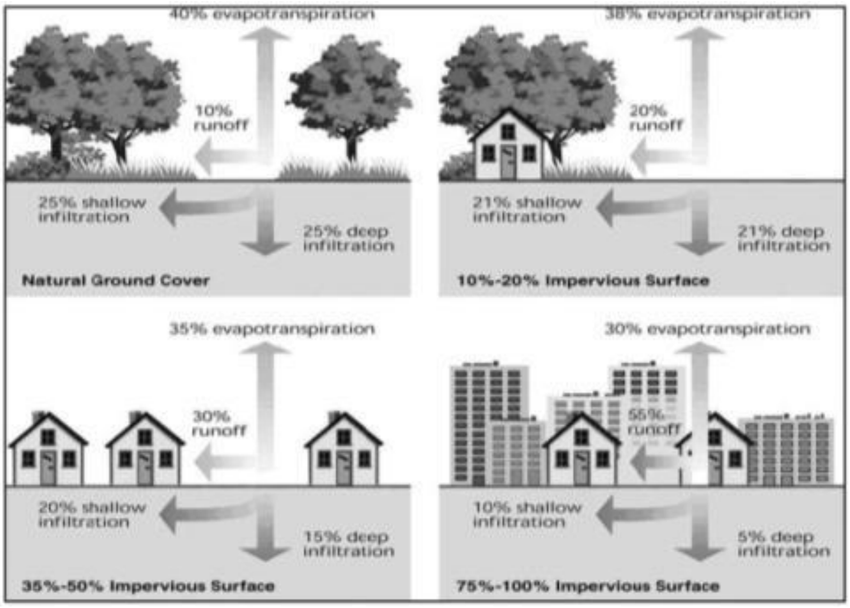

Figure 1. Changes in site hydrology with increasing impervious cover (EPA, 1994)

As roads and structures are built, this ratio begins to change, with runoff increasing as the amount of impervious cover increases. For instance, the total runoff volume for a one-acre parking lot is approximately 16 times that produced by an undeveloped one-acre pasture (Schueler, 2000). Therefore it's understandable why sub-settlement and settlement communities have more severe flooding than undeveloped areas. Because the water is spending less time on site, infiltration declines dramatically. This is a particular concern in many settlement and sub-settlement regions, where groundwater has been decreased because there is not enough precipitation absorbing into the ground. The increase in runoff that becomes during this process, combined with the loss of recharge to groundwater, has effective impacts on streams (Flinker and Miller, 2010).

In the study, the aim is to examine floods, overflows and landslides which led to loss of lives and property in and around Artvin-Hopa on 24 August 2015 in ecological terms. In the study the focus was on impervious surfaces which are effective in transformation of rain waters to floods and overflows. For this purpose, the watersheds where Hopa central, Sugören and Yoldere villages are located, which experienced the flood and overflow to the highest extent, were evaluated separately.

2. MATERIAL AND METHODS

Forest management plan belonging to Hopa Forest Management Office, meteorological measurements, satellite and radar images were used to perform this study. Especially, effects of impervious surfaces (forest road, village road, highway etc.) and stream surfaces were investigated on flood and overflow.

2.1. Study Area

Hopa, Sugören and Yoldere watersheds where are more effective flood and landslide on 24 August 2015 were determined as study areas (Figure 2). This watersheds are located between 41˚20' - 41˚26 N latitudes and 41˚23' - 41˚33' E longitudes.

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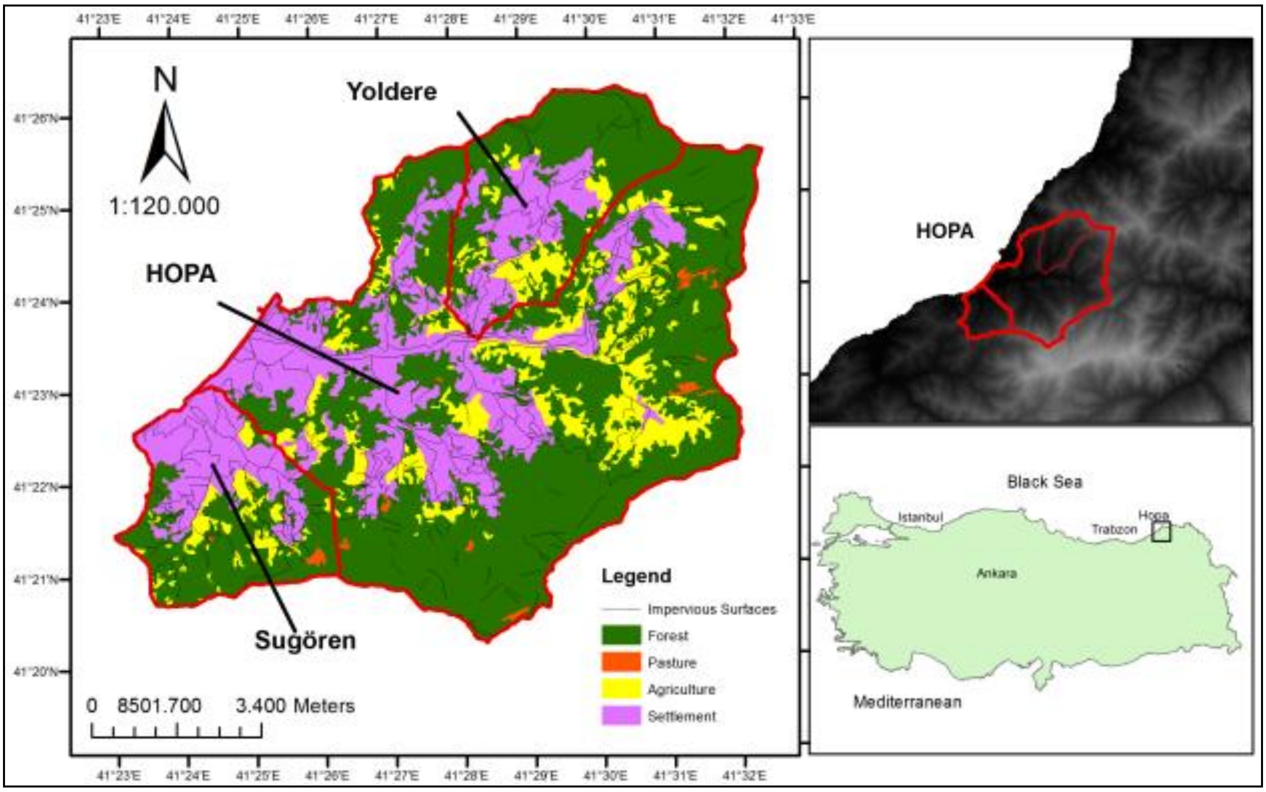

Figure 2. Location of study area

Some climate data for study area are showed in Table 1. Precipitation amount of Hopa on August (535.2 mm) and October (626.3 mm) is very high. According to Hopa meteorological station data, precipitation amount during 24 hours (23 - 24 August 2015) is 287.2 mm (Url-1). These are heavy rainfalls being extraordinary. Furthermore, meteorological satellite imagery of Turkey (24 August 2015) shows that exposed to heavy rainfall of Hopa and its environment (Figure 3, Figure 4).

Table 1. Some climate data of Hopa meteorological station (2015)

	Months												
	1	2	3	4	5	6	7	**8**	9	10	11	12	Annual
Average Temp. °C	8.4	9.3	9.0	10.9	16.5	20.6	22.7	**24.8**	23.2	17.0	14.2	7.8	15.4
Min. Temp. °C	4.8	5.9	6.3	6.9	12.7	18.3	19.7	**22.3**	20.2	14.4	10.7	4.9	12.3
Max. Temp. °C	12.3	13.1	12.5	15.9	20.0	23.6	26.1	**29.1**	27.4	20.9	17.8	11.8	19.2
Average Precip., mm	131.3	130.1	110	190	85.3	121.8	49.5	**535.2**	29.9	626.3	402.8	239.6	2651.8

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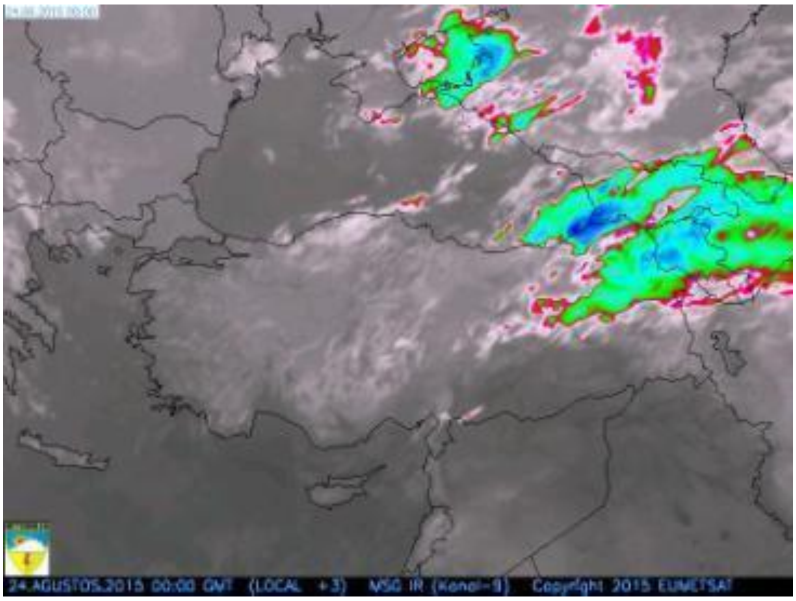

Figure 3. Meteorological satellite imagery of Turkey (24 August 2015)

Figure 4. Runoff on impervious village road after precipitation

In the Hopa watershed outcrops mostly volcanic rocks, sedimentary rocks, crumbs and carbonates. Aquifers are geological medias including gaps related to each other and impermeable floor. In generally, volcanic rocks have not aquifer character (Öztaş, 1982).

According to forest management data, almost all of forest areas in Hopa Creek watershed occur from broad-leaved forests. About 60% of forest areas is in Alder dominance. Also, Beech, Chestnut and Hornbeam species are distributed in Hopa Creek watershed (GDF, 2010). Sugören and Yoldere watersheds are similar to Hopa Creek watershed in terms of species distribution.

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2.2. Methods
In the study, Hopa Creek, streams, dry streams, forest roads, village roads and highways that are line layers in ArcGis program as impervious surfaces. In field measurement of impervious surfaces was used widths and lengths of this line layers. Accepted widths of impervious surfaces were showed in Table 2.

Table 2. Platform widths of impervious surfaces

	Hopa Creek	Stream	Dry Stream	Forest Road	Village Road	Highway
Platform Width (m)	25.0	5.0	2.0	6.0	7.0	10.0

Total precipitation amount falling on impervious surfaces was found multiplying fields of impervious surfaces and during 24 hours rainfall amount measured between 23 Aug (Hour: 21.37) - 24 Aug (Hour: 21.37) 2015 by meteorological station.

3. RESULTS

Impervious surfaces play important role in transformation from precipitation to floods. According to calculating, fields of impervious surfaces were showed in Table 3. Precipitation amounts falling to impervious surfaces in watersheds between 23 Aug - 24 Aug 2015 (during 24 hours) were given in Table 4. This precipitation amount (287.2 mm) was determined as maximum precipitation by meteorological bulletin (Url-1).

Table 3. Calculation of impervious surface areas

	Hopa Creek	Stream	Dry Stream	Forest Road	Village Road	Highway	Total
Platform Width (m)	25.0	5.0	2.0	6.0	7.0	10.0	
Length (m)	7534.0	209514.5	98917.1	104706.6	24306.4	25356.9	470335.5
Area (m^2)	188350.0	1047572.5	197834.2	628239.6	170144.8	253569.0	2485710.1

Table 4. The amount of water falling on impervious surfaces in the watersheds during 24 hours (m^3).

Watersheds	Impervious surfaces					Total
	Stream	Dry Stream	Highway	Village Road	Forest Road	
Hopa	354956.9*	56818.0	72825.0	48865.5	180430.4	713895.8
Yoldere	37491.5	11590.4	-	21254.1	50485.4	120821.4
Sugören	67062.1	1149.1	979.7	31844.0	25562.8	126597.7

* Hopa creek was added to stream.

Land use/cover status of watersheds was given Table 5. Runoff amount in agriculture, urban and pasture lands is more from forest lands. Percent of agriculture, urban and pasture lands is about 40.1% in Hopa watershed, 43.5% in Sugören watershed and 37.0% in Yoldere watershed (Figure 5).

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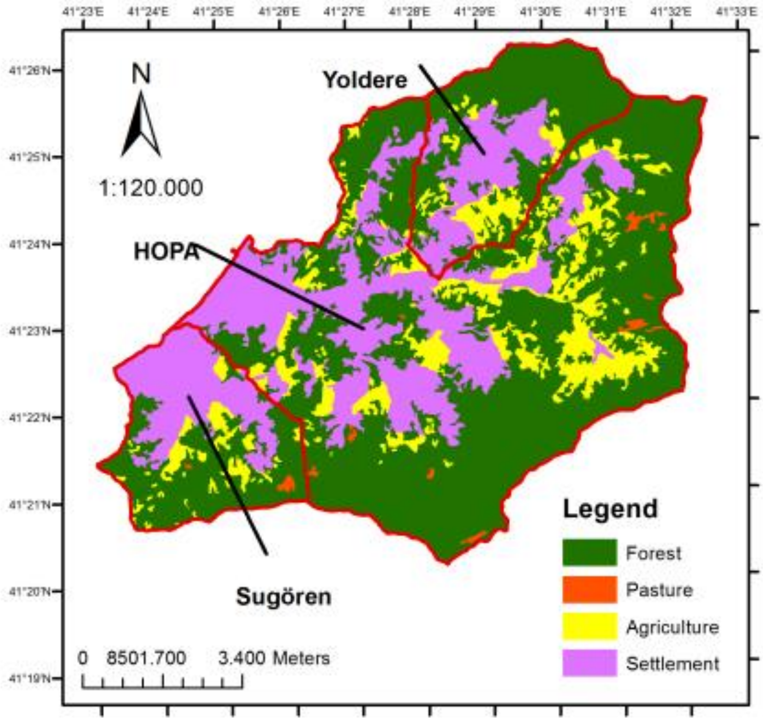

Figure 5. Land use/cover map of Hopa, Yoldere and Sugören Watershed

Table 5. Land use/cover of watersheds

Watersheds	Land Use/Cover (ha.)				Total Area
	Forest	Pasture	Agriculture	Settlement	
Hopa	5947.3	51.5	1230.8	2700.6	9930.2
Sugören	852.2	10.4	165.9	480.0	1508.5
Yoldere	1102.8	0.0	192.4	455.6	1750.8

Note: The field of impervious surfaces is deducted from account.

Also in the study was taken into account other land uses/covers that are indirect effective in transformation from precipitation to floods. The precipitation amount falling on this land uses/covers was accounted during 24 hours between 23 Agu - 24 Agu 2015 (Table 6).

Table 6. Indirect effective land use/cover in transformation from precipitation to floods

Watersheds	Land Use/Cover (million m^3)				Total of Precipitation
	Forest	Pasture	Agriculture	Settlement	
Hopa	17.02	0.15	3.41	7.63	28.21
Sugören	2.39	0.03	0.45	1.26	4.13
Yoldere	3.12	0.00	0.54	1.23	4.89

About 40% (11.19 milyon m^3) of water falling on Hopa watershed (28.21 million m^3) came on indirect effective land uses/covers (agriculture, urban and pasture land). Sugören and Yoldere watersheds are smaller than Hopa Creek watershed. About 42% (1.74 million m^3) of water falling on Sugören watershed (4.13 million m^3) and 36% (1.77 million m^3) of water falling on Yoldere watershed (4.89 million m^3) came on indirect effective land uses/covers (agriculture, urban and pasture land).

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Considering forests in coastal areas where precipitation is more effective, broad-leaved species having lower interception capacity than coniferous (28 - 48%) are dominant in this areas. This situation increases the risk of flooding. According to the interception measurements, annual interception amount varies between 28 - 48% in coniferous forests and between 14.4% - 18% in broad-leaved forests (Balcı and Özyuvacı, 1988).

4. CONCLUSION

Floods caused great damage in Hopa Creek, Yoldere and Sugören watersheds. Impervious and indirect impervious surfaces have important share in damage. The precipitation amount falling Hopa Creek watershed is approximately 29 million m^3 (during 24 hours). The precipitation amount falling impervious and indirect impervious surfaces is 11.9 million m^3. This amount corresponds to 1.9 million m3 water in Sugören and Yoldere watersheds.

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ASSESSMENT OF HELICOPTER LOGGING METHOD FOR ENVIRONMENTALLY FRIENDLY HARVESTING PRACTICES

Abdullah E. AKAY*, Ebru BİLİCİ

Bursa Technical University, Faculty of Forestry, 16330 Bursa, Turkey. Tel: +90 224 3003626
Fax: +90 224 3003429 E-mail: abdullah.akay@btu.edu.tr*

ABSTRACT

Helicopter logging provides important advantages of implementing environmentally friendly harvesting techniques especially in protected areas. However, the cost of helicopter logging can be much higher than that of ground-based logging due to high equipment costs, maintenance costs, the cost of flight crew, and fuel costs. Thus, the helicopter logging operation should be carefully planned to implement cost effective and environmentally friendly logging operations. In this study, the stages of helicopter logging and operational factors were first described, and then the operation cost, environmental concerns, and safety practices in helicopter logging were discussed. It can be concluded that the helicopter logging can be effectively used for harvesting high quality logs and for extraction of timbers from environmentally sensitive areas where road construction and logging operations are usually restricted.

Keywords: Forest harvesting, Helicopter logging, Protected areas

1. INTRODUCTION

Helicopter logging is an aerial harvesting method in which forest products are removed vertically from the stands and flown to the roadside landing areas (Chua, 2001). Helicopter logging can be considered as a common method in the Pacific Northwest of the USA and in western Canada in timber production (Akay et al., 2008). Amount of timber harvested by helicopter logging is about eight million cubic meters per year in British Columbia in Canada (Dunham, 2006). They are preferred by logging managers for harvesting timbers from difficult steep sites and sensitive forest lands, and for accessing unreachable areas due to terrain conditions or remoteness from the road network.

Helicopter logging, also called as helilogging, has been employed since early 1970's as a reduced impact logging method. Even though logging with helicopter costs more than other logging systems, the use of this alternative method continues to expand in forestry. Helicopter logging provides logging managers with following advantages (Aust and Lea, 1992; Akay et al., 2008):

- Requires less road constructions, reduces soil disturbance, and minimize logging related sediment production
- Provides access to remote and difficult terrain that cannot be reached through ground transportation
- Minimizes damages on residual stand and other forest vegetation
- Increases productivity by producing large amount of logs quickly
- Makes it possible to extract longer with high quality and sale price

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- Provides better working conditions in terms of worker health and safety
- Minimizes visual impacts from harvesting operations

On the other hand, helicopter logging has following potential constraints that should be considered by logging managers (Bruce, 2003; Akay et al., 2008; Dunham, 2006):

- Requires high investment and operating cost
- Affected by difficult weather conditions
- Requires large landing areas
- Demands for trained and experienced personnel

In order to overcome downside of helicopter logging, the operation should be well-planned. Besides, equipment should be carefully selected to minimize cost and reduce environmental impact. There are various types and sizes of helicopters which have been employed during logging operations (Figure 1). Specifications for the most common logging helicopters are listed in Table 1.

Figure 1. Some of the helicopters used in logging operations

Table 1. Specifications for some logging helicopters (Dunham, 2006)

Make/Model	Rated payload capacity (ton)	Engines	Engine Power (kW)
Bell 204B	1.8	1	820
Bell 204A	2.3	1	1044
Bell 212	2.3	2	671
Bell 214B	3.6	1	2185
Boeing V-107 II	4.8	2	932
Boeing CH-234LR	12.7	2	3039
Sikorsky S-64E	9.1	2	3356
Sikorsky S-64F	11.3	2	3579
Eurocopter A-Star B2	1.2	1	732
Eurocopter SA-315B Lama	1.2	1	640
Kaman K-1200	2.7	1	1342
Kamov KA-32A	5.0	2	1645
Sikorsky S-58T	2.3	2	700
Sikorsky S-61N	3.6	2	1044
Sikorsky S-61N Shortski	4.1	2	1044

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2. HELICOPTER LOGGING STAGES

Extraction of forest products by helicopter logging system starts with felling and bucking operation. Then, operation continues with yarding cycle that includes outhaul, hooking, inhaul, and unhooking stages. Helicopter logging also requires service cycle which involves flying to service area for fuel, the process of refueling and any maintenance activities at landing area. In helicopter logging, there are usually two pilots; one for flying the helicopter and controlling the lifting cable and other for the monitoring instruments of the helicopter (Chua, 2001).

2.1. Felling and Bucking

The felling operations should be well planned ahead of time, coordinated by the timber operators, and proper felling techniques should be implemented during the operation. Felling of trees is usually done couple weeks prior to scheduled arrival move in time of the helicopter because the felling by chainsaw has lower production rate comparing with capacity of logging helicopters (Stampfer et al., 2002). Due to difficult terrain conditions, average of five trees can be cut by felling crew of two people per day (Hui, 2001). There is another system, called fly-in feller-buncher, in which a custom-built feller-buncher is delivered to the woods by aerial transport in pieces and rebuilt at stump. This system is used in British Columbia for harvesting second and third growth timber (Dunham, 2006).

After felling operation, trees are generally bucked into suitable log sizes according to the payload capability of the helicopter. Besides, log lengths and grades desired by the market should be considered during bucking operation. For each cycle, designated logs should be marked to make them easily visible by the pilot (Hartsough et al., 1986). To ensure safe lifting operation, any obstacles around pre-bunched logs should be cleared (Chua, 2001).

2.2. Yarding Cycle

A typical yarding cycle of the helicopter logging operation includes flying outhaul to the harvest area, hooking the logs in woods, flying inhaul loaded to the landing area, and unhooking logs at the drop zone. At the beginning of the yarding cycle, helicopter moves in to the woods where trees are fallen and drops the lifting cable which is located under the helicopter (Figure 2).

Figure 2. A logging helicopter flying inhaul from landing to harvest area

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There are three types of rigging systems including grapple, load-hook, and standing stem (Dunham, 2006). The logs are commonly carried by a grapple or load-hook positioned at the end of a lifting cable (Akay et al., 2008). The length of lifting cables ranges from 75 m to 100 m (Hui, 2001). There are various grapple control systems such as electrical, hydraulic, or mechanical. During hooking stage, a grapple or load hook should be dropped at the point where logs are located, which requires experienced and well trained pilots (Sloan et al., 1994). Generally, logs are pre-choked on the ground by choker setters. A logger, called hooker, grabs lifting cable and slides the chokers into the hook suspended below the helicopter (Figure 3). In some applications, lifting cable attached with double load-hooks that allow pilots to release part of the load when it exceeds the payload capacity (Krag and Clark, 1996).

The standing stem is another rigging system that can be employed to carry high value timber from the woods or to extract mature trees from environmentally sensitive areas. In this system, full length trees are extracted from the standing position (Dunham, 2006). Trees are first delimbed, topped by chainsaw, and cut at the bottom (cut up), then carried by using a horizontally oriented grapple (Figure 3). After picking up the logs, the helicopter moves up vertically to lift the logs off of the ground and over the forest canopy (Stampfer et al., 2002). Logging crew should always stay clear when helicopter is climbing up after loading for safety purposes.

(a) (b) (c)

Figure 3. The hooker attaching chokers to the lifting cable (a), helicopter grapple (b), cut up standing stem (c)

In the inhaul stage, helicopter caries the logs from the hooking point to the landing area. For each trip, logging helicopter should carry optimum payload which is slightly less than maximum load capacity (Akay et al., 2008). Payload capacity is mainly adjusted based on temperature and altitude. Christian and Brackley (2007) reported that the optimum payload for Sikorsky 61N helicopter is about 3400 kg when flying at elevation up to about 900 meters. It is more convenient to carry heavy logs when the air temperature is coolest and air is dense. It is also suggested that heavy logs should be extracted near the refueling cycle since total weight of the helicopter will be lower (Chua, 2001). At the final stage of yarding cycle, the pilot flies back to landing area and gently places the logs on the ground in the drop zone (Figure 4). Then, chaser releases the chokers from the hook at the landing. For operation take place in coastal regions, logs can be also dropped water drop zones located in salt water adjacent to harvest area (Figure 5). Water drop zones should be away from the main water traffic route. Minimum water depths in drop zone and log storage are 30 m and 20 m, respectively (BCTS, 2009).

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Figure 4. Placing logs on the ground (left) and releasing the lifting cable for next cycle (right)


Figure 5. Water drop zones used in helicopter logging

After releasing the logs, the pilot maneuvers the hook, clears the landing area, and returns back to the woods for the next turn. The yarding cycle usually continues for 60 to 90 minutes till refueling of helicopter (URL-1).

3. OPERATIONAL FACTORS

3.1. Yarding Distance

To perform productive and cost effective helicopter logging operations, logging managers should carefully determine the optimum flying (yarding) distance which is usually kept within two kilometers from the drop zone (Akay et al., 2008). Yarding distance can be defined as the flight path of the helicopter from the landing area to the harvesting unit. The main factors that affect yarding distance are elevation differences between landing and log pick up location, wind direction, and natural or manmade obstacles (i.e. hills, power lines, etc.) in the region (URL-1).

The flight distance increases as elevation between landing and log pick up point increases. Wind direction negatively affects operation, especially unhooking stage over landing area. The obstacles in the region prevents pilot to fly straight-line flight path. In order to minimize adverse effects of these factor, location of the landing area has to be properly determined prior to operation (Hui, 2001). Besides, enough space should be provided for piling logs, servicing helicopter, etc. at the landing area (Akay et al., 2008).

3.2. Weather

Helicopter logging is susceptible to poor weather conditions such as strong wind and fog. It becomes very difficult to operate logging helicopters during windy weather (more than 55 km/hr) conditions (URL-1). Foggy weathers cause serious problems when they affect visibility of pilots. Deep snow and heavy rain makes it impossible for ground team to work in woods. In order to minimize weather effects, helicopter logging operations should be carried out in late spring, summer, and fall seasons (Dunham, 2006). Besides, local weather broadcast should be regularly obtained to determine appropriate time for helicopter logging.

3.3. Crown Closure

The cycle time of helicopter logging is negatively affected by high crown closure because less wood is being removed from unit area (URL-1). In stands with high crown closure, longer chokers are used to collect logs from a greater lateral distances, which results in slower lifting operation. Pilots often spend longer time to find the hooker on the ground. Besides, pilots slow down the lifting operation to prevent residual stand damages.

3.4. Wood Availability

The helicopter logging is very productive extraction method; however, it is an expensive operation which requires proper planning, coordination, and monitoring activities (Hui, 2001). It is crucial to make optimum payload ready for each cycle to ensure high volume per turn and fast cycle times. First of all, felling crew has to select appropriate trees to be cut and buck them into log lengths considering payload capacity of helicopter. Then, choker setters pre-set chokers on available logs to be extracted. Finally, the hooker has to make sure that the helicopter is loaded by a full payload capacity for each cycle. Therefore, providing optimum payload for each cycle highly depends on wood availability in harvest area. It was reported that a wood availability of less than 80% is considered as low helicopter productivity (URL-1).

4. PRODUCTION RATES AND COSTS

Helicopter logging provides very high daily production rate comparing with other logging methods. Wang et al. (2005) reported that the production rate of helicopter logging was 1.5 to 2.8 times more than ground-based harvesting methods. The critical parameters that affect the productivity of helicopter logging include timber volume per unit area, stem volume, and optimum payload capacity (Heinimann and Caminada, 1996). A minimum amount of timber volume required for a helicopter logging is estimated as 10000 m^3, considering the cost of planning, reconnaissance, cruising and layout work (BCTS, 2009). The rated payload capacity of various helicopter types ranges from 1.2 ton (e.g. Eurocopter A-Star B2) to 12.7 ton (e.g. Boeing CH-234LR) per turn (Dunham, 2006). The actual weight of tree species should be considered since a m^3 of coniferous tree weight less than that of a deciduous tree.

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The production rate increases by an experienced ground crew and pilot (Hartsough et al., 1986). An experienced helicopter pilot potentially increases productivity by 63% (Stampfer et al., 2002). Besides, the productivity of the helicopter logging is affected by yarding distance which directly reflects cycle time. Average yarding distance is usually under two kilometers, but it may slightly vary based on helicopter types. For example, optimal yarding distance is 600-800 m for Skycrane helicopters while it is about 1000 m for Bell 214B helicopters (BCTS, 2009). The production of helicopter logging is also affected by rigging systems. It was reported that productivity of load-hook system is 20-30% more than a grapple system, and 5-15% less than standing stem system (Dunham, 2006).

The helicopter logging is generally more expensive than ground-based harvesting systems due to high ownership cost, operating costs, and higher labor costs of felling crew (Akay et al., 2008). The ownership and operation costs of logging helicopter comprise half of the total harvesting cost (Dunham, 2006). Hui (2001) reported that helicopter logging cost is twice the tractor harvesting cost under similar difficult terrain conditions.

The cost of helicopter logging is mostly affected by the loading operation, flying distance, and pilot experiences (Sloan et al., 1994). In another study, Sloan and Sherar (1997) reported that the main factor affecting the operation cost was estimation of suitable payload sizes. To overcome the high costs, the amount of material removed per turn should be maximized and the time per turn has to be minimized (URL-1).

5. ENVIRONMENTAL CONCERNS AND WORK SAFETY ISSUES

Helicopter logging provides logging managers with advantages of environmentally friendly harvesting practices and safer work conditions for the loggers. Besides, it enables access to unreachable areas due to extreme terrain conditions or remoteness from the road network (Bruce, 2003). Helicopter logging can be only option to extract mature trees in environmentally sensitive areas where road construction and logging operations are restricted (Akay et al., 2016).

Table 2 indicates comparison of some harvesting methods with respect to environmental concerns and work safety issues. Using helicopter logging reduces soil disturbance, minimizes sediment yield to streams, and protects water resources by reducing forest road, skid trails, and cable corridors (URL-1).

Table 2. Comparisons of various harvesting systems (adapted from Akay et al., 2016)

	Helicopter Mi-8 MTV	Skidding CAT TT-4	Cable system ML-43	TJ Harvester1270 TJ Forwarder 1110
Forest roads, check	-	√	√	√
Undergrowth damage, %	0	80	75	60
Soil deterioration, %	0	100	80	100
Noise affect, %	100	100	50	100
Safety of work, %	0	50	80	50

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Compared with ground-based harvesting methods, helicopter logging increases the woody biomass regrowth and minimizes undergrowth damages (Aust and Lea, 1992). Besides, it reduces damage to residual trees and forest vegetation, especially during selection cutting systems. Thus, helicopter logging can be implemented as reduced impact logging system especially in environmentally sensitive areas such as high-use recreational areas, special wildlife areas, archeological sites, and sensitive landscapes.

In terms of work safety and occupational health issues, helicopter logging cause potential noise effects on loggers. Logging crew should be provided with necessary ear protection equipment during operations. The ground team always needs to stay clear of flight paths. The landing areas are the most risky area during helicopter logging; thus, it should be properly organized and should have enough space to ensure an efficient and safe logging operation (Akay et al., 2008). According to OSHA requirements, drop zones should be at least twice the length of logs and located at least 40 meters from the loading and decking area. Besides, number of loggers on the landing area should be kept to a minimum during dropping logs (Hui, 2001).

If there is powerlines around harvesting unit, landing areas and log pick-up points should be at least 60 meters away from the power lines (URL-1). Poor weather conditions increase the risk of accidents due to mechanical failure or inexperienced pilots (Figure 5). The helicopter should be regularly maintained to prevent mechanical failures during flights.

Figure 5. A logging helicopter crashed in Oregon at a logging site

6. CONCLUSION AND SUGGESTIONS

It is highly anticipated that helicopter logging operations have great potential to improve forest operations and protect forest ecosystems especially in environmentally sensitive areas in Turkey. Besides, helicopter logging may be the only option to solve timber extraction problems in protected areas and difficult terrains with steep slope. Helicopter logging provides important advantages over ground-based harvesting methods regarding with reduced impact logging procedures. The total forested area affected during logging operations is reduced by helicopter logging. Helicopter logging results in minimal damages on residual stand and other forest vegetation. Helicopter logging requires less road constructions which

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reduce damages on forest soil and minimize sediment yield to water bodies. Besides, visual impacts from harvesting operations can be minimized by helicopter logging.

By implementing helicopter logging, it is possible to extract longer and larger logs with high quality and sale price, while it is not possible to extract those logs using ground-based harvesting methods or to transport them through low-standard forest roads in Turkey. Forested areas located in remote and difficult terrain cannot be reached through ground transportation while these areas can be accessed by helicopter logging. Also, helicopter logging operations provide better working conditions and ensure worker health and safety.

The disadvantages of helicopter logging include lack of well-trained and skilled loggers in forest industry in Turkey and potentially high initial purchase price and operation costs of helicopters. Although there are several helicopter companies that produce special helicopters for logging operations there is still need for alternative types of helicopters to improve productivity and reduce total cost of helicopter logging operations.

Helicopter logging operations are highly susceptible to windy and rainy weather conditions. Besides, helicopter logging requires relatively large landing areas that should include well-organized drop zone, enough storage area for piling logs. Thus, helicopter logging demands for very strong and professional operation coordination in order to implement cost effective and environmentally friendly logging operations.

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CAN LOGGING BE BETTER ORGANIZED IN ENVIRONMENTALLY SENSITIVE AREAS: A CASE STUDY OF IHSANGAZI FOREST DIRECTORATE

Arif Oguz Altunel*, Çiğdem Özer Genç, Pakize Torun

Kastamonu University, Faculty of Forestry, Department of Forest Engineering, 37200 Kastamonu, Turkey. Tel: +90 366 2801712 Fax: +90 366 2801038
E-mail: aoaltunel@kastamonu.edu.tr*

ABSTRACT

The initial phase of forest operations, timber extraction (logging), involves felling of timber and removing them out of the stands. This phase of forestry, if not planned and supervised properly, is the reason for various adversities one never expects happening in forested areas, such as erosion, sedimentation, soil compaction and displacement, etc. Human intervention introducing the above-mentioned undesired effects starts with furnishing the forests with forest roads for administrative purposes. Other things set aside, forest roads originated erosion is related to "physical factors" i. e. soil type, geology and climatic factors, "road density", "road location" and "road standards". Studies show that the initial increases in erosion following road building subsides and the figures come to normal levels due to the facts that good road building practices were employed and exposed slope cuts and embankments got stabilized. Logging on the other hand, is a never ending process which will happen here and there as the forests continue to exist. That's why this unavoidable part of forest management demands operational planning in micro level because especially edaphic and topographic factors differ tremendously in close distances. Although extensively taught in schools, logging is contracted and practiced relatively unprofessionally in Turkey and creates far more serious circumstances to soil and the environment. In the scope of this study devised following a logging operation which occurred in Ihsangazi Forest Directorate in the spring of 2015 after an unexpected windstorm had swept a 100+ years old Scots pine forest in February, 2015, what an unplanned logging operation would do to forest soil in an environmentally sensitive area.

Keywords: Operational Planning, Skidding Route Planning, Soil Compaction

1. INTRODUCTION

Forest soils will be much more extensively utilized as the demand for forest product continues to increase, and the amenities (aesthetic, ecologic, social, etc.) forests provide, are enjoyed by people. Forest management practices such as shortened rotation cycles, the introduction and adoption of fast growing hybrid species, mechanical and chemical site preparation techniques, abruptly executed logging operations might have dire effects on soil and water quality (Young and Giese, 1990). Site preparation generally refers soil displacement techniques formulated to disseminate or eliminate the logging residue or any other type of organic/inorganic debris, control weed or fast growing unwanted plant competition, prepare a mineral bed for seeds to take hold, reduce compaction and improve better drainage, create more preferable microhabitats for planting tree, and keep the diseases at bay.

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Improper and hastily materialized road building techniques, whether haul or skid roads, have often been cited as a primary cause of sediment movement toward lower elevations where a stream drains most of the time in mountainous areas (Eroglu, 2012). Accelerated surface erosion on severely disturbed soils i.e., forest road construction or a logging site is the highest immediately after disturbance (Gorcelioglu, 2004). Logging most certainly contribute to increased accumulations of sedimentation in perennial streams, lakes and reservoirs by disturbing the forest floor, especially during timber skidding. Skidding of timber with tractors, which is the predominant method of transporting logs off the forest tracks in Turkey and any type of rubber tired vehicles causes soil erosion and sediment movement and extensive soil displacement compared to other types of logging methods in which the logs are hoisted off the ground i.e., cable cranes. Logging on wet or saturated soil creates situations that must be avoided at all cost if proper timber harvesting techniques could not be employed. Although there are simple measures like deflating some of the air form rubber tired skidding tractors or hauling trucks/trailers so the enlarged tire footprint better disperses the dragged or carried heavy load to the already weak soil or not so high quality forest road so the degree of deterioration can be kept to a minimum (Altunel and deHoop, 1998), there is no hauling truck or logging machinery in Turkey equipped with a system like Central Tire Inflation, which could do such changes in minutes. On the other hand, soil strength and bulk density which are the common variables when checking for soil compaction, were reported to remarkably increase on untreated skidding lanes even after a couple of trips rubber tired tractors make between the felled tree and road side landing. Especially, in the first 10cm of the mineral soil, soil strength increase ranged from 43 to 139% depending upon the number of trips (Akay, et al., 2007). However, under extraordinary situations where an unpreventable insect infestation or an unexpected wind storm causes extensive damage, and an immediate salvage attempt needs to be performed, then some harvest planning, although not expected to address all concerns, might still ease up the ill effects of a hastily executed logging operation. The utilization of specialized logging systems or implementation of well-organized planning can result in lower costs and acceptable/quickly remedied environmental impacts when compared to one size-fits-all kind of approach (Bayoglu, 1996).

Organizing logging which will minimize or to some degree eliminate the ill effects of it can only be achieved if all conditions considered such as size of the track to be harvested, accessibility to and from the track, type of logging machinery to be used, the number of machinery to be used at one time, the volume to be harvested, tonnage of a single load to be skidded, minimum and maximum skidding distances, landing locations, slope, elevation, the length of the harvesting season, etc. are known and orchestrated through an operational planning. Thus, while the output is optimized to the highest achievable level, many environmental constraints would have been taken into account (Eker, 2004).

Unfortunately, caring for the environment is not an issue taken very seriously in Turkey. Being the educated professionals, even forest engineers and foresters are not concerned about the aftereffects of their routine practices. Natural disasters like wind and snow are frequently and unexpectedly affecting forests in unprecedented ways. In average, four mill. m^3 of timber are lost to heavy snows in Europe annually (Nykanen et al., 1997). Two separate wind storms ravaged 7 mill. m^3 of timber in Finland in 2001. In 2010 again, four consecutive summer storms devastated a total of 8 mill. m^3 of timber (Gerendiain et al., 2012). In March 15th of 2013, a severe wind storm hit Kastamonu Regional Forest Directorate and caused 1.6 mill. m^3

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of damage in six enterprises. When the nature calls, there is not much that can be done to prevent what's going to happen. However, when cleaning up the mess, we should not create any additional problems that will affect the environment we live in. This study outlined the aftereffects of a logging operation practiced, following a wind storm in a critical location.

2. MATERIAL AND METHODS

2.1. Study Area

The study was conducted within the administrative boundary of the Ihsangazi Forest Directorate, which is a part of the Ihsangazi Forest Enterprise within Kastamonu Regional Forest Directorate. An unexpected wind storm with gusts reaching up to 50-55 km/h on the evening of February the 8th, 2015 swept through in and around central Kastamonu township. Consequently, the same storm affected and did moderate level damage on the forests of Ihsangazi Forest Directorate. The data were collected from a picnic site situated along Kastamonu-Karabuk provincial highway housing an old, 90-112 years, Scots Pine stand. The geographical location of the directorate and the locations of the fallen trees through which this study was conducted are given in Figure 1.

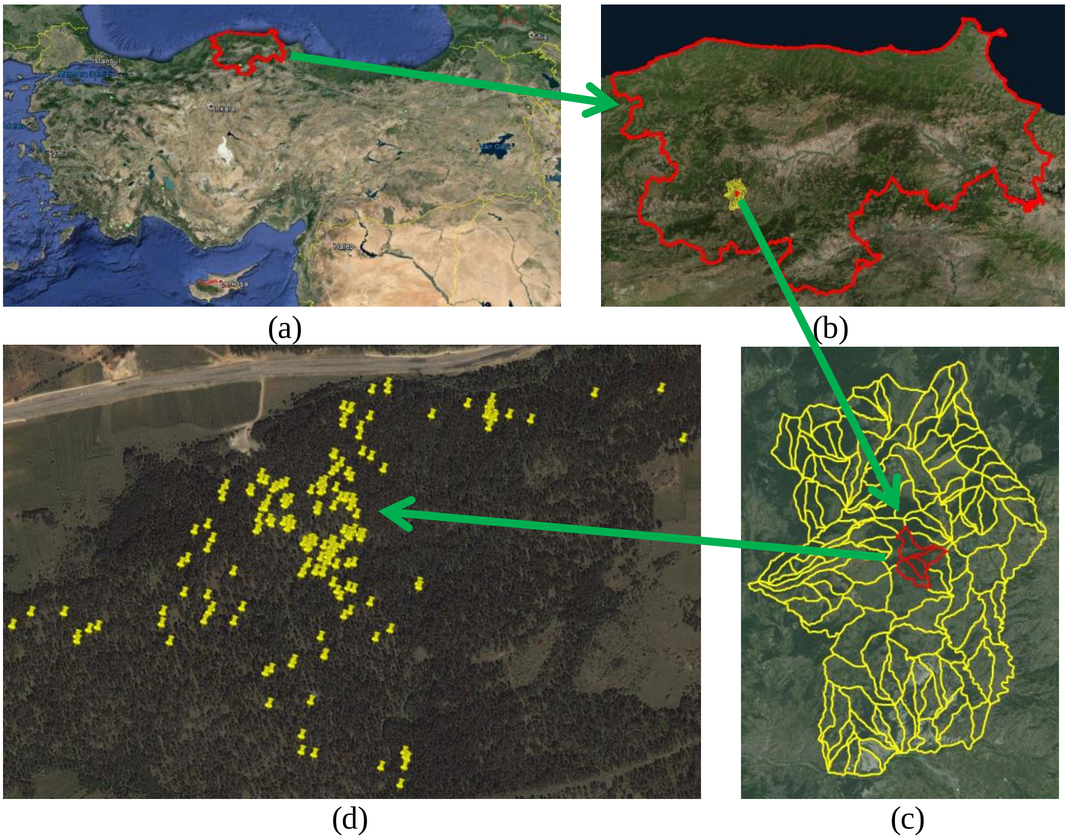

Figure 1. Kastamonu Regional Directorate (b), Ihsangazi Forest Directorate (c), Fallen trees (d)

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2.2. Methods

Occasional wind and snow damage, degree of which varies depending on the time of a year, cause losses on the forests of Kastamonu Regional Forest Directorate. In 2013, a serious late winter storm caused extensive damage, ravaging 1.6 mill. m^3 of timber in six forest enterprises of the directorate. The damage caused by the localized storm of February the 8th, 2015 affected predominantly the compartments of Ihsangazi Forest Directorate within Ihsangazi Forest Enterprise. When the news reached our faculty, a team of scholars mobilized and visited the compartments the next day. It was seen that the damage got concentrated along highways and forest roads where road orientation related to wind direction is known to exacerbate the effects of wind speed, turbulence formation, relative humidity and soil drying tendencies (Forman, Sperling et al., 2003).

When the compartments along Kastamonu-Karabuk provincial highway checked, it became obvious that the fallen trees were in close proximity to one another and the ground was waterlogged. When we traced from the edge of the waterlogged area, we noticed there an excessive amount of ground water surfacing within the area (Figure 1).

Figure 1. Waterlogged ground and fallen trees

The data pertaining to the fallen trees such as dbh, length of tree, green stem height, fall direction, crown dimensions, etc. were recorded in order to established a significance between the stand dynamics and the sylvicultural treatment being applied in the area. Also, a Global Positioning System (GPS) coordinate from each root hole and stem butt in order to establish the distribution pattern of the fallen trees was taken and a point cloud was generated. When we intersected the point with waterlogged area, we saw that >80% of the fallen trees were inside this area. When collecting the data (Figure 2), we figured the authorities would have difficulty because the forest soil was beyond any acceptable condition to perform any ground based logging. After checking with the responsible engineer we learned the fact that no cable crane was available anywhere in Kastamonu Regional Forest Directorate, nor was there any in the neighboring directories. We thought it would be a real test for foresters to salvage the wood because the common application

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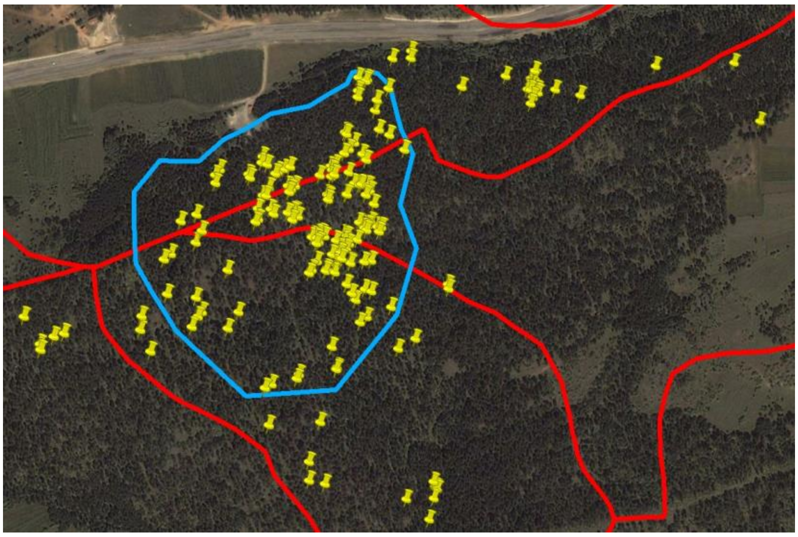

Figure 2. The concentration of the fallen tree in waterlogged area (in blue), compartment borders (in red)

in Turkey if some unexpected natural or unnatural situation causes damage to forests, it would be best for the sake of the timber to be salvaged or the residual stands, to do the wood extraction in the earliest possible time available (Ozcan, 2009).

When the timber extraction and the salvage operation were over two months later, we revisited the site and saw the logging operation created an environmental disaster because the impossibilities forced the responsible engineer to go with the ground operation, which devastated the forest floor beyond recognition (Figure 3). After seeing the aftermath of one of the worst logging jobs, the skidding routes that were used during the extraction operation were traced, using a GPS and were superimposed over Google Earth to calculate the length of the disturbed forest soil (Figure 4).

Figure 3. Heavy soil damage after timber extraction

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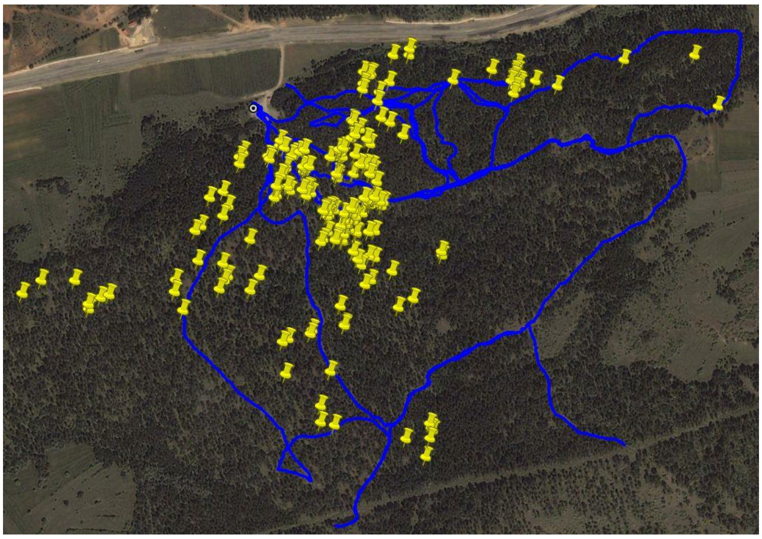

Figure 4. The extend of skidding roads used during timber extraction

3. RESULTS AND DISCUSSION

3.1. Results

GPS tracking showed there was heavy soil damage along 7.3 km of skid trails which were recklessly laid out inside the area during logging operations. The width of the trails was approximately 1750 mm since same type of farming tractors were used to drag and skid the logs to the landing. We calculated that 1.2775 ha of forest soil were severely damaged from an area of 50 ha in which the salvage operation had taken place. It was reported that ground based harvesting created definitive skid trails on the forest soil during timber extraction, and the area adversely affected in this process amounted to 18 to 36 percent after a single harvesting attempt. Repeated entries could most certainly increase the area up to 80 percent of the entire harvested track (Froehlich, et al., 1981). Data showed heavy soil damage concentrated along skid trails amounted on 2.55 percent of the entire harvest track. Whereas, inside waterlogged area, skidding trails were concentrated within a tighter 16.2 ha area, and GPS tracking showed 5.302 km of skid trails were present. Concentration of soil damage inside waterlogged area amounted to 32.7 percent. Whereas, the alternative skid trails that could be devised through Google Earth showed that no more than 3 km of would have been needed to keep the degree of inevitable soil damage at bay (Figure 5). The situation also created heavy soil displacement and compaction problems inside the stand. Compaction is known to create problems ranging from insufficient aeration of the roots to bad drainage so the transmission of the air, water and nutrients to the plant itself is hindered, and plant development in the long run is adversely affected (Savacı and Sariyildiz, 2015). To assess the degree of the compaction, we created a 20x20m grid oriented to North and intersected it with the laid out skid trails (Gorman et al, 2001) (Figure 6), and a group of grad students were taking penetrometer measurements from the first 20 cm of the mineral soil with 5 cm intervals. To increase the amount of sampling, we selected the grid cells diagonally intersected with the skid trails, and random undisturbed soil samples were also being taken throughout the area. Unfortunately, the results of the penetrometer measurements could not be made ready to for this study.

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Figure 5. Google Earth devised skidding roads

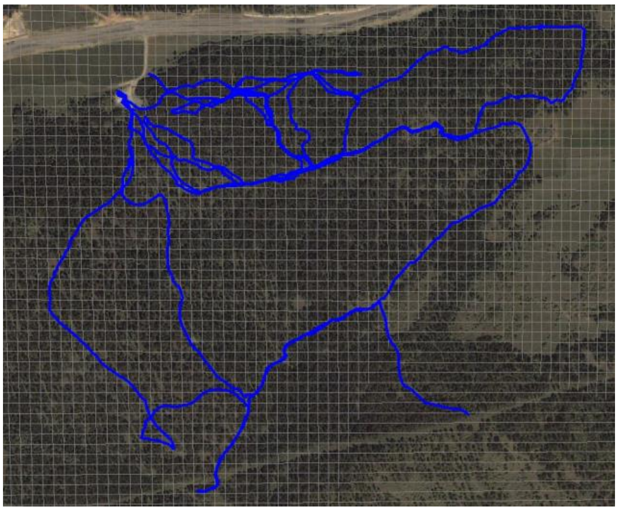

Figure 6. 20x20m grid intersected with skidding roads used during timber extration

3.2. Discussion

When routine timber cruising or the ones performed after such unexpected situations is done, the responsible forest engineer announces the operation. The interested parties i.e., forest cooperatives, villagers, etc. accept the invitation, and the job is scheduled. Whenever the job begins, the track to be harvested and the operation to be carried out are handed over to the loggers supervised be the forester the operation in conjunction with the loggers. Turkish forests are administered, regarding the principles of ecosystem based forest management, so multiple usage is intended. Besides production, ecological and sociocultural functions of forests which guarantee the wellbeing of all living creatures are also strictly defined (Teblig #299). However, the practices on the field are overwhelmingly timber production oriented, which knowingly or unknowingly undermines any other function. In such cases, easily avoidable problems become major issues that need whole new approaches to be remedied. Designated skid trails, which could have easily been planned and applied on tracks to be harvested, can limit the degree of soil damage. Strategically placed bedding also can also limit

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the damage and allow the site to ameliorate itself quickly (Aust, et al., 1997). Careful directional felling will as well ease up the skidding and limit the damage to logs since they will be oriented to the laid out skid trails (Hendrison, J., 1989). Logging is the final and maybe the most important part of forest management because the long awaited timber and the site nourishing it are at stake. It needs constant supervision and guidance to get the job done properly. The achieved knowledge and expertise in forest management today are well defined and practical for anyone to easily follow, that’s why the invaluable building blocks of the entire Turkish Forest Service, the forest engineers need to be as sharp and aware as possible while performing their duties because solely timber production should not be the only agenda on their mind.

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CAN OPERATIONAL PLANNING HELP CUT THE COST OF LOGGING: A CASE STUDY OF IHSANGAZI FOREST DIRECTORATE

Arif Oguz Altunel*, Çiğdem Özer Genç, Pakize Torun

Kastamonu University, Faculty of Forestry, Department of Forest Engineering, 37200 Kastamonu, Turkey. Tel: +90 366 2801712 Fax: +90 366 2801038
E-mail: aoaltunel@kastamonu.edu.tr*

ABSTRACT

There are roughly 7 to 8 million people, called forest villagers, living in or around state forests in Turkey today. Their means of making a living for themselves and their immediate families are totally depended upon the possibilities and opportunities generated by the forest service and its subordinate enterprises, directorates, etc. The forest service is bound by Turkish constitution to offer such opportunities to these people. They form forest cooperatives, not very specialized logging companies, to carry out the forest operations starting from tending the stands in every stage of management practices to hauling the timber to log yards or mills. This is how they make a living, besides they are the first inline benefiting from none-wood forest products available to general public. After the completion of such an operation, the villagers are paid as per cubic meter of volume they process and deliver. The stages of such an operation involve felling the timber, debranching, debarking and bucking it on site, then skidding to roadside landing, finally loading to transport vehicles. Since the timber to be harvested is already stamped and taken a dbh reading during timber cruising, the responsible engineer already knows the approximate cubic meter of volume, which would be delivered to log yard. What he/she does not know is the exact location of particular trees so he/she relies upon the operation sheets delivered to him/her by the loggers after the completion of the operation. A simple GPS reading for each tree during timber cruising, which will be incorporated with certain criterias such as type of species, coniferous vs broad-leafed, slope gradient, average length of skidding distance, etc. affecting the final payment at the end of the operation will help him/her almost finalize the cost of such operation even before the first logger sets foot on the stand. This particular study will compare the skidding cost of removing a windtrown stand in Ihsangazi forest directorate to a hypothetical operation in which the locations of each tree to be harvested is known.

Keywords: Operational Planning, Global Positioning System, Google Earth, Timber Cruising

1. INTRODUCTION

Logging, when thought conceptually, include all regulations and restrictions formulated while accessing a forest, transporting the mechanization means to it and extracting the timber out of it, by minimizing or eliminating the mishaps which might likely occur over the soil, within the stands and on the environment. Thus, forests will properly be managed, and economical and social gain will sustainably be supplied over the long run. The facilities that exploit forests are classified in two groups: 1) Primary forest transport facilities involving skidding roads and lanes, and mobile cable cranes and 2) Secondary forest transport facilities involving haul roads and sled type cable cranes.

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The progression especially in Turkey has brought the current forest road network to a point that as of today; roughly 160000 km forest road has been laid out within 22343000 ha forest area. Through this road network, accessibility to any forest track, stand, area, etc. are becoming rather easier from the foresters' perspective. Although the existing roads and the planned ones to be constructed in the future are the indispensable parts of any forest management and related activities, they are considered as the most costly and dire undertakings within the forests economically and environmentally. Studies have shown that maintenance to existing road network is a much better approach to accomplishing the objectives of the secondary forest transportation without putting additional constraints into the environment (Lugo and Gucinski, 2000). Besides, forest roads are the proven culprits of sediment transportation to waterways (Binkley and Brown, 1993)

Timber production in forestry has long been plagued with high operational costs. Logger wages, higher investment and uncontrollable operational costs, longer primary transport means, etc. all contribute to these. Thus, a planning regime dictating how, where, when and in what way workforce and machinery will be utilized, how much wood will be harvested, what type of logging means (animal, human, machinery) will be employed, where timber will be hauled, if topography will be an issue to overcome, must be organized individually per operation (Eker, 2004).

Planning in forestry can be conceptualized in three approaches; long (strategic), intermediary (tactical) and short (operational). Operational planning at this point might help timber production reach the intended targets. Timber production, aka logging, in Turkey is traditionally conducted, employing brute human, animal and partially machine power. Mechanization is still not fully embraced throughout the country, that's why the country wide percentage of it was given at 13% in 2010 (Demir, 2010), and it is still possible to encounter logging operations running primarily on human and animal power. It is a widespread phenomenon both in Turkish timber production and Worldwide that there are unaccounted and undermined losses and degradation on produced timber quality, forest soil, wildlife habitat, water resources and within residual stand.

During manually oriented timber productions that the overwhelming majority of Turkish logging operations are, noticeable residual stand disturbances to the amount of 50% up and along the skid trails were reported in Northern Belize (Whitman et al., 1997) and even more up to 70% in Southwestern Nigeria (Adekunle and Olagoke, 2010). When skid trails were repeatedly used, the resulted soil compaction has long been known to decrease the likelihood of new seedling germination. Logging and forest road building also contribute to habitat loss for wildlife and fragmentation. Carnivores especially are reported to be hard hit. Studies showed disturbed rainforest tracks became rather disliked grounds for mongoose to live in (Gerber, et al., 2012). Although there is no study documenting the effects of such forest management activities on wildlife in Turkey, forest transportation and logging practices as they are performed today, made us think why the situation would be any different. Last, but not the least, logging is considered as a nonpoint source of pollution creating sediment movement causing dire influences in waterways' temperature, dissolve oxygen concentrations and the amounts of suspended material (Binkley and Brown, 1993). Except a few, since the main agenda in Turkish forest management is predominantly timber production, the above mentioned negative impacts are mostly underestimated.

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Forestry and its derivatives are considered as a lesser category under the broader agriculture sector in Turkey. Their contribution to Annual Gross Domestic Product (GDP) is around 0.7%, and operational expenses are rather high. Annual average operational expenses in producing a cubic m of timber in Turkey cost more than 25% of the general management expenses of the Forest Service. At this point, an orchestrated planning regime might help ease up the difficult and high logging costs.

Although the forests have long been owned and professionally managed by the State Forest Service, the same level of professionalism is nowhere to be seen in timber harvesting. Logging is the primary source of income generation for almost 8 to 9 million people, called forest villagers, living in or around forests or forest land. Forest service is bound by the national constitution to create possibilities for this people to make a living. Since the majority of Turkish forests are standing on unfavorable, mountains grounds, there is pretty much no other way i.e., husbandry, raising livestock, etc. for these people to raise income, but grasp any forestry and its derivatives related opportunity offered by the Forest Service.

The level of expertise and professional knowledge to carry out an arduous task like logging which is considered as one of the most dangerous jobs one can handle (Enez, et al., 2014), is fairly low, so the above mentioned ill effects cannot even be comprehended by them. However, through the raising awareness towards certification for both the operations undertaken and the products offered to the domestic markets, some degree of know-how is finally available for Forest Sector to grasp. Forest Stewardship Council (FSC) is the common norm of certification in Turkey. Practical applications in any phase of the forest management, just like the US's Best Management Practices, have the potential to correct the mistakes. Since its inception in 2009, Bolu Aladag Forest Directorate has been the first state forest administration earning the FSC certification in 2010. The feedback from the actors in every aspect of forest management, concerning the certification and its derivatives were reported positive (Türkoğlu and Tolunay, 2014). Since the degree of professionalism being brought by various initiatives like certification is rather limited, the wide extend of Turkish forest management practices still needs stiff guidance which will be instructed by the foresters, aka state forest engineers who is responsible for an administrative unit, forest directorate.

In the scope of this study, it was shown that simple level of operational planning that would easily be achieved through the effective use of some common technological advancements like Google Earth and Global Positioning System (GPS) would change our understanding from forestry.

2. MATERIAL AND METHODS

2.1. Study Area

The study was conducted within the administrative boundary of the Ihsangazi Forest Directorate, which is a part of the Ihsangazi Forest Enterprise within Kastamonu Regional Forest Directorate. An unexpected strong wind storm with gusts reaching up to 50-55 km/h on the evening of February the 8^{th}, 2015 swept through in and around central Kastamonu township. Apparently, the same storm affected and did some to moderate level damage on the forests standing inside the various compartments of Ihsangazi Forest Directorate. The data

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were collected from 4 neighboring compartments housing an old, 90-112 years, Scots Pine stand. The geographical location of the directorate and the compartments in which this study was conducted are given in Figure 1.

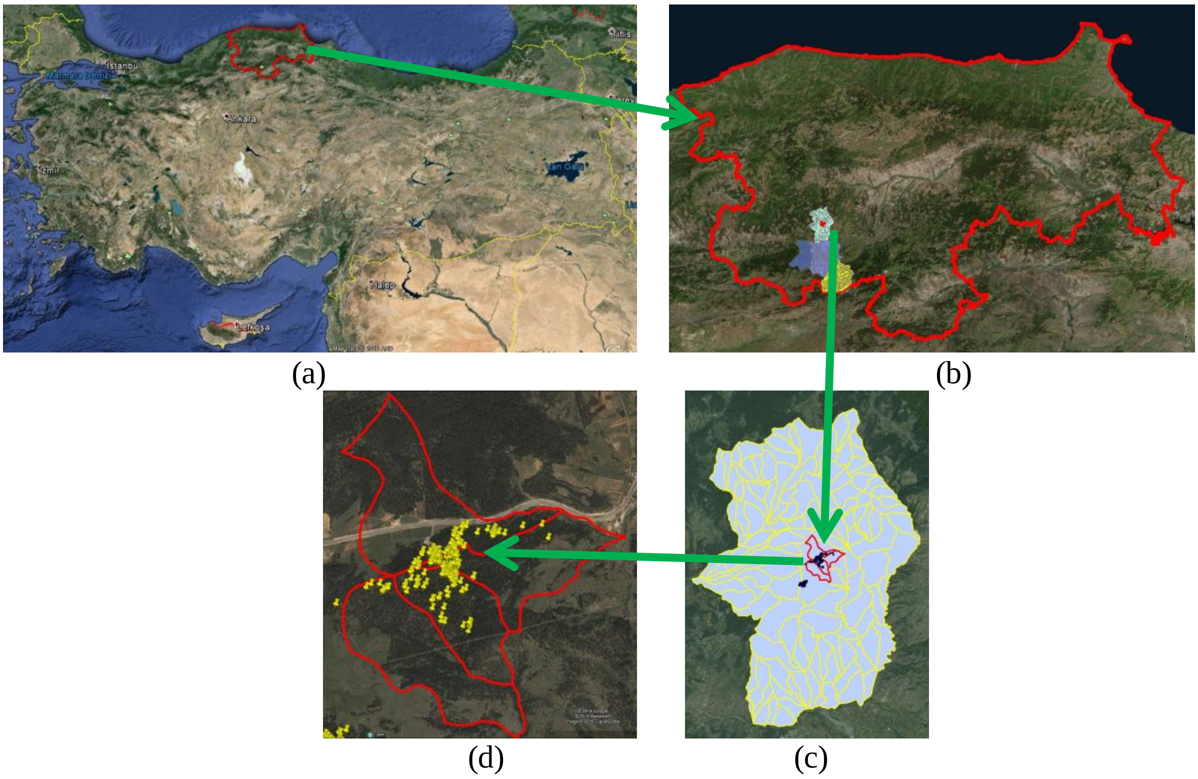

Figure 1. The geographical location of Kastamonu Regional Directorate, Ihsangazi Forest Enterprise and Its' directorates (b), Ihsangazi Forest Directorate (c) and Studied compartments within Ihsangazi Forest Directorate (d)

2.2. Methods

As mentioned previously, a localized storm swept through the region on the evening of February the 8^{th}, 2015. Information stating that moderate to extensive level of wind-thrown stands were scattered especially within Ihsangazi Forest Directorate reached our faculty the next day. In such extraordinary situations in which trees are uprooted, leaned to a side beyond recovery or broken, etc, the accepted course of action as the case in many other countries is to remove and salvage the damaged trees as early as the seasonal conditions allow. These need to be completed before any insect infestation might occur, jeopardizing the remaining and surrounding forests (Ozcan, 2009). Since the season was still winter and the ground was saturated, it was heard from the forest director that the salvage operation would still wait for another month so this gave us time to collect the data properly (Figure 2).

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Figure 2. Fallen trees in Ihsangazi Forest Directorate

Along with the individual tree measurements like dbh, length of tree, green stem height, fall direction, crown dimensions, etc, in order to establish the distribution pattern of the fallen trees, we took a Global Positioning System (GPS) coordinate from each and every fallen tree root hole and stem butt in case the tree got leaned over or broken. Although the GPS device that we used was a hand held and had an inherent error margin of 3 m on any direction, we undermined this fact with the validation of the reasoning that the same error would affect the entire point cloud at the very end and would not make any adverse effect on the distribution pattern. We wanted to see the distribution pattern of the fallen trees because we knew the stand we took the data was subdivided into various compartments through which the transportation calculations were individually made. The Ihsangazi Forest Directorate's vectorized compartment map along with other administrative data was obtained from the Kastamonu Regional Forestry Directorate. It was intersected with our fallen tree point cloud and superimposed over Google Earth to question our scenario.

3. RESULTS AND DISCUSSION
3.1. Results

Logging in Turkey is not as professionalized as it is in many other countries including the US, Canada, and many of the European countries. It was performed by the forest cooperatives established by the members of the neighboring forest villagers. Majority of these cooperatives, although there are a few big and better equipped ones, are inferior both expertise-wise and mechanization-wise. Loggers have no formal education as to how the task has to be performed. That's why the accident rate is rather high (Enez et al., 2014).

When the management plan dictates any cubic m of annual cut from a compartment and the seasonal conditions permits, the responsible forest engineer goes to that particular compartment and does the timber cruising. During timber cruising, all the responsible engineer does is to wander around the stand and pick the likely candidates for removal without harming the stand dynamics and crown closure. A "dbh" measurement is taken from the selected tree and a cut is made to the butt of the tree, on which a number is written or stamped. The numbers are tallied along with the corresponding "dbh" on a standing volume sheet.

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After the timber cruising is done, the responsible forest engineer announces the upcoming operation. The priority of undertaking the job is given to the adjoining forest village, villagers or cooperative, if there is any by default, because these people or cooperative with its members are first in line for living around the job advertised by the state forest administration. If the neighboring villagers do not want to perform the logging job, then outsiders might be invited.

Cutting, delimbing, debarking and bucking the timber into merchantable dimensions which is priced through another calculation is categorized under 12 types of products. They are as follows:

Product Type	Pricing
Debarked Pulp Wood	TL/m^3
Timber > 5m	TL/m^3
Utility pole (7-8 m)	TL/m^3
Utility pole (9-11 m)	TL/m^3
Utility pole (>11m)	TL/m^3
Mine pole (8-18 cm diameter)	TL/m^3
Large diameter industrial	TL/m^3
Small diameter industrial	TL/metric cord (aka STER*)
Pulp wood with bark	TL/metric cord (aka STER)
Wood for particle board	TL/metric cord (aka STER)
Stake or sapling	TL/metric cord (aka STER)
Firewood	TL/metric cord (aka STER)

** STER is 1.10 cm high stacked wood which was previously cut into a meter in length segments*

Unit pricing per cubic meter of timber, which would be paid to loggers for skidding the processed logs from the harvested track to the roadside landing, which is the focus of this study is calculated, using the formula below (1);

$$Unit\ Price = HBM/60 * HCZ + IBM/60 * ICZ \quad (1)$$

where HBM: Cost of Pack animal or Machinery (issued by the State every year)
HCZ: Pack animal or Machinery working time (overall work time of the logging operation from start to end in minutes)
IBM: Cost of a logger (issued by the State every year)
ICZ: Logger working time (overall work time of the logging operation from start to end in minutes)

Two other independent variables entering the above calculation are the slope and skidding distance. Slope is categorized in four intervals: 0-30%, 31-60%, 61-100% and >100%. Skidding distance is chosen as half of the longest dimension of the harvested compartment perpendicular to the roadside landing.

Under normal circumstances where timber cruising is done homogenously throughout the compartment skidding distance is objectively calculated most of the time. However, in

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extraordinary situations for which this study was formulated, skidding distance varies tremendously so simply fixing the figure to some average creates disadvantages for the loggers.

To test our hypothesis of if "operational planning helps cut the cost of logging" we took a Global Positioning System (gps) coordinate from each and every fallen tree root hole. We wanted to see the distribution pattern of the fallen trees because we knew the stand we took the data was subdivided into various compartments through which the skidding calculations were individually made. The Ihsangazi Forest Directorate's vectorized compartment map was obtained from the Kastamonu Regional Directorate. It was intersected with our fallen tree point cloud and superimposed over Google Earth to question our scenario.

Position coordinates from 156 out of 214 damaged trees were distributed on the vectorized compartment map, then groups of fallen trees were clustered, a skidding road route was laid on Google Earth (2.15 km), tree clusters were tied to this route and new skidding distances were calculated for each cluster as shown on Figure 3.

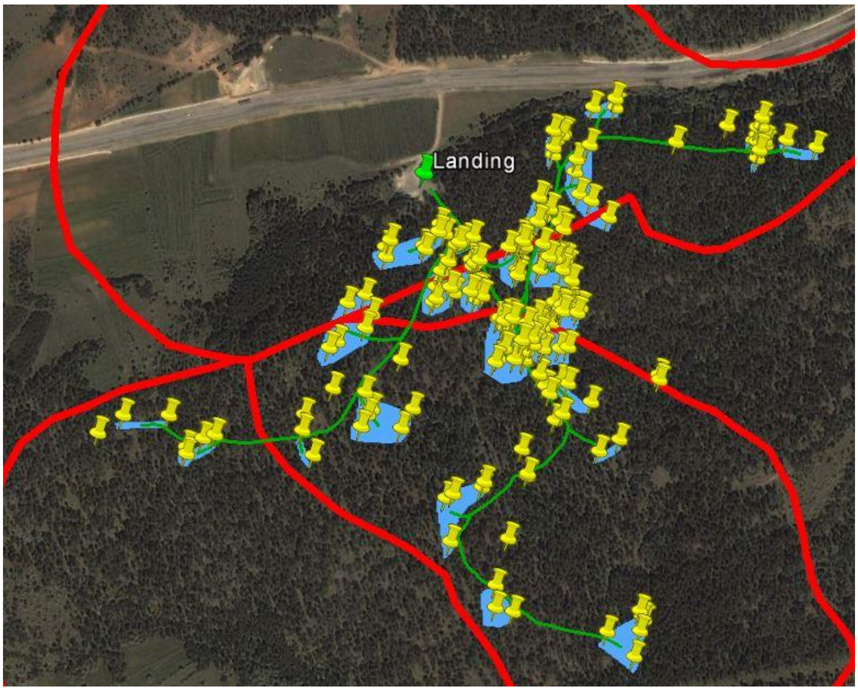

Figure 3. Point cloud of the fallen tree locations (yellow), distribution over four compartments (red), grouped trees (blue), skidding road route (green) and landing

The calculations were made, using the algorithm (1) Forest Service is mandating in each administrative unit, and the following results were acquired in Table 1. State calculations based upon a single skidding distance, whereas we used multiple skidding distances as measured on the Google Earth, starting from the middle of the clustered trees (blue areas on Figure 3) to the landing through the laid out skidding route. There appeared to be a 22.5% missing allocation in the amount paid to the loggers.

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Table 1. The difference in the earnings as a result of skidding

Unit price (TL) per cubic m of wood skidded (**based on timber >5m)**								
State unit price paid Comp#82	Total Volume Skidded #82	State unit price paid Comp#83	Total Volume Skidded #83	State unit price paid Comp#84	Total Volume Skidded #84	State unit price paid Comp#85	Total Volume Skidded #85	Total Earnings
14,23	**9,478**	35,58	**99,712**	28,46	**77,448**	18,98	**55,815**	
Total Earnings per Compartment	**134,87194**		**3547,75296**		**2204,17008**		**1059,3687**	**6946,16368**
New scenario unit price (TL) per cubic m of wood skidded (**based on timber >5m)**								
62,81	3,599	84,15	11,313	20,02	7,238	26,09	8,85	
55,69	5,879	68,78	4,608	38,9	11,639	28,65	12,181	
		56,55	7,105	66,89	8,596	14,8	10,87	
		26	27,892	66,41	5,181	16,51	8,333	
		26,09	19,825	11,39	5,483	20,02	13,869	
		30,83	8,082	12,71	20,048	16,51	1,712	
		37,76	9,744	30,83	4,261			
		44,12	0,387	45,54	6,619			
		34,72	5,311	52,37	4,122			
		42,69	4,658	75,14	4,261			
		44,12	0,787					
	9,478		**99,712**		**77,448**		**55,815**	
Total Earnings per Compartment	**553,4547**		**3965,28751**		**2802,81653**		**1184,25848**	**8505,81722**

3.2. Discussion

It was our belief that we could have saved from various stages of logging, one of which is skidding because logging especially the manual one with its inherent risks has always been considered as one of the unavoidable stages of forest management increasing the overall costs. This study did not look into the cost contribution of logging inside the overall spendings of a management plan, but focused on if a saving can be obtained when skidding can be better organized through micro level operational planning. It instead showed that the implementation of a simple coordinate recording through a GPS and seeing the result of timber cruising on Google Earth which can easily supply the critical inputs such as, elevation, slope, aspect, distance measuring, point marking, polygon circling, i.e., simple Geographic Information System (GIS) capabilities without any licensing requirement might further increase the skidding cost of logging. But the data used in this study were from an unexpected timber cruising. A further study looking into a routine timber cruising can easily produce an unbiased result.

Forest engineers in Turkey are trained and equipped with all kinds of technological advancements by their administrative body, Forest Service. Their software handling capabilities especially are rather advanced. There is no directorate without a GPS in its inventory in Turkey today. However, handing over a gadget to somebody without giving the proper training to the person is just a waste of resources. The only practical use of a GPS in a directorate today is to help the users, engineers, foresters, etc. not to stray away from the administrative boundaries of his/her directorate so he/she will not interfere with the management practices of his/her neighboring directorate. The same deficiency or ignorance is also the case in the consideration/ applicability of Google Earth to forest management. It’s very apparent through this study that combining GPS with Google Earth during timber cruising or any other type of forest management practices might help open up new horizons or planning strategies for forest management because the feedback they will provide is invaluable.

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GIS-BASED EVALUATION OF LANDSLIDE-FOREST ROADS INTERACTIONS: A CASE STUDY OF TWO FOREST DISTRICTS IN DÜZCE FOREST DIRECTORATE (TURKEY)

Abdurrahim AYDIN, Remzi EKER*

Düzce University, Faculty of Forestry, Konuralp Campus, 81620 Düzce, Turkey.
Tel: +90 380 5421137 Fax: +90 380 5421136 E-mail: remzieker@duzce.edu.tr*

ABSTRACT

Forest roads are indispensable constructions of managed forest lands for many forestry objectives such as timber harvesting, fire management among others. However, forest roads mainly responsible for instabilities of slopes (e.g. occurrence of landslides) where they are located, depending on interactions with different geomorphological, hydrological and ecological processes. In addition, occurrence of landslides renders roads unusable because the displaced material of a landslide can block the roads as well as destroy the road platform, resulting in serious maintenance costs. In present study, a GIS-based overlay analysis was made using the forest road network (in total 322 km) and the landslide inventory map (including 109 landslides) in two forest districts (Odayeri and Çiçekli Forest Districts (FD)) in Düzce Forest Directorate (Turkey). While 69 landslides and 218.4 km of all road routes in network are located in Odayeri FD, remains are located in Çiçekli FD. In total, 84 of all landslides (i.e. 77%) are located over 109.9 km road routes and 30 km of roads remains directly in landslide areas. The outputs of analysis are real and general landslide frequency and real and general road-landslide index values. These values were calculated by using an algorithm developed in GIS platform and evaluated for both whole study area and two districts separately. Real and general landslide frequencies were calculated respectively as 0.76 and 0.26 in whole area, 0.74 and 0.27 in Odayeri FD, and 0.82 and 0.25 in Çiçekli FD. Real and general road index values were calculated respectively as 0.28 and 0.09 in whole area, 0.29 and 0.11 in Odayeri FD, and 0.22 and 0.07 in Çiçekli FD. According to real and general landslide frequency values in whole study area, one landslide in every 1.3 km and 3.9 km is observed, respectively.

Keywords: Forest Roads, GIS, Landslide Frequency, Road-Landslide Index

1. INTRODUCTION

Forest roads are indispensable infrastructures of managed forest lands, because they are constructed for mainly timber harvesting and fire management as well as other many objectives (Wemple et al. 2001). However, forest roads are also exotic structures that interact with geomorphic, hydraulic, and ecological processes. Even though forest roads commonly occupy a small portion of the landscape, they have a high edge length per unit area, because they are widely distributed networks. That's why, they have great opportunity for interaction with neighboring patches (Jones et al. 2000). One of the negative effects of roads is the loss of forest area (Sorkhi et al., 2012). Arıcak et al. (2010) stated that 0.6 - 1 ha of forest area, corresponding to 400 - 3500 trees (depending on forest age), must be clear-cut for the construction of each kilometer of forest road. In addition, forest roads which are mostly

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unpaved, are located commonly over across steep slopes because natural forests are located in mountainous regions (e.g. in Turkey). As a consequence, abandoned and unmaintained forest roads have potential effects that range from the local site to broad watershed scales (Forman and Alexander, 1998). These effects are (Wemple et al., 1996): i) increased rates of surface erosion, ii) occurrences of landslide/mass wasting iii) changes in peak flow magnitude, and iv) attendant impacts on stream sedimentation and channel morphology.

It is inevitable that road construction on any hill slope will render the slope unstable. Road networks in mountainous forest lands have the potential to increase susceptibility to shallow landsliding by altering subsurface flow paths (Borga et al. 2004). Several studies have quantified relative rates of road- and non-road related landslide erosion rates in forested areas (Sessions et al., 1987). Allison et al. (2004) stated that roads increase landslide occurrence in steep and unstable terrain by 25 - 350 times compared to undisturbed forested land. Forest roads increase the sediment yield in many catchments due to mass movements on steep embankments or the direct impact of raindrops and the turbulence of runoff (Swanson and Dyrness, 1975, Ziegler et al., 2000). Coker and Fahey (1993) stated that a total of 263 slope failures of all types, including rotational slide, topple, earth flow, etc., were recorded over 142 km of roads during a survey in Golden Downs and Motueka Forests. This is equivalent to a sediment yield of 142000 m^3. It was also stated in their study that the total volume of displaced material over a 209-km road network amounted to 193000 m^3 of granite, corresponding to 80 years of sediment yield from surface erosion.

Besides, occurrence of landslides renders roads unusable because the displaced material of a landslide can block the roads as well as destroy the road platform, resulting in serious maintenance costs. Heam et al. (2007) stated that in Lao PDR, the cost of emergency repair works due to landslides and their related effects was between US$ 1000 and 1500 per kilometer of road per year. Forest roads decrease slope stability in four ways: i) overloading the slope in the embankment fill; ii) increasing slope gradient in the road cut and fill, iii) removing material from the toe of the slope; and iv) re-routing and concentrating drainage water (Sidle et al., 1985; Megahan, 1987, Allison et al., 2004; Borga et al., 2004). Thus, it is crucial that better road location, harvest unit design, and engineered road construction, as well as timely and appropriate maintenance (Duncan et al. 1987). Otherwise, careless or improper excavation of marginally stable slopes, poor construction and fill placement on steep slopes, and improper drainage design lead to increase frequency of road-related landslides (Swanston and Swanson, 1976).

Decisions about road alignment, building, maintenance, or decommissioning are complex because of the many tradeoff involved (Lugo and Gucinski, 2000). Many forest engineers still use traditional methods that are entirely manual for determining road locations (Hosseini et al., 2012). Traditionally, the planning of forest road network is based on economic and social considerations. For instance, in the traditional planning of road networks, road locations have been determined without taking into account landslides. However, landslides and their impacts on forest road networks should be taken into account. In the present study, landslides-forest road interactions were evaluated via a GIS based overlaying analysis. For this aim, landslide inventory and forest road network data were used. Landslide frequencies and road-landslide index values were calculated.

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2. MATERIAL AND METHOD

2.1. Study Area and Data Description

Odayeri and Çiçekli Forest Districts (FD) in Düzce Forest Directorate (Turkey) were selected as study area (Figure 1). The top, left, right, and bottom coordinates of the study area are 4516653, 339563, 352655, and 4500064 in ED50 UTM Zone 36N, respectively. Total area of the FDs is 12135.43 ha. Çiçekli FD covers 3944.29 Ha, while Odayeri FD covers 8191.14 ha.

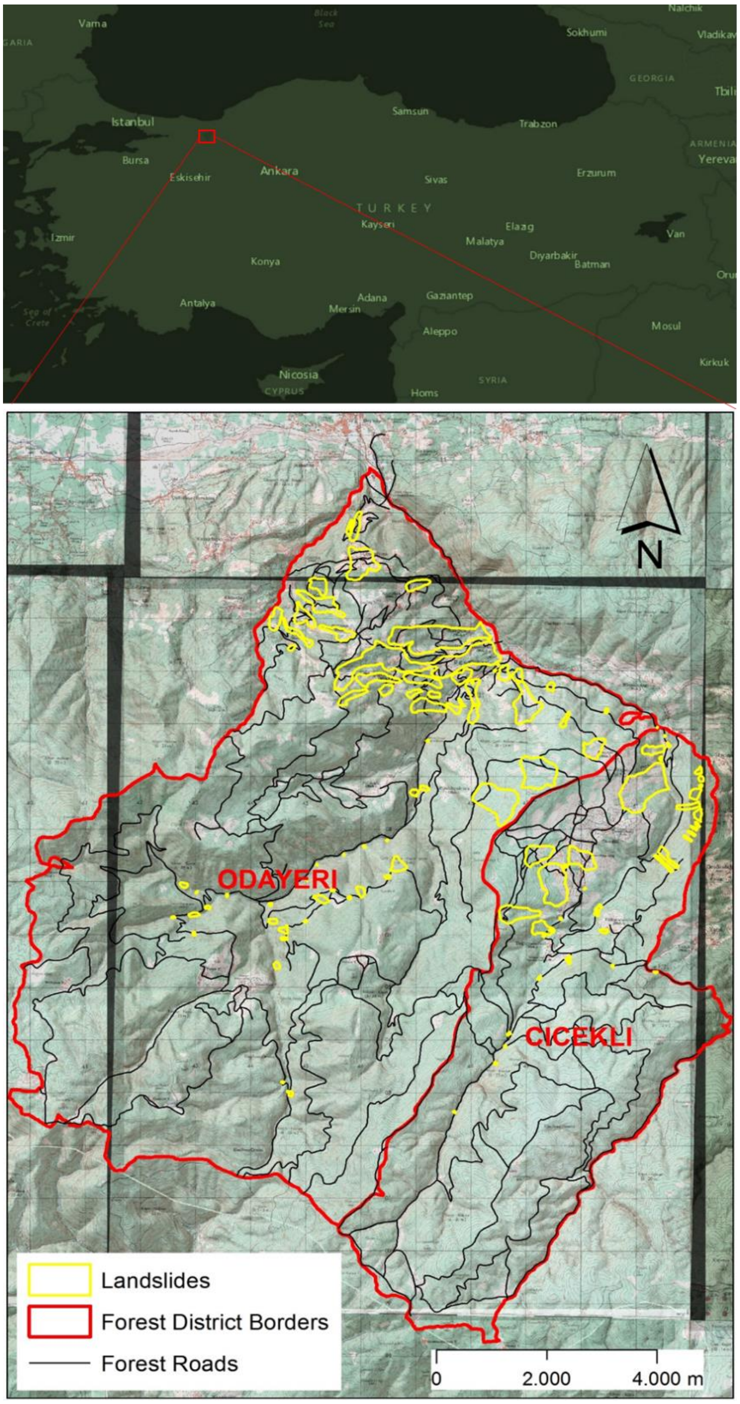

Figure 1. Location map of study area

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Forest road network data was obtained from Bolu-Regional Directorate of Forestry (OBM) in vector format and, in total, 322.0 km forest roads are located in the selected two forest district (Figure 1). Çiçekli forest district have 103.6 km forest roads, while Odayeri forest district have 218.4 km forest roads.

An inventory of 109 landslides (Figure 1) was generated through fieldwork as well as inventory data obtained from the Mineral Research and Exploration General Directorate (MTA). According to landslide inventory in the area, Çiçekli forest district have 40 landslides, while Odayeri forest district have 69 landslides. Areal size of landslide varies between 0.025 ha and 92.52 ha.

2.2. Overlaying forest road network and the landslide inventory

An overlay analysis was made using the forest road network and the landslide inventory for GIS-based evaluation of landslide-forest roads interactions. In addition, landslide frequency and road-landslide index values were calculated. For this aim, similar approach used by Eker and Aydın (2014) was applied. All analysis was carried out by using an algorithm developed using Python language which works under ArcGIS software.

In the study, landslide frequency defined as the number of landslides located over a road route per kilometer of road, was calculated (Wemple et al., 2001). Furthermore, landslide frequency was categorized and formulized as general landslide frequency and real landslide frequency. General and real landslide frequency values were calculated using the following equations:

$$GLF = \frac{\sum NL}{\sum RL} \quad (1)$$

$$RLF = \frac{\sum NL}{\sum RRL} \quad (2)$$

where GLF is the general landslide frequency, RLF is the real landslide frequency, $\sum NL$ is the sum of the number of landslides located over road routes, $\sum RL$ is the sum of lengths of all road routes in the area (regardless whether of landslide occurrences), $\sum RRL$ is the sum of road route lengths where landslides have occurred (only routes with landslide occurrences).

Besides, in the study, road-landslide index term was defined and categorized as general road-landslide and real road-landslide index (Eker and Aydın, 2014). The aim of describing these index values was to determine how many roads were directly affected by landslides. While the general road-landslide index can be defined as the ratio of length of road routes where falls in landslide area to total length of road routes (regardless whether of landslide occurrences), the real road-landslide index value can be defined as the ratio of length of road routes where falls in landslide area to the sum of road route lengths where landslides have occurred (only routes with landslide occurrences). Road-landslide index values were calculated using the following equations (Eker and Aydin 2014):

$$RLI_g = \frac{\sum RL_i}{\sum RL} \quad (3)$$

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$$RLI_r = \frac{\sum RL_i}{\sum RRL} \quad (4)$$

where RLI_g is the general road-landslide index, RLI_r is the real road-landslide index, $\sum RL_i$ is the total length of road routes where falls in landslide area.

3. RESULTS AND DISCUSSION

In present study, a GIS-based overlay analysis was simply made using the forest road network and the landslide inventory map (including 109 landslides) in Odayeri FD and Çiçekli FD in Düzce Forest Directorate (Turkey). While 69 landslides and 218.4 km of all road routes in network are located in Odayeri FD, remains are located in Çiçekli FD.

Overlay analysis allows to determine road segments directly located in landslide areas (Figure 2). According to overlay analysis, in total, 30 km of roads remains directly in landslide areas. This information was used to calculate road-landslide index values. This information can also help the forest managers (or engineers) to decide which forest roads primarily can be taken into account in maintenance planning. Because it provides the location of the expected landslide damage along the transportation network. Of course, field checks should be done because there are many factors affecting the requirement of maintenance in any road route such as state of activity of landslide, whether the road have maintenance before, and logging and harvesting activity.

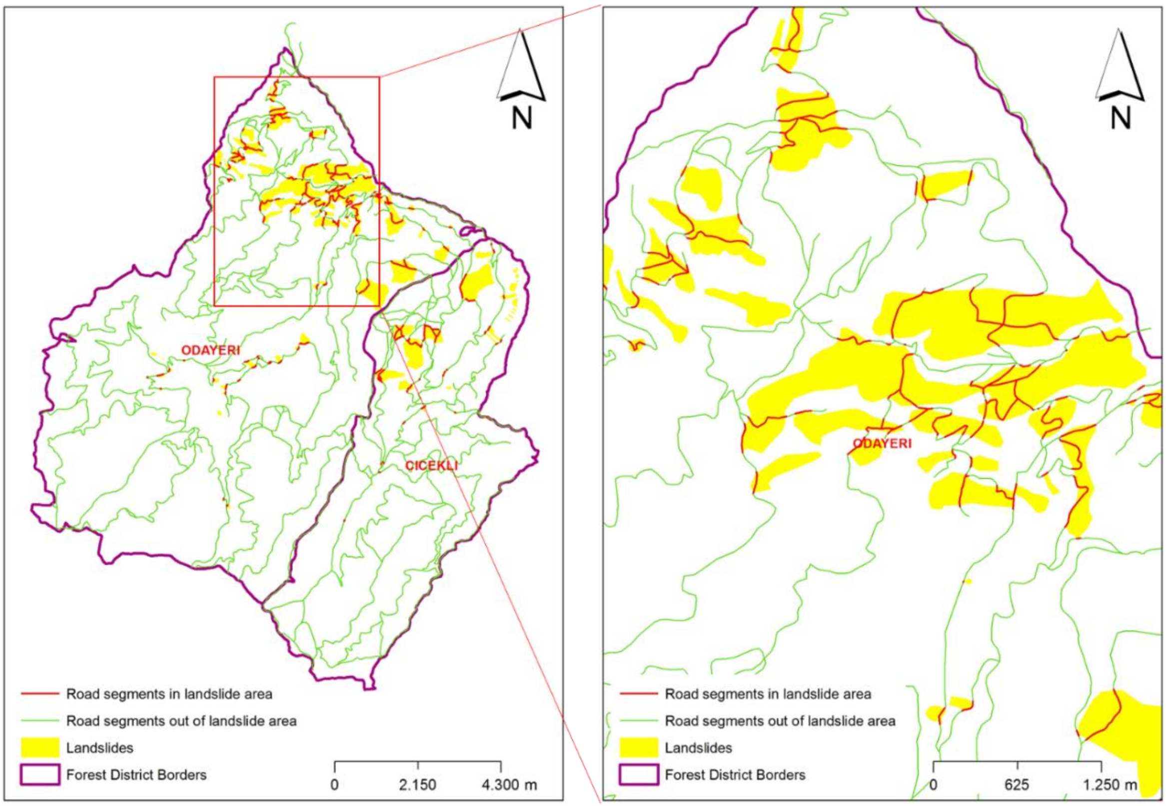

Figure 2. Road segments directly located in landslide areas

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In addition, overlay analysis provide road routes where landslides have occurred (i.e. only routes with landslide occurrences). According to this, 84 of all landslides (i.e. 77%) are located over 109.9 km road routes. Figure 3 shows the road routes where landslides have occurred. This information was used to calculate RLF and RLI_r values.

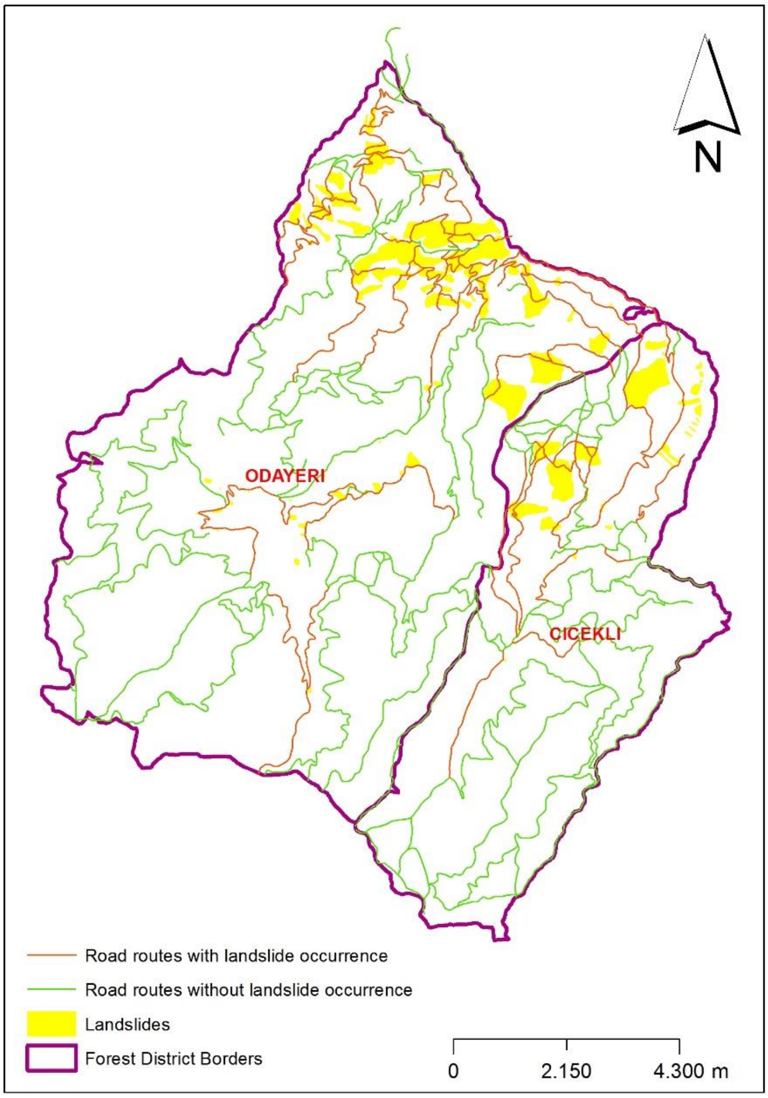

Figure 3. Road routes where landslides have occurred

Moreover, GLF, RLF, RLI_g, and RLI_r values were calculated using an algorithm developed in GIS platform and evaluated for both whole study area and two districts separately. RLF and GLF were calculated respectively as 0.76 and 0.26 in whole area, 0.74 and 0.27 in Odayeri FD, and 0.82 and 0.25 in Çiçekli FD. RLI_r and RLI_g values were calculated respectively as 0.28 and 0.09 in whole area, 0.29 and 0.11 in Odayeri FD, and 0.22 and 0.07 in Çiçekli FD. According to RLF and GLF values in whole study area, one landslide in every 1.3 km and 3.9 km is observed, respectively. According to RLI_r and RLI_g values, 3% of road routes were located in the whole area directly affected by at least 1 landslide, while 1% of all roads in the whole area were directly affected by landslides. Due to differences in total length of roads in

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networks and number of landslides, the percentage of roads affected by at least one landslide for each FD has different values.

4. CONCLUSION

GIS-based overlay analysis and calculations of landslide frequency and road-landslide index values can be used to evaluate road landslide interactions. GIS-based overlay analysis allow to identify road segments where landslides intersect. In addition, the landslide inventory provides useful information on the frequency of landslides over the road network, a valuable information for assessing road-landslide interactions. This analysis is also useful for determining the landslide risk along the transportation network, and for planning remedial and maintenance policies (Reichenbach et al., 2002). Also, road-landslide index values describe how many roads were directly affected by landslides.

5. ACKNOWLEDGEMENTS

The field works made to generate landslide inventory of relevant area in this study was funded by the Scientific Research Projects Directorate of Düzce University (with project no: 2013.2.2.180).

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EVALUATION OF FOREST ROADS CONDITIONS IN TERMS OF LANDSLIDE SUSCEPTIBILITY IN GÖLYAKA AND KARDÜZ FOREST DISTRICTS (DÜZCE-TURKEY)

Remzi EKER*, Abdurrahim AYDIN

Düzce University, Faculty of Forestry, Konuralp Campus, 81620 Düzce, Turkey.
Tel: +90 380 5421137 Fax: +90 380 5421136 E-mail: remzieker@duzce.edu.tr*

ABSTRACT

Landslide susceptibility maps (LSM), used for different aims such as reducing the effects of landslides, decision making, and planning, have become common tools and relevant studies have increasingly made during the last few decades. One of the further usage of LSM is to overlapping analysis with forest roads in order to get information about how planned road routes are located in terms of landsliding potential. Because unsuitable located roads cause slope instabilities such as landslides as well as landslide occurrence can result in serious maintenance costs destroying and/or causing deformations of road platforms. Statistical approaches such as logistic regression (LR) are well adopted to GIS based evaluation of landslide probability of slopes in larger regions. In present study, LSM of two forest districts (Gölyaka and Kardüz) in Gölyaka Forest Directorate (Düzce, Turkey) was generated using LR method based on an inventory of 52 landslides and eight conditioning parameters: elevation, slope, land-use, lithology, aspect, distance to faults, distance to streams, and distance to roads. Landslide susceptibilities in study area obtained between 0 and 0.57 with 0.85 AUC (Area Under the Curve) value. According to results, all parameters selected here has positive effect on landslide occurrences. Following normalization of generated susceptibility values between 0 and 1, obtained map was classified as very low (0-0.2), low (0.2-0.4), moderate (0.4-0.6), high (0.6-0.8), and very high (0.8-1) and then overlapped with forest roads in total 380.8 km. According to classified susceptibility map, more than 95% of total area is located in very low and low susceptibility classes. While 3% of the area has moderate landslide susceptibility, remains have high and very high susceptibilities. According to overlapping analysis, 1.3 km of roads is located in very high susceptibility, 5.1 km of roads is located in high susceptibility classes. Remains (more than 95% of all roads) are located in other susceptibility classes.

Keywords: Forest roads, Landslide susceptibility, Logistic Regression

1. INTRODUCTION

Landslide susceptibility maps (LSM), used for different aims such as reducing the effects of landslides, decision making, and planning, have become common tools and relevant studies have increasingly made during the last few decades. Particularly in the last 2 decades, it has become an important subject for earth scientists, engineers, planners, and decision makers (Ercanoğlu and Gökçeoğlu, 2002). Since the early 1970s many scientists have attempted to produce susceptibility maps, often applying Geographical Information System (GIS)-based techniques (Vahidnia et al., 2010). Logistic regression (LR) has been widely used by many researchers for mapping landslide susceptibility (Ayalew and Yamagishi, 2005; Nefeslioğlu et

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al., 2008; Kıncal et al., 2009; Erener and Düzgün, 2010; Akgün, 2011; Ercanoğlu and Temiz, 2011; Süzen and Kaya, 2011, Eker and Aydın, 2014). LR is used to analyze the relationship between the categorical or binary response variable and one or more categorical or binary explanatory variables (Bai et al., 2008).

One of the further usage of LSM is to overlapping analysis with forest roads in order to get information about how planned road routes are located in terms of landsliding potential (Eker and Aydın, 2014). Because as a result of selecting inappropriate road locations, adverse impacts on the natural environment emerge in conjunction with the occurrence of technical and economic problems (Görcelioğlu, 2004). Unsuitable located roads cause slope instabilities such as landslides as well as landslide occurrence can result in serious maintenance costs destroying and/or causing deformations of road platforms. The occurrence of landslides can make roads unusable because the resulting displaced material can block roads as well as destroy roadbeds, creating serious maintenance costs. The impact of landslides on a road network depends on the type of landslide, the location of the roads, and the geomorphology of the area (Reichenbach et al., 2002). Thus, determining the road location is the most difficult stage of road network planning. That's why, landslides have to be taken into account in forest road planning. Particularly in mountainous regions, road construction causes increased slope stability problems and higher road maintenance costs. These costs are directly related to stability problems like landslides. However many forest engineers still use traditional methods that are entirely manual for determining road locations (Hosseini et al., 2012).

In present study, LSM of two forest districts (Gölyaka and Kardüz) in Gölyaka Forest Directorate (Düzce, Turkey) was generated using LR method based on an inventory of 52 landslides and eight conditioning parameters: elevation, slope, land-use, lithology, aspect, distance to faults, distance to streams, and distance to roads. Then, an overlapping analysis was made using the forest road network and the landslide-susceptibility map to determine the distribution of roads in susceptibility classes and to evaluate them in terms of landslides.

2. MATERIAL AND METHODS

2.1. Study Area and Data Description

Gölyaka and Kardüz forest districts, located in Gölyaka Forest Directorate (Düzce, Turkey) were selected as study area (Figure 1). These forest districts are located in Black Sea Region of Turkey, where landslides incidents mostly occur. The top, left, right, and bottom coordinates of the study area are 4521007, 320760, 336020, and 4503527 in ED 1950 UTM Zone 36, respectively. Gölyaka and Kardüz forest districts covers 9128.13 Ha and 5098.12 Ha, respectively. Forest road network data was obtained from Bolu-Regional Directorate of Forestry (OBM) as vector data. According to this, in total, 380.8 km forest roads are located in the selected two forest district (Figure 1). Gölyaka forest district have 242.42 km forest roads, while Kardüz forest district have 138.38 km forest roads.

An inventory of 52 landslides (Figure 1) was generated through fieldwork as well as inventory data obtained from the Mineral Research and Exploration General Directorate (MTA). According to landslide inventory in the area, Gölyaka forest district have 44 landslides, while Kardüz forest district have 8 landslides.

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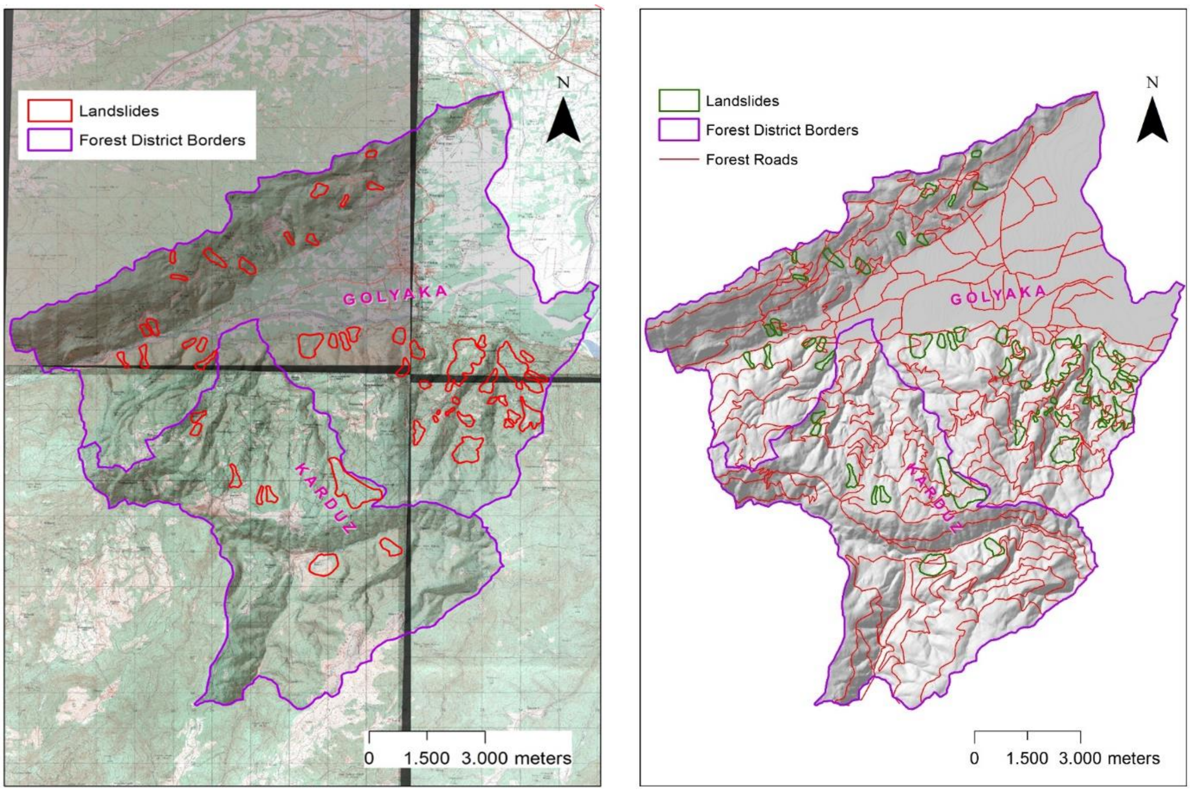

Figure 1. Location map of Gölyaka and Kardüz forest districts (left) and Forest road network (right)

Also, lithology and fault data was obtained from MTA, as vector data. Digital Elevation Model (DEM), used to derivate elevation, slope, and aspect data, was generated from 1/25000 topographical maps. In addition, streams were digitized over the topographic maps. Landuse data was derived from forest stand data obtained from Bolu OBM.

2.2. Landslide Susceptibility Mapping with Logistic Regression (LR)

The goal of LR in mapping landslide susceptibility is to find the best-fitting model using the relationship between the presence or absence of landslides and a set of explanatory variables (Ayalew and Yamagashi, 2005). Based on the observations in the field studies, 8 landslide conditioning parameters (i.e. set of explanatory variables) were selected for the landslide-susceptibility mapping: elevation, slope, land-use, lithology, aspect, distance to faults, distance to streams, and distance to roads (Figure 2). The LR method was applied with the LOGISTIREC module of Idrisi Selva 17.0, which uses a maximum likelihood estimation procedure to find the best-fitting set of explanatory parameters.

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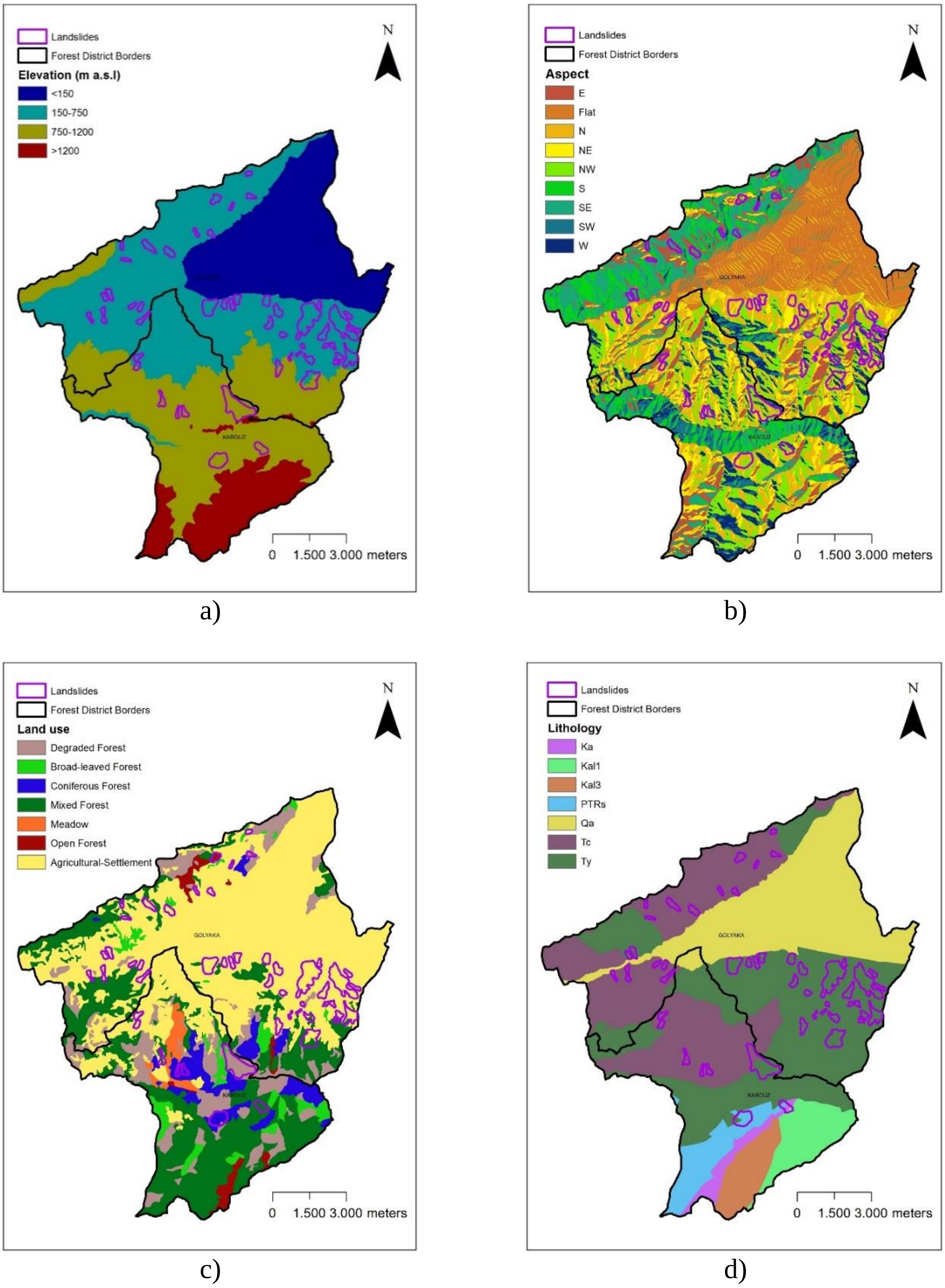

Figure 2. Landslide conditioning parameters used in LR: a) elevation, b) aspect, c) land use, d) lithology (Qa: alluvion, PTRs: marble, Ka: metasandstone-metaclaystone-metapelitic, Kal1: serpantinite, Kal3: gabbro, Tc: sandstone-mudstone, Ty: pyroclastic rocks-andesite-basaltic

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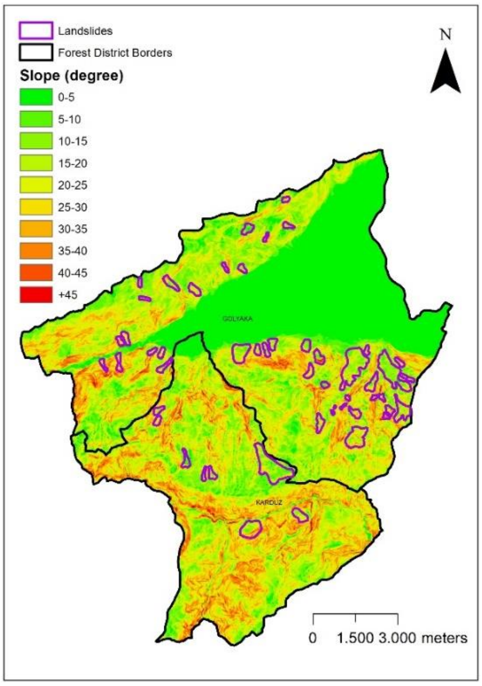

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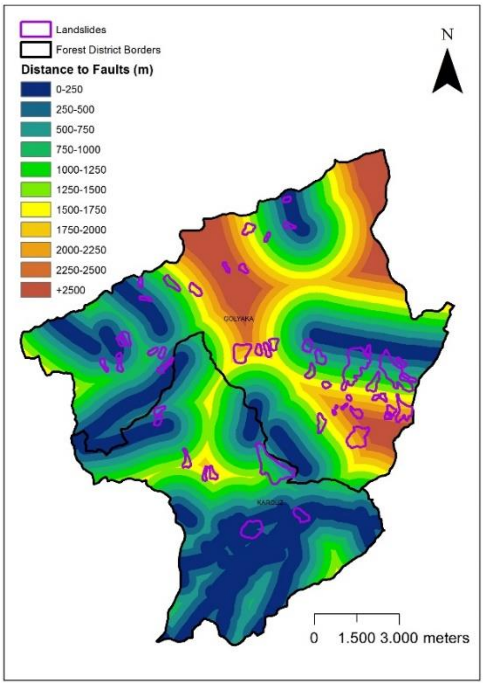

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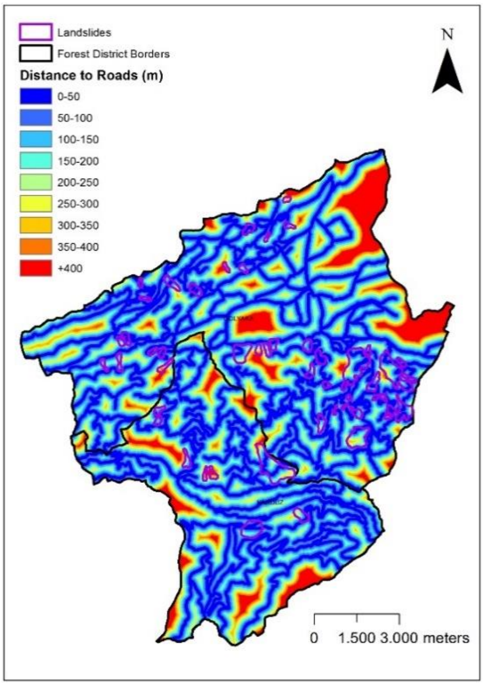

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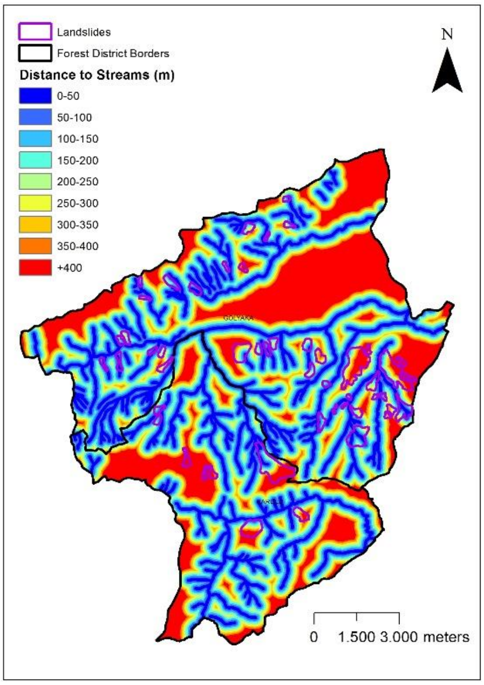

h)

Figure 2 (cont.). Landslide conditioning parameters used in LR: e) slope, f) distance to faults, g) distance to roads, h) distance to streams

The LR model was performed with 10% stratified random sampling procedure. Then, the landslide-susceptibility map generated with LR was divided into 5 susceptibility classes including very low susceptibility (0–0.2), low susceptibility (0.2–0.4), moderate susceptibility

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(0.4–0.6), high susceptibility (0.6–0.8), and very high susceptibility (0.8–1), following normalization of generated susceptibility values between 0 and 1. However, before the LR model was performed, the parameter maps were classified, and the number of pixels in each class was calculated. Following this process, frequency ratio (FR) of all classes was calculated by constructing a table for each parameter map, as stated by Lee and Talib (2005). LR analysis was carried out by using calculated FR values assigned to each class of each parameter map. Further information can be found in Eker and Aydın (2014).

Area under the curve (AUC) value was used for validation of the susceptibility map generated. The AUC value was calculated using the true positive percentage and the false positive percentage values for each class that constitutes the curve. The relative operating curve (ROC) module of Idrisi Selva 17.0 software was used for this aim (Eker and Aydın, 2014).

2.3. Evaluation of Forest Roads Conditions in terms of Landslide Susceptibilities

After successfully finding best fitting model, i.e. generating LSM, an overlapping analysis was carried out using forest road network data, in order to evaluate forest road conditions in terms of landslide susceptibility. Because the output LSM of LR analysis made via LOGISTIREC module is in raster format, it was necessary to convert the classified LSM to polygon vector format for conditioning it to overlap with the road network. The whole process of evaluating forest roads conditions in terms of landslide susceptibilities is given in Figure 3.

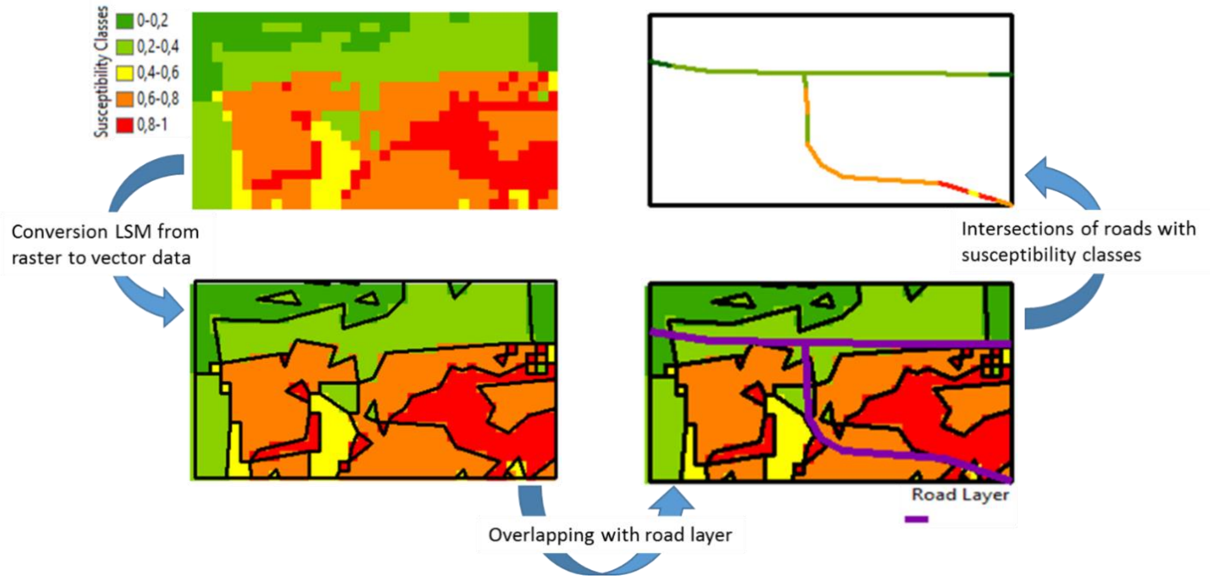

Figure 3. The process of evaluation of forest roads conditions in terms of landslide susceptibility

3. RESULTS AND DISCUSSION

According to results, all parameters selected for LR analysis has positive effect on landslide occurrences (Table 1). The AUC value of the model was 0.849, which is also in the satisfactory range (Yılmaz, 2009; Van Den Eeckhaut et al., 2010; Ercanoğlu and Temiz, 2011). Because this value indicates a perfect fit when it is equal to 1, and indicates a random fit when it is equal to 0.5. Raw LSM and classified LSM are given in Figure 4.

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Table 1. Obtained coefficients of variables in LR model.

Variables	Coefficient
Intercept	-10.44735859
Slope	0.68687297
Lithology	0.66749428
Landuse	0.91873841
Elevation	0.81044910
Distance to Streams	0.72818978
Distance to Roads	0.64134472
Aspect	0.85735124
Distance to Faults	0.97427890

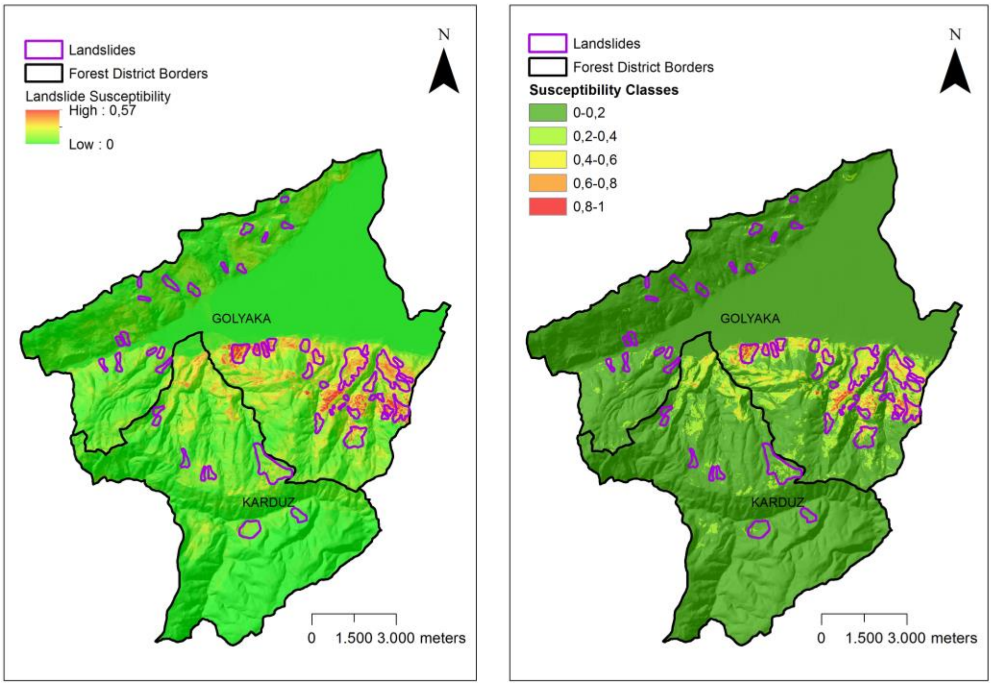

Figure 4. Raw LSM (left) and classified LSM (right)

Landslide susceptibilities in raw LSM vary between 0 and 0.57 depending on the selected parameters. According to classified LSM, more than 95% of total area (13638.76 Ha) is located in very low and low susceptibility classes, while only 1% of total area (143.51 Ha) is located in very high and high susceptibility classes. Remain is located in moderate susceptibility class. Table 2 summaries the distribution of susceptibility classes in the area.

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Table 2. Distribution of susceptibility classes in the study area

Susceptibility Classes	Area (Ha)	Percentage (%)
Very High (0.8-1.0)	25.88	0.18
High (0.6-0.8)	117.63	0.83
Moderate (0.4-0.6)	443.98	3.12
Low (0.2-0.4)	1017.06	7.15
Very low (0-0.2)	12621.70	88.72

Forest road network map overlapped with classified LSM is given in Figure 5. This map represents intersections of forest roads with susceptibility classes. According to overlapping analysis, 1.3 km of roads is located in very high susceptibility, 5.1 km of roads is located in high susceptibility classes. Remains (more than 95% of all roads) are located in other susceptibility classes. Table 3 summaries the distribution of roads over the susceptibility classes. Overlapping forest road network with landslide susceptibility provides information about how planned road routes are located in terms of landsliding potential. That's why, forest road planners can be use this data in determination of suitable road routes. In addition, this data can help making decision in determination of necessity of counter-measures against the sliding. Of course, obtained result should be checked in the field. Because there are several factors, which have play important role on the degree of roads suffering from landslides such as the type and state of activity of landslide, the location of the roads, and the geomorphology of the area. For instance, as depicted in Figure 5, some roads can be located in low or very low susceptibility class, even they are located in landslide area. Nevertheless, this data will provide useful brief information on landslide susceptibility and road interactions.

Table 3. Distribution of roads in susceptibility classes

Susceptibility Classes	Road Length (km)	Percentage (%)
Very High (0.8-1.0)	1.27	0.33
High (0.6-0.8)	5.05	1.33
Moderate (0.4-0.6)	16.74	4.40
Low (0.2-0.4)	33.74	8.86
Very low (0-0.2)	324.0	85.08

4. CONCLUSIONS

Forest roads are important infrastructures that enable forestry activities. In traditional planning of road networks, road locations have been determined without taking into account environmental factors such as landslides. In the present study, the aim was to show the use of a landslide-susceptibility map as a database for planning forest road networks. For the assessment of forest road conditions in terms of landslide susceptibilities, LSM was generated using a GIS-based LR method. LR based susceptibility map was created with a satisfactory validness. Eight conditioning parameters were used by computing FR values for each class of

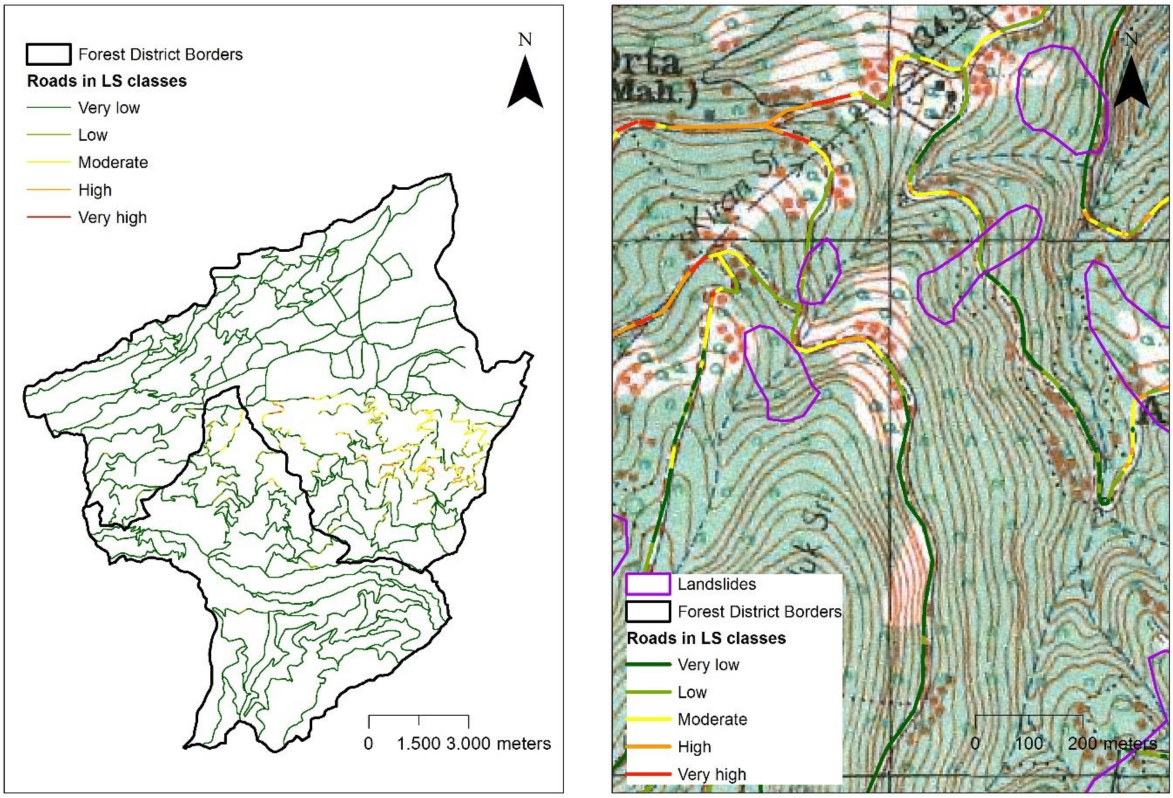

Figure 5. Forest roads overlapped with landslide susceptibility classes (left) and roads in susceptibility classes and landslide incidents in inventory (right)

each parameter. Even though obtained overlapping results should be checked in the field, because there are several factors, which affect the degree of suffering roads from landslide such as the type and state of activity of landslide, the location of the roads, and the geomorphology of the area, this overlapping analysis will provide useful brief information on landslide susceptibility and road interactions.

5. ACKNOWLEDGEMENTS

The field works made to generate landslide inventory of relevant area in this study was funded by the Scientific Research Projects Directorate of Düzce University (with project no: 2013.2.2.180).

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FOROR – A GIS BASED SPATIAL MULTIPLE CRITERIA DECISION SUPPORT TOOL FOR FOREST ROAD ROUTE IN STEEP TERRAIN

Erhan ÇALIŞKAN[1*], Volkan YILDIRIM[2], Şevket BEDİROĞLU[2]

[1]Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, 61080 Trabzon, Turkey. Tel: +90 462 3773000 Fax: +90 462 3257499
E-mail: erhan_caliskan@yahoo.com*
[2]Karadeniz Technical University, Department of Geodesy and Photogrammetry Engineering, 61080 Trabzon, Turkey.

ABSTRACT

Forest road route determination process is a complex process involving many variables to be analyzed simultaneously, and is one of the important process steps for forest road projects. In this study, Geographic Information System for the detection of forest road routes (GIS) environment and Multiple Criteria Decision to give (MCDA) is a decision support system based on the introduction of a FOROR is aimed. FOROR decision support system; MCDA methods, the determination of weight, contains layers of normalization of the extent and Cost distance algorithm. FORCE is also a decision support system for MCDA, AHP, Simple Weighted Total, Promethee, Topsis and Fuzzy overlay; determining weights for sorting, grading and comparison, and dual linear scale transformation for normalization method can be used. In the linear scale transformation "maximum value" and "the smallest and largest values" it can be done with normalization. Layer resulting in normalization weight multiplied by coefficients from the desired layer MCDA method comprising the accumulated cost of the surface. When applied on the surface of the resulting accumulated costs Cost Distance algorithm optimal forest road optimal route can be determined. In conclusion, the determination of a forest road routes FOROR has been revealed on the advantages of decision support systems.

Key words: GIS, Spatial multiple criteria decision support system, Forest road route, FOROR, Environmentally sensitive

1. INTRODUCTION

Forest roads are among the most important infrastructure facilities for operating forests which are also renewable natural resources. It is necessary to establish a road route which will enable the achieving of targets in order to plan forestry operations within the frame of sustainability concept. There are numerous studies in which GIS has been used for route determination.

A number of computer-assisted and GIS-based models have been developed in recent years for determining the forest road routes automatically. Among these, ROUTES (Reutebuch, 1988), G-ROUTE (Ellis 1990), TRACER (Akay and Sessions 2005) and PEGGER (Rogers 2005) can be mentioned. Several scientific studies were performed in Turkey in which computer software (Demir 2007; Demir and Öztürk 2004) and GIS methods (Altunel 2000;Gümüş and Erdaş 2000; Akay et al. 2008) were utilized. Choi et al. (2014) developed a

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raster-based GIS model using Multi-Criteria Decision Making (MCDM) methods to determine the optimum transportation route with the minimum cost for heavy vehicles.

An intensive managing of forest road network is complex and typically has multi-objective nature in mountain ecosystem, in particular when environmental regulations are incorporated into economical objectives makes the task even more complicate for forest engineers. S-MCDM methods are interactive and flexible tools for the analysis of complexity among the alternatives which contain different environmental and socio-economic effects. Combining GIS and S-MCDM techniques provides convenience to the users in determining the various alternatives of criteria and objects having multiple and complex structures. Selection of the suitable route in planning of forest roads is a complex engineering problem depending on major factors. In this respect, utilization of GIS technologies and spatial multi-criteria decision making methods (S-MCDM) are required.

In this study, forest route determination was dynamically realized by a raster-based decision-support system we developed, called FOROR which is based on GIS technologies. For this application, Analytical Hierarchy Process (AHP), Simple Average Method (SAM), fuzzy logic, Promethee and Topsis methods of S-MCDM were used.

2. MATERIAL AND METHODS

On the purposes of accelerating process steps, minimizing human-user mistakes and adding special custom-defined algorithms we have created a new GIS-S-MCDM extension for ArcMap 10.3 (Figure 1). We used Microsoft Visual Studio and ArcGIS SDK (Software Developer Kit) for Python using ArcObject libraries. This extension named Forest Road Route (FOROR) is a comprehensive tool automating all the analysis and discussion steps. After opening vector based GIS files and giving factor and sub factor weights it just remains choosing analysis patterns pre-defined on tool is enough for applying all analysis.

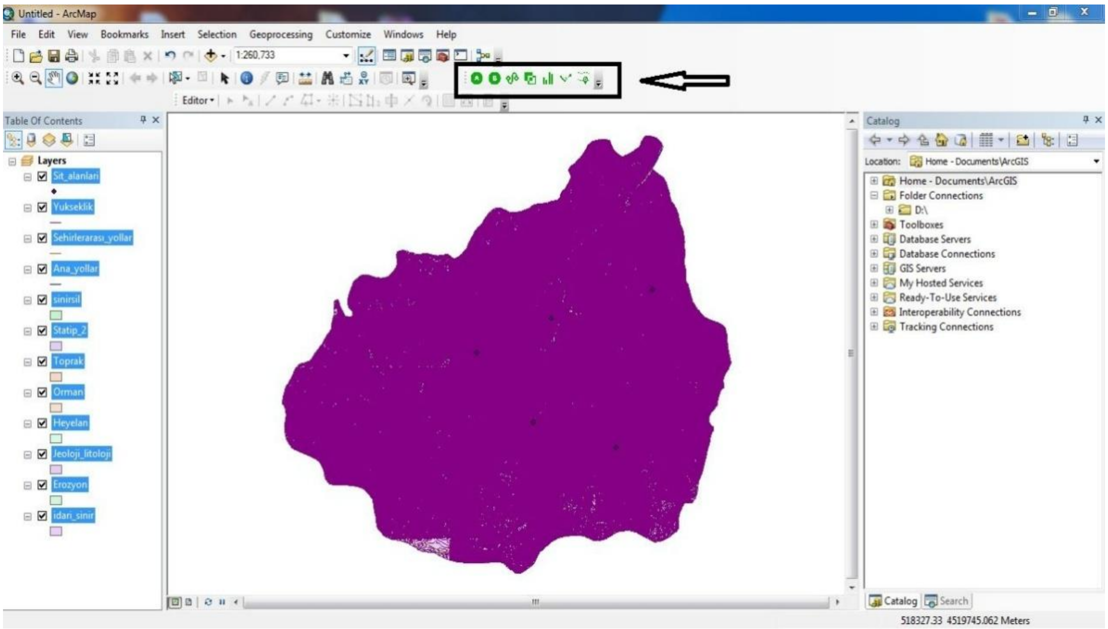

Figure 1.Software plugin (FOROR) view on the GIS software

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The tool consists all related GIS functions such as Vector-Raster conversation, GIS Analysis (Buffer, Intersect, Overlay etc.), Kriging-IDW Interpolations, Accumulated Cost Surface Calculation and finding optimum routes with Cost Distance Cost Path Algorithms. TOPSIS, SAW, PROMETHEE, AHP and FUZZY OVERLAY algorithms and mathematical formulas also included into extension.

3. RESULTS AND DISCUSSION

3.1. Software Design of the (FOROR) Structure

3.1.1. Editing

Stage of the work, Multi used in CBS buffer (Multiple Buffer) analysis method is preferred. This method satisfies the desired output can be easily stored in the database.

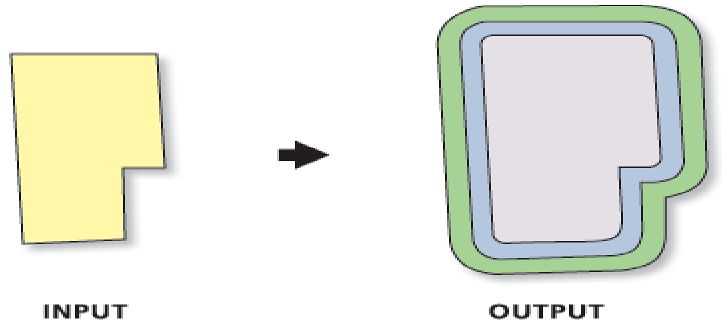

Figure 2. Input and output

For the stage, the layers will be converted into GIS format used and the information recorded in the column attributes of the data type, has a structure that allows the conversion in the interface. For step TIN of creation is ArcGis using the triangulation principle is used.

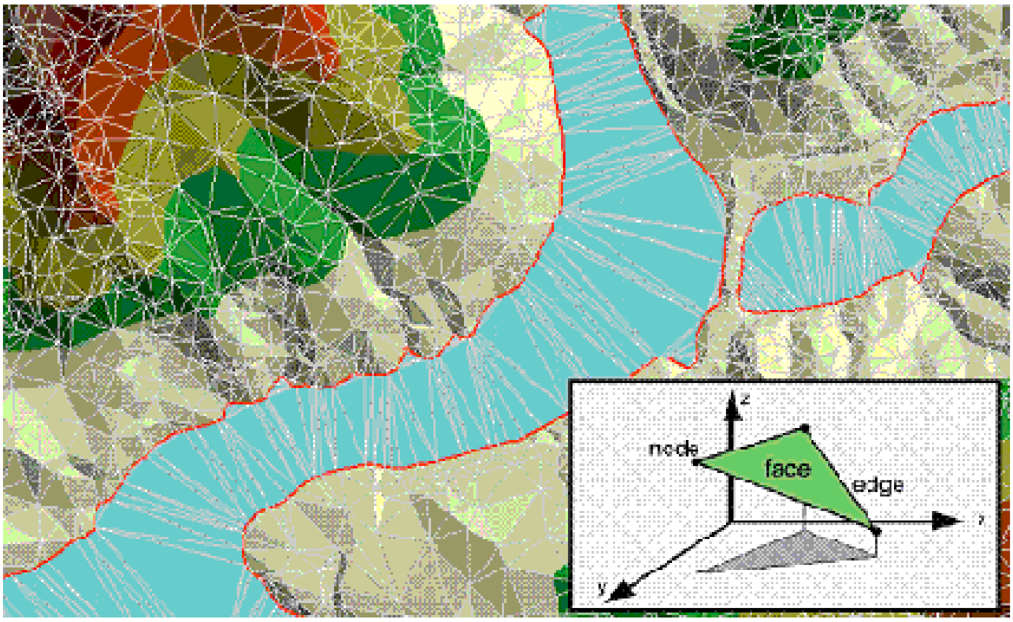

Figure 3. TIN

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Mountain region, wooded area on the road route of the corridor at the desired distance around the vector layer to be used in the determination (regions) can be represented by different data in the same layer. for example, a stream of 0-100 m, 101-200 m, expressed in a discrete manner different corridors as 201-300 meters.

Mountain region, according to the attribute type to polygon data in vector format, scoring can be done e.g. in soil layers; 1st class land 100 points, 70 points, etc. Mountain region, using linear contour data point or TIN, DEM etc. It can generate the topographic surface model.

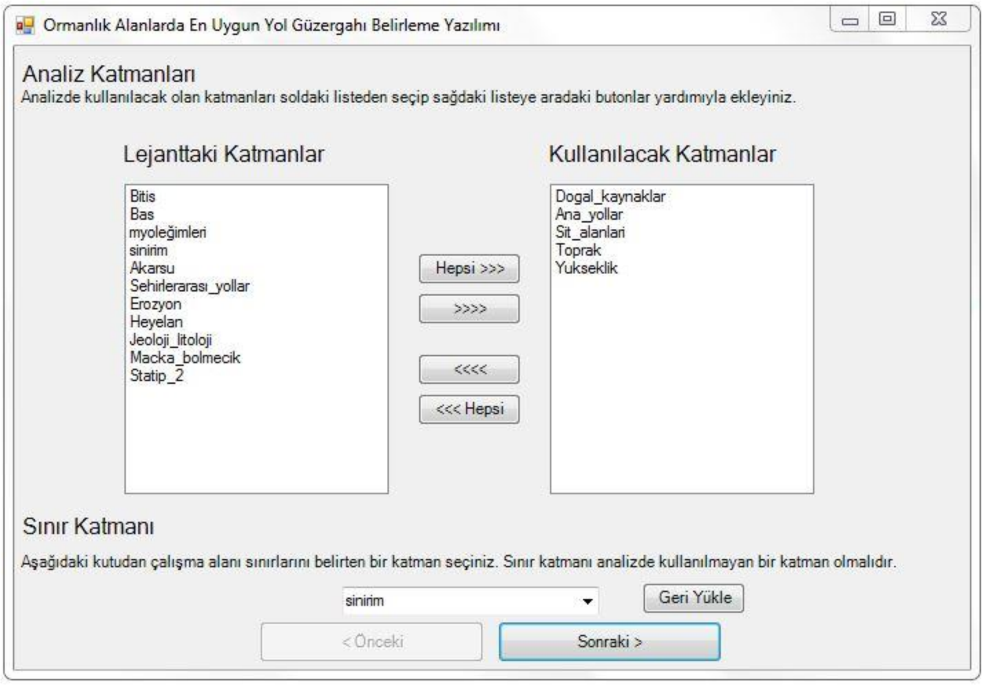

Figure 4. Data editing FOROR

3.1.2. Data Conversion

Data resulting from the data editing step is converted into raster data format. At this stage of the polygonal data "Polygon to Raster" The TIN's data "TIN to raster" method is decided to be converted into a raster format.

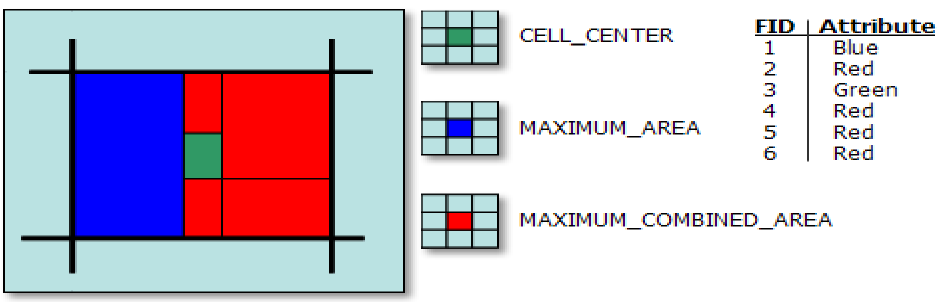

Figure 5. Data Conversion

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3.1.3. Data Standardization

The data converted into raster format to facilitate the analysis of image processing classification, be organized according to the same pixel size, are cut to the same external borders.

Different points of the different layers are standardized by normalization method of weight. Example: x / max, x-min / max-min and so on.

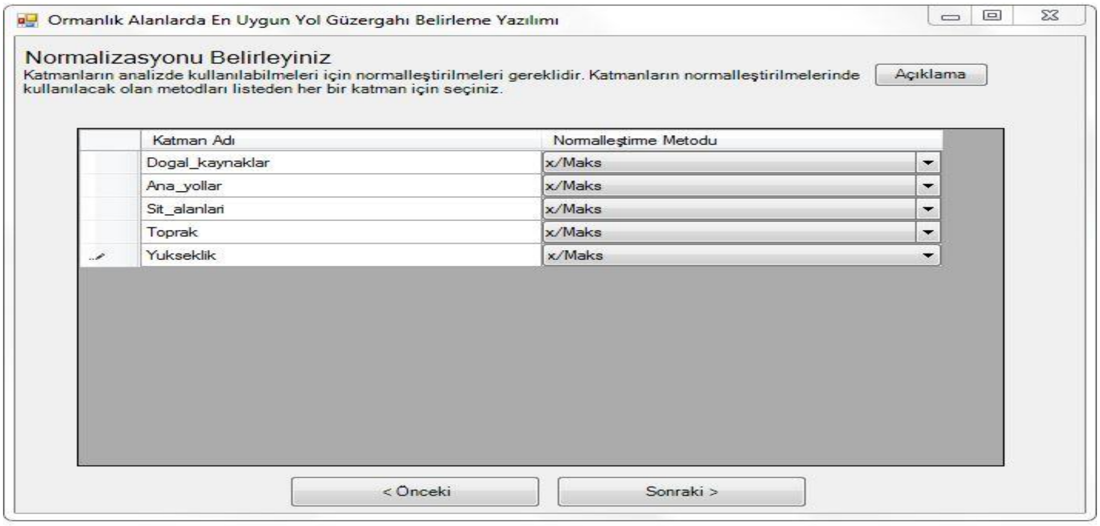

Figure 6. FOROR standardization normalization

3.1.4. Create Accumulated Cost Surface

The standard has become, by selecting the desired data from the factor weights given to the MCDA method cost surface model is created,

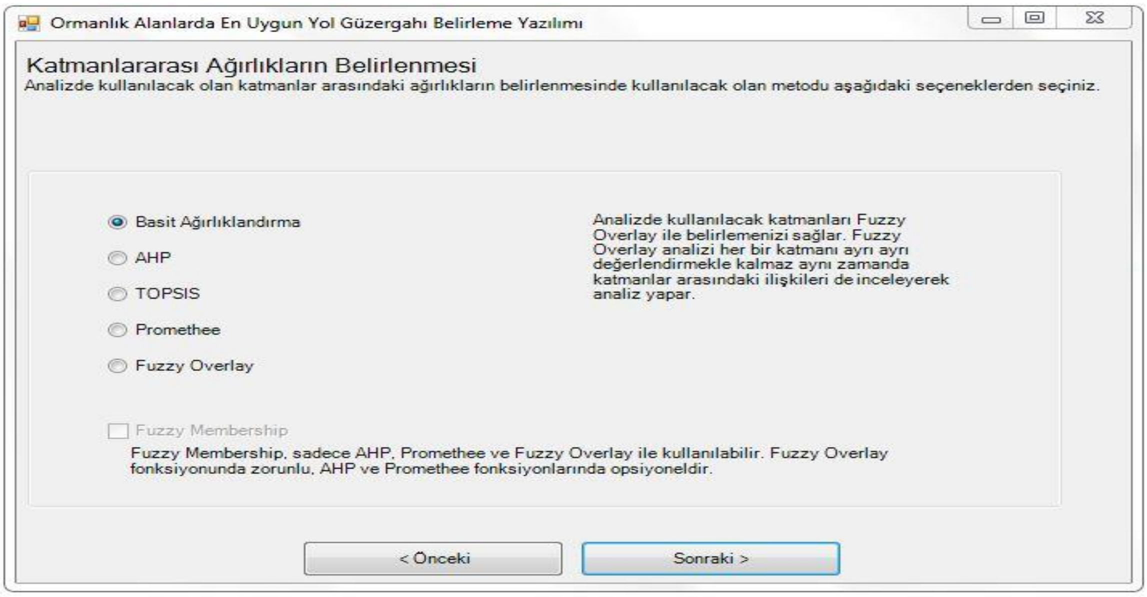

Figure 7. FOROR in the desired MCDA Methods

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3.1.5. The most suitable route of forest road detection;

Cost surface optimal route can carry out model selection process. The resulting output can translate the results of the road route vector format. The resulting road route to Google Earth (KML) can convert the file. A single database for all process stages (Geodatabase) is in storage.

Cost is an issue that is important when preparing Distance interface design, finding the most suitable route such as Cost Path tools are used. Because ArcGIS Spatial Analyst software is included as part of a direct reference to the future in all network analysis ArcToolbox box to add ArcGIS can be updated automatically. In addition, the interface directly to the desired algorithm Python, or Java language coded in Charpin can be easily added and re koşturularak executable program. Extension interface results in the literature and in the current situation analysis for the selection of the most appropriate route through the forest path accumulated cost surface, Distance-Cost Path Cost is determined to be appropriate algorithms.

4. CONCLUSIONS

In this study, forest road route determination was dynamically realized using a raster-based decision-support system based on GIS technologies developed by us, namely FOROR. The decision support tool FOROR aims at providing this information based on forest road inventory data and necessary geographic data layers were determined accordingly and were then classified according to the standards. Moreover, to allow for a consistent comparison of decision alternatives FOROR provides a spatial multiple-criteria decision methods evaluation.

5. ACKNOWLEDGEMENTS

This study is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with the project number 114O599.

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THE ROLE AND IMPORTANCE OF FOREST ROAD NETWORKS IN THE FIGHT AGAINST BARK BEETLES

Temel GOKTURK*, Ahmet MIHLI, Mustafa ACAR

Artvin Coruh University, Faculty of Forestry, 08000 Artvin, Turkey. Tel: +90 466 2151034
Fax: +90 466 2151034 E-mail: temel.gokturk@gmail.com*

ABSTRACT

Forest road networks are made use of in fighting against bark beetles. The Pheromone Traps, which are used in the fight against bark beetles in Turkey, are hung in the roadsides in the forests, and the bark beetles that are caught in these traps are exterminated. In addition, the trees with beetles are determined and cut. Then they are brought to the forest roads, loaded into vehicles and taken away from the area. In this way, the purpose is keeping the harmful insect population at a balanced level. With this study, the role and importance of forest roads in fighting against bark beetles have been determined. The rates of catching insects by the pheromone traps hung in areas where there are forest roads and where there are no forest roads have been considered, and it has been observed upon the statistical analyses that the data show a normal distribution. In the fight against bark beetles, on the other hand, significant differences have been observed between the areas where there are forest roads and where there are no forest roads. In addition, the removal of overthrown and destroyed trees on the forest roads are realized earlier times in areas where there are forest roads. The removal times of the trees that are cut from the area is important for the fighting against bark beetles, and the wood harvest, as well as the fight against the harmful insects must be considered in planning the forest road networks.

Key words: Forest road networks, bark beetles, pheromone trap

1. INTRODUCTION

Forests are known as the indispensable elements in sustaining the life for all living creatures and as the source of life. 27,6% of the surface area of Turkey consists of 21,7 million hectare forest. Artvin is among the cities that have rich forest areas with 404.208 hectare forests. Forest roads are compulsory structures in order to perform forestry activities. Artvin forests have a forest road network of 3500km.

Caucasian Spruce trees (*Picea orientalis*) cover the widest diffusion area with 25,628 hectare area of Artvin forests, and this area has been exposed to intense bark beetle since 1960, hundred-thousands of cubic meters of trees have dried up because of the bark beetle damages (Gokturk et.al., 2006; Gokturk and Eldemir, 2005). The use of Pheromone Traps, which is considered in the integrated pesticide management, has been applied by Artvin Regional Directorate of Forestry for long years to fight against harmful insects (Gokturk and Eldemir, 2005). The epidemic formation of the beetles is prevented by using Pheromone Traps, and thus it becomes possible to decrease the population intensity (Byers, 1999; Raty et al., 1995). Pheromone Traps have contributed to the integrated fight against Eight-tooth Caucasian Spruce Bark Beetle (*Ips typographus* L.) since 1998 in Artvin. As of late 2015, 458.000.000

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pcs *Ips typographus* mature insects have been caught with 148.600 Pheromone Traps hung to the areas where the beetles have given harm intensely within 17 years. Within this time period, TL8.500.000 has been spent on the fight against this beetle. Only in 2015, 3425 Pheromone traps were hung, and TL 55000 were paid only for Pheromone Trap preparations (Gokturk et al., 2010; Anonymous, 2015).

Forest roads are extremely important for the hanging of Pheromone Traps, because the distances between the traps, the places where they are hung, and their receiving light issues are important, and the areas that are near the forest roads are considered as being the most suitable places (Safranyik et al., 2004; Lobinger, 1995). When the Pheromone Traps are not hung in forest areas with 10-15 m distance, some of the beetles are caught in the traps while the others flee to other trees nearby (Gokturk et al., 2006).

Artvin forests were in the forefront in Turkey with 191.000 cubic meter wood production capacity in 2015 (Anonymous, 2015). The transfer of this production from forest areas of storage units requires great costs. The collapsed trees due to snow and storm in areas where there are no forest roads increase the population of bark beetles (Gokturk et al., 2010; Jakus, 1998). In this study, the role and importance of the forest roads in the fight against bark beetles have been examined.

2. MATERIAL AND METHODS

This study was conducted in 2 different Study Areas selected within the Caucasian Spruce Forests, one of which having Forest Roads and the other having no forest roads in Genya Location (1750 m) in Artvin Regional Directorate of Forestry in 2015. When the Study Areas were selected, the areas where there were plenty of collapsed trees due to storms were selected. The material of this study consists of the Caucasian Spruce trees in Artvin Genya forests, the *Ips typographus* mature insects, Scandinavian Type Three-Funnel Traps, pheromone preparations (IPSTYP® Dispenser), digital camera and sensitive scale.

20 traps were given numbers in both Study Areas, and placed in 10-15 m to the Caucasian Spruce trees with 40-50 m distance among them hanging 0.5m from the ground facing south. The traps were hung to the road sides in areas where there were forest roads; and they were hung in the open areas in the forest where there were no forest roads. The biology of the beetles was considered and the study was conducted with 1st and 2nd generations. In both areas, the traps were hung on May 15, 2015 when the temperature was 18 C^{o} when the 1st generation was alive. The traps were checked at 7-10 days intervals. The Pheromone Preparation was changed on July 15, 2015, which corresponds to the 2nd generation life cycle, and the data were continued to be collected until September 2. Aside from the Pheromone Traps check, the damage of the beetles in the area and the status of the area were considered and evaluated.

The *I. typographus* individuals that were caught in the Pheromone Traps were collected periodically, counted, and the average values were taken and analyzed statistically in the SPSS 15.0 Package Program. In order to find whether the data showed normal distribution or not, the Normality Test (Shapiro-Wilk) was applied. In order to reveal whether or not the

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forest roads had influences in the fight against the beetles, the Independent Sampling t-test was used.

3. RESULTS AND DISCUSSION
3.1. Results

In Caucasian Spruce tree forests in Genya location where there were forest roads and where in some areas there were no forest roads, the *Ips typographus* individuals were collected with Pheromone Traps (Figure 1). *Ips typographus* individuals fell into the traps that were hung in both Study areas (Table 1.). 63060 insects were caught with all the traps that were hung in the Study Area. 46820 insects were caught in the traps that were hung in the areas where there were forest roads; and 16240 insects were caught in the traps that were hung in areas where there were no forest roads.

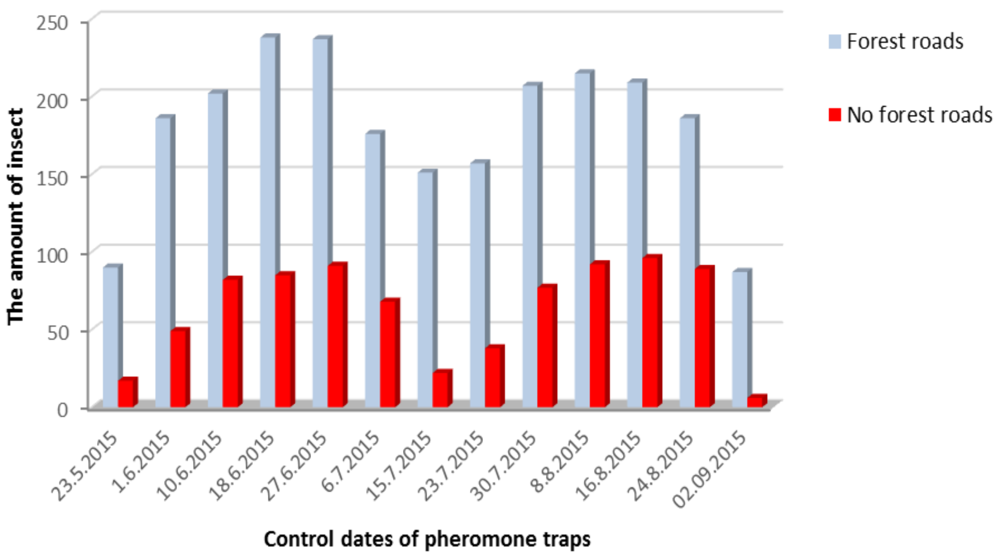

Figure 1. The amount of insects caught on pheromone traps

Upon the statistical analysis, it has been observed that the data show a normal distribution. In the fight against bark beetles, a significant difference was observed between the areas where there were forest roads and the areas where there were no forest roads ($p<0.05$) (Table 2, 3) (Figure 2).

Table 1. Normality test

	Shapiro-Wilk		
	Statistic	df	Sig.
The effect of the presence of forest roads	,923	26	,052

Table 2. Group Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Forest roads area	13	180,08	48,390	13,421
No forest roads area	13	62,46	32,041	8,886

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Table 3. Independent samples t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	Df	Sig. (2-tailed)
Equal variances assumed	1,000	,325	7,307	24	,000
Equal variances not assumed			7,307	20,826	,000

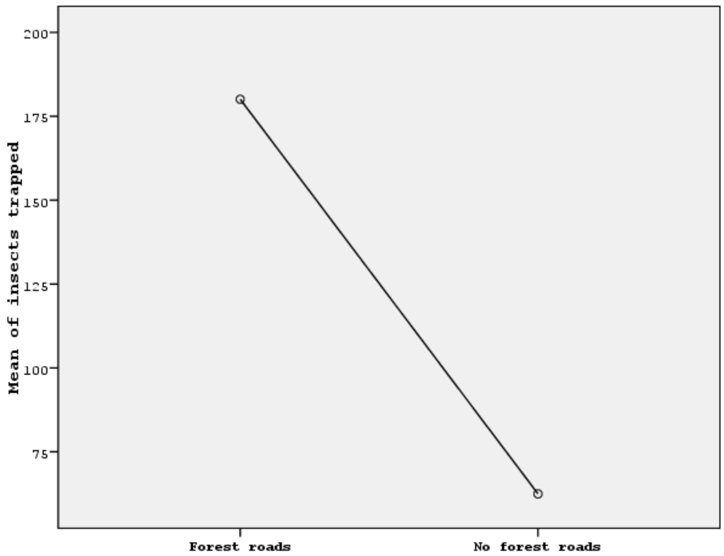

Figure 2. Means Plots

3.2. Discussion

One of the most important factors in forming epidemic by bark beetles is the increase in the amount of the suitable hosts. The forest with disrupted stand structures and the trees under stress, increase the rate of this harmful beetle reaching them and damaging them. Collapsed, overthrown, and newly-cut trees release attractive substances for these harmful insects and become a *trap tree*. In case the barks of these trees are not 'peeled' within the proper duration, they become the source of the epidemic. When this situation is considered, it becomes extremely important to reach the areas where there are harmful insects by using forest roads and removing the destroyed trees from these areas. The timely cutting of the trees with beetles and peeling the barks of such trees are important for the success of the mechanical fight against harmful insects. It has been observed in the study that the overthrown and collapsed trees or the trees that are cut for production can be removed from the forest areas very easily and timely in areas where there are forest roads, while these processes take longer times in areas where there are no forest roads. Leaving the forest assets in the forests or keeping them waiting in the forests and being not able to remove them from the forest areas prepare the medium for bark beetles to perform mass reproduction. When the fact that the trap trees have 14-fold more effective catching property than the Pheromone Traps is considered (Drumont et al., 1992), it becomes extremely important to remove the collapsed trees from the areas before they become trap trees.

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Another important issue to be cared for in the fight against bark beetles is the removal of the residues of the cutting process from the areas. While these residues may be removed from the areas where there are forest roads easily, it is not possible to remove them in areas where there are no forest roads. These residues will thus prepare the ground for bark beetle to reproduce. In recent years, considerable improvement has been observed in the fight against *Ips typographus* in Caucasian Spruce tree forests with the use of pheromones and in the follow-up of this fight. In a study conducted in Artvin by using the Re-Catch Method in order to determine the efficiency of the Pheromone Traps, it was reported that the efficiency of the traps was 25.87% (Gokturk et al., 2010). In this study it is considered that the Pheromone Traps caught more insects in the areas where there were forest roads than the areas where there were no forest roads, there were suitable places to hang the traps on the roadsides, and the traps that were hung in these areas released more pheromone and attracted the beetles.

In order to prevent the bark beetles from reproducing in great amounts in the forests of our country and damage the trees, the precautions that will prevent the increase of the bark beetles population must definitely be taken. First of all, a clean forestry management must be applied. The overthrown trees or the trees that are cut must be removed from the forest as soon as possible without any delay.

The trees are removed from the forests by dragging them on the ground in Artvin or by air-lines in areas where there are no forest roads. The inadequate effective areas in mountainous areas, frequent dry-up of trees and the need for removal, the need for an adequate forest road in the forest areas and similar reasons may be considered as the negative sides of the air-lines in forest areas (Acar, 2004).

As a conclusion, when the rates of catching the beetles of the Pheromone Traps are considered, it has been revealed with statistical analyses that there are significant differences between the areas where there are forest roads and the areas where there are no forest roads; and the fight against bark beetles in the areas where there are forest roads is more successful.

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ORAL PRESENTATION

ESTIMATING ABOVEGROUND BIOMASS OF EVEN-AGED SCOTCH PINE (*PINUS SYLVESTRIS* L.) FORESTS USING REMOTE SENSING DATA IN ÇIFTLIK FOREST PLANNING UNIT

Alkan GÜNLÜ[1]*, İlker ERCANLI[1], Muammer ŞENYURT[1], Aydın KAHRIMAN[2]

[1]Çankırı Karatekin University, Faculty of Forestry, 18200 Çankırı, Turkey. Tel: +90 376 212 2757 Fax: +90 376 213 6983 E-mail: alkangunlu@karatekin.edu.tr*
[2]Artvin Çoruh University, Faculty of Forestry, 08000, Artvin, Turkey.

ABSTRACT

Accurate aboveground biomass (AGB) estimations are significant forest inventory measurements and are essential in the prediction of carbon stocks, greenhouse gas inventories and fuel accumulations, and in the management of fuel wood production for bioenergy. The use of remote sensing data can reduce cost and labor for inventory in forestry. The remote sensing data can produce more successful results with lower cost than classical methods. In this study, the relationships between the AGB and band reflectance values obtained from Landsat TM satellite image were evaluated by statistical methods in Çiftlik Planning Unit, Taşköprü Forest Enterprise, Kastamonu Forest Regional Directorate. The AGB of individual trees were calculated by using the species-specific and regional allometric equations developed by Yavuz (2010) for Scots pine trees. A multiple linear regression technique was used to evaluate whether remote sensing data are essential to predict the aboveground biomass. The results indicated that a linear combination of TM 1, TM4 and TM5 for stand biomass (adjusted R^2=0.445; standard error=11.179 ton/ha).

Keywords: Aboveground Biomass, Landsat TM, Regression Analysis

1. INTRODUCTION

Even though fossil-fuel emissions may account for a important amount of global carbon emissions, biomass estimations are required for the sustainable planning of forest resources, especially to support decision making for forest management policies (Brown et al., 1999; Fehremann et al., 2008). In classical forest inventory studies, the AGB is usually predicted by using individual allometric equations that were established from measurements of felling trees. In many forest applications, these equations, relating tree biomass (kg) or stand biomass (ton/ha), as well as their components, with easily measurable variables, using regression techniques have been developed for specific geographic areas and tree species. Although the most predictive results for estimating forest biomass are obtained based on ground measurements, these ground measurements are time-wasting and labor-intensive, and it is impossible to most cases such as large forest areas. As alternative approach, remote sensing can assist the prediction of the AGB at multiple scales with large spatial and temporal coverage by taking into considerations with correlations between spectral information detected by satellite image data and forest biomass. Especially, remote sensing data, e.g., the well obtainability of higher resolution satellite data, provides an opportunity to obtain the required biomass predictions at lower costs and in rationally short time (Leckie and Gillis, 1995; Trotter et al. 1997; Peuhkurinen et al. 2008, Mısır et al., 2011). In some studies, it is

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focused on using Landsat TM/ETM+ and SPOT satellite data to predict forest stand parameters such as stand volume, basal area, tree density and stand age (Pax et al., 2001; Zheng et al. 2004; Makela et al., 2004; Freitas et al., 2005; Hall et al., 2006; Sivanpillai et al., 2006; Huiyan et al., 2006; Mohammadi et al., 2010; Poulain et al., 2010; Mısır, 2013). In many studies, essential efforts were reserved to combine remote sensing data with terrestrial inventory surveys, and focused the estimation of forest stand attributes through multiple regression analysis using various remote sensing data as independent variables. Despite the opportunity of the remote sensing data for predicting stand biomass, there are only a few studies concerning the prediction systems based on linear models including stand biomass as dependent variable and some band reflectance values from satellite images as independent data in forest areas. Therefore, the goal of this research was to examine the relations between the AGB from sample plots and band reflectance values originating from Landsat TM satellite image in studied Çiftlik forest areas in the middle Black Sea Region of Turkey.

2. MATERIAL AND METHODS

2.1. Study Area

The study area is the Çiftlik planning unit located in Kastamonu city in north of Turkey. This area is between 41° 14' 11'' and 41° 19' 58'' E and 34° 09' 39'' and 34° 21' 59 N'' (Figure 1). The elevation ranges from 1100 to 11920 m above sea level and is 1510 m on average. Mean annual temperature and precipitation are 9.8 °C and 449.7 mm, respectively. The vegetation is composed of *Pinus sylvestris* L, *Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe, *Abies nordmanniana* (Stev.) Spach. subsp. *bornmuelleriana* (Mattf.), *Fagus orientalis* Lipsky, *Quercus* spp.,*Carpinus betulus* and the other broad-leaved trees (Anonymous, 2008).

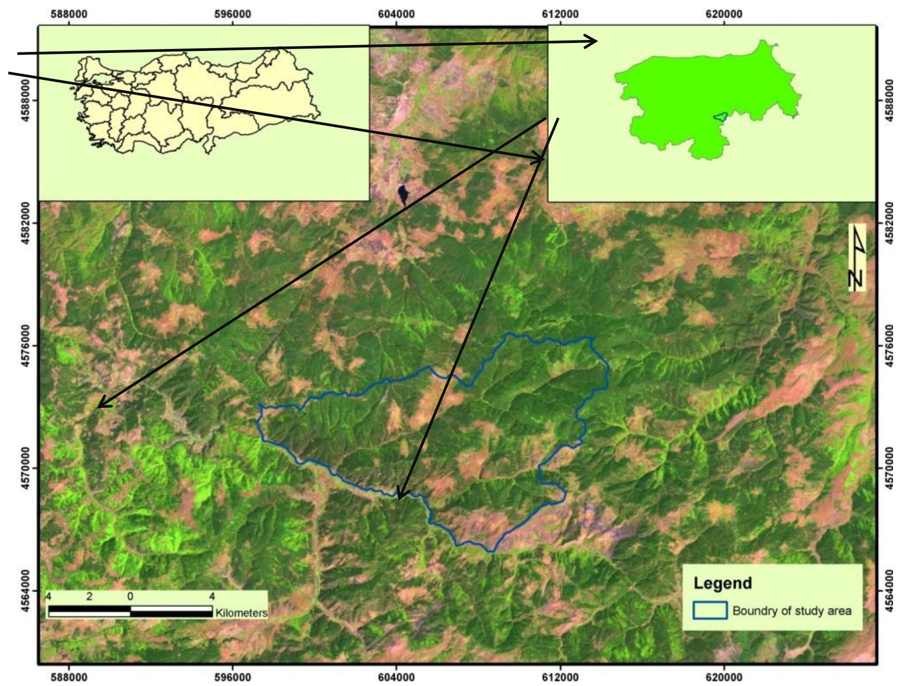

Figure 1. Location of the study area

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2.2. Ground measurement data

In this study, total 150 sample plots of pure *Pinus sylvestris* L. forest areas were taken. The size of the sample plots changed from 400 to 800 m^2. A Global Positioning Systems (GPS) receiver was placed at the center of each sample plot and the UTM (Universal Transverse Mercator) coordinates of each sample plot were also recorded by GPS. In the sample area, the diameter of each tree at breast height (dbh) was measured to the nearest 0.1 cm using calipers with dbh > 7.9 cm. The biomass values of single trees were directly calculated by using the species-specific and regional allometric equations developed by Yavuz et. al. (2010) for Scots pine trees obtained from Northern of Turkey. The four equations for predicting the stem, branch, needless, and bark of individual trees are based only on dbh and are single entry biomass equations (Yavuz et al., 2010):

$$\text{Biomass values of tree stem} = 15.0845 - 3.3166 \cdot \text{dbh} + 0.3358 \cdot \text{dbh}^2 \quad (1)$$
$$R^2 = 0.932, \text{S.E.} = 33.799$$
$$\text{Ln(Biomass values of tree branch)} = -5.278 + 2.365 \cdot \text{Ln(dbh)} \quad (2)$$
$$R^2 = 0.605, \text{S.E.} = 0.866$$
$$\text{Biomass values of tree needless} = 1.1331 \cdot 1.0704^{\text{dbh}} \quad (3)$$
$$R^2 = 0.431, \text{S.E.} = 0.8662$$
$$\text{Ln(Biomass values of tree bark)} = 2.9763 - \frac{26.7852}{\text{dbh}} \quad (4)$$
$$R^2 = 0519, \text{S.E.} = 0.519$$

The total aboveground biomass values of each sample plots were obtained by summing the biomass values of all single trees in sample plots and transformed to per hectare based on the size of sample plots.

2.3. Remote sensing data

Landsat TM satellite image was acquired on 27 August 2010 (path/row 176/31). The six bands (TM1, TM2, TM3, TM4, TM5 and TM7) of Landsat TM with 30 m spatial resolution were used. The Landsat TM satellite image was georeferenced to UTM WGS 84 Zone 36. Using 25 control points taken from Google earth map, a root square mean error of 0.5 pixels was obtained. The UTM coordinates of the sample plots determined by GPS. However, the GPS points have positional errors, which normally average to ±4m. Therefore, it is difficult to correctly locate each sample plot on the center of the 30 m grid of Landsat TM pixels. Therefore, many researchers used a moving window, such as a 3 x 3 pixel (Makela and Pekkarinen, 2004, Labrecque et al., 2006). Similarly, we used a moving window to average the reflectance values in the neighboring pixels and the band reflectance values were calculated for each sample area on the Landsat TM satellite image. Data processing, interpreting and analysis were performed using Erdas Imagine 9.1™ version (Erdas, 2002).

2.4. Statistical analysis

In this study, to examine the relations between the spectral reflectance values obtained from Landsat TM image and the AGB values, multiple linear regression analysis were used in studied species and stands. This multiple linear regression models were developed though Ordinary Least Squares technique using the band reflectance values and their combination as

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independent variable, which dependent variables in models were stand biomass values. The multiple stepwise regression analysis was carried out by SPSS (SPSS Institute Inc, 2007). The stepwise regression technique was used to select the best site variables that are significant ($p<0.05$) with the highest value of coefficient of determination adjusted by number of parameters (R^2_{adj}), also called adjusted the coefficient of determination. The model structure used in this study to below:

$$AGB = \beta_0 + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + ... + \beta_n \cdot X_n + \varepsilon \tag{5}$$

Where AGB is the aboveground biomass values, X_1 …… X_n are variable vectors corresponding to Landsat TM satellite image data, the spectral reflectance values, TM 1-5 and TM 7 variables, β_1 …… β_n represent model coefficients and ε is the additive error term (Corona et al., 1998; Fontes et al., 2003).

3. RESULTS AND DISCUSSION

The selected best regression models including some accuracy statistics such as the coefficients of determination (R^2) and the standard error of model (Sy.x) are presented in Table 1 for the spectral reflectance values. In these selected regression models for the AGB values, the F statistics and coefficients were significant at a probability level of 95 percent ($p<0.05$). The stand biomass model based on the spectral reflectance values were developed by TM 1, TM 4 and TM 5 as independent variables, and this model performance were calculated an adjusted R^2=0.445 with Se=11.179. TM 1 and TM 4 have a negative relationship with AGB, but TM 5 has a positive relationship (Table 1). Figure 2 shows the scatterplots of residuals versus predicted biomass values. When examining the literature, there are many studies for estimating aboveground biomass using Landsat satellite images. Lu (2005), when predicting the AGB using Landsat images for five different regions, demonstrated that the AGB was highly correlated with the TM 5 (R^2 = 0.683), TM 4 (R^2 = 0.701), and TM 4 (R^2 = 0.746). Maynard et al. (2007) modeled the AGB using band reflectance values obtained from Landsat 7 ETM+ satellite image and the R^2 value was 0.53 for ETM 4 and ETM 7. Our results also agree with previous study that showed a correlation between AGB and Landsat TM band reflectance values (Günlü et al., 2014).

Table 1. Parameters of the ‘best fit’ regression models of stand biomass from the band reflectance values based the TM 1-5 and TM 7.

Independent Variables	Coefficients of Independent Variables	S. E. of Variables	t-statistics	p-value
Constant	303.596	39.933	7.603	0.000
TM 1	-4.293	0.901	-4.768	0.000
TM 4	-0.795	0.287	-2.769	0.000
TM 5	1.352	0.229	5.913	0.000
R^2=0.445	S_e=11.179			

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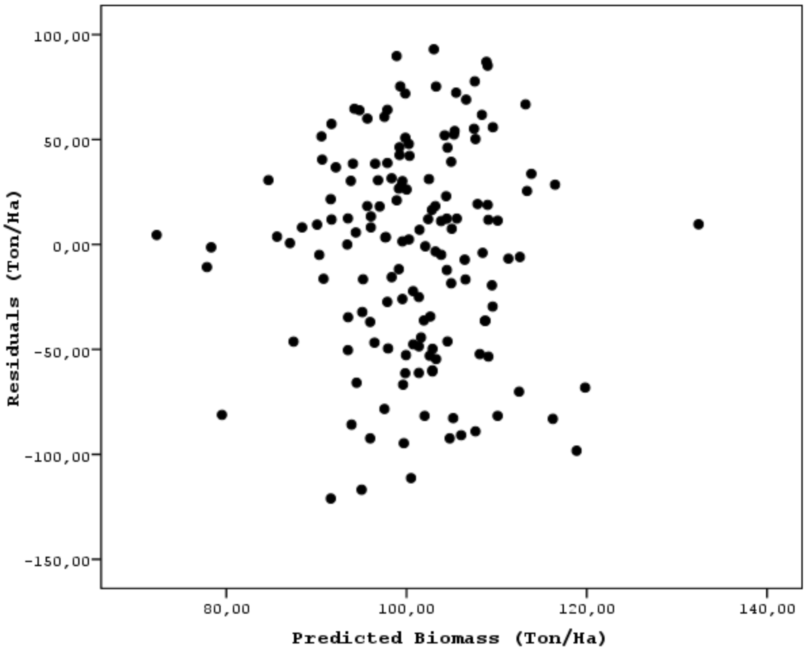

Figure 2. Residuals versus predicted biomass values from multiple regression model

4. CONCLUSIONS

The relationships between band reflectance values obtained from Landsat TM data and the AGB was determined by multiple linear regression analysis. The model including TM1, TM3 and TM5 as independent variables was the best predictor of the AGB (adjusted R^2=0.445; standard error=11.179 ton/ha). As a result of this study, the estimation of the AGB using Landsat TM satellite image moderate correlation was found in this study

5. ACKNOWLEDGMENT

We would like to thank to for support to the Head of Forest Management and Planning Department, General Directorate of Forestry, Republic of Turkey.

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ESTIMATION OF SOME STAND PARAMETERS USING GÖKTÜRK-2 SATELLITE IMAGE

Sinan BULUT*, Alkan GÜNLÜ, Sedat KELEŞ

Çankırı Karatekin University, Faculty of Forestry, 18200 Çankırı, Turkey. Tel: +90 376212 2757 Fax: +90 376 2136983 E-mail: sbulut@karatekin.edu.tr*

ABSTRACT

In forestry, inventory data are based on both remotely sensed data and ground measurements with temporary sample plots. Stand parameters such as stand volume (V), stand basal area (BA), tree density (N), dominant height and crown closures are fundamental knowledge needed in preparing forest management plans. However, the traditional forest inventory evaluation is expensive and time-consuming to conduct. Remote sensing data have become indispensably important in forestry for several decades, particularly as a tool for acquiring information on the composition and spatial structure of forest ecosystems as a part of forest inventory. Several studies have been carried out worldwide on use of remotely sensed data in forest inventory studies in Turkey. In our study, Göktürk-2 satellite image and data obtained from 120 temporary plots were used to estimate some important forest stand parameters. Multiple stepwise regression analysis is carried out to predict the V, BA and N. According to R^2, mean absolute error (MAE) and root mean square error (RMSE), the performance of regression analysis were compared in estimating V, BA and N. The results demonstrated that a linear combination of Band 1, Band 2, Band 3 and Band 4 for stand volume and basal area (adjusted R^2=0.61; RMSE=30.92 m^3 ha^{-1}; MAE=25.24) and (adjusted R^2=0.50; RMSE=5.29 m^2 ha^{-1}; MAE=4.24), respectively, and a linear combination of Band 1 and Band 2 for tree density (adjusted R^2=0.31; RMSE=244.94 stems/ha^{-1}; MAE=198.77) were better predictors than a linear combination of Infrared Percentage Vegetation Index (IPVI) and Difference Vegetation Index (DVI) for stand volume and basal area (adjusted R^2=0.23; RMSE=43.66 m^3 ha^{-1}; MAE=34.54) and (adjusted R^2=0.21; RMSE=6.67 m^2 ha^{-1}; MAE=5.38), respectively, and a linear combination of DVI for tree density (adjusted R^2=0.06; RMSE=287.04 stems/ha^{-1}; MAE=234.18).

Key words: Stand parameters, Regression analysis, Göktürk-2 satellite image

1. INTRODUCTION

Consistency and sensitivity of planning depend on the accuracy of forest inventory. In planning process, stand parameters such as stand volume (V), stand basal area (BA), tree density (N), dominant height and crown closures are obtained from ground measurements in temporary sample plots in forest inventory. Forest inventory is the most intensive and costly stage of planning process (Trotter et al., 1997). Recently, remote sensing and geographic information system (GIS) has played an important role in forest management planning (Leckie and Gillis, 1995; Chiavetta et al., 2008). Many studies have indicated that there have been empirical relationships among the ground measurements and band reflectance values and vegetation indices generated from satellite image in both the world and our country. These studies have tried to estimate some stand parameters using different satellite images (Trotter et al., 1997; Kayitakire et al., 2006, Leboeuf et al., 2007; Gebreslasie et al., 2010, Özdemir and Karnieli, 2011, Günlü 2013, Mısır, 2013, Şenyurt et al., 2013, Günlü et al. 2014, Günlü et al., 2015). The goal of this study is to predict stand parameters of V, BA and N using our country's national satellite Göktürk-2 satellite image in Çankırı Planning Unit in the Central Anatolia Region of Turkey.

2. MATERIAL AND METHODS

2.1. Study Area

The study area is located in Ankara Forest Regional Directorate, Çankırı Forest Enterprise, Çankırı Planning Unit in the Central Anatolia Region of Turkey. It is bounded by 529200-541200 on the east longitudes and 4481500-4507000 on the north latitudes (Figure 1). The study area is 30600 ha and 9589.74 ha (31.3%) of it is covered by trees that include Black pine, Scots pine, Oak, Poplar and Hornbeam. Elevation ranges are between 540 and 1809 m. Mean annual temperature is about 11.1 ^{o}C and precipitation is about 397.7 mm.

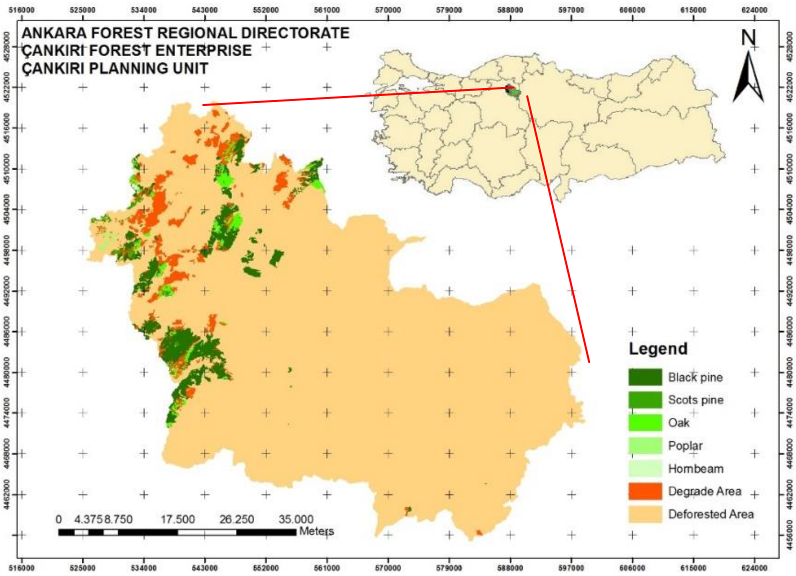

Figure 1. Map of the study area

2.2. Field Measurements

In this study, 120 temporary plots from forest management inventories in 2011 were used. According to size of sample plots, sample plots were chosen from low (800 m^2), medium (600m^2) and full crown closure (400 m^2) of Black pine and Scots pine stands. The coordinates of each sample area was determined by using Global Positioning System (GPS) device. Then, diameter at breast height (DBH) was measured in all trees with a diameter greater than 7.9 cm at breast height in each sample plot. Stand volume (V), stand basal area (BA) and stem density (N) were calculated in each sample plot and convert to per hectare.

2.3. Remote Sensing and Processing

The Göktürk-2 satellite image was acquired on 2014. It is consisted of four spectral bands with 5 m spatial resolution. The Göktürk-2 satellite image was rectified using 22 ground control points depend on the Google earth map. The size of a sample plot (400, 600 and 800

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m^2) was bigger than size of one pixel (25 m^2). Thus, reflectance value of one pixel was not represent a sample plot. To resolve this problem, buffer zones were discarded depending sample size. The reflectance value of each sample plot was calculated by averaging the pixels located in the buffer zone. Also, using the reflectance values for each band, some vegetation indices were obtained and used in this study. The vegetation indices used in this study were given in Table 1.

Table 1. The vegetation indices

Vegetation indices	Equations	Reference
NDVI	(NIR-Red)/(NIR + Red)	Rouse et al. (1973)
SR	(NIR)/(Red)	Jordan (1969)
SAVI	(NIR-Red)*(1+L)/(NIR+Red+L)	Huete (1988)
EVI	(NIR-Red)/((NIR+(C1*Red)-(C2*Blue)*(1+L))	Huete et al. (1999)
IPVI	(NIR)/(NIR+Red)	Crippen (1990)
DVI	(NIR)-(Red)	Clevers (1988)

NDVI, Normalize Difference Vegetation Index; SR, Simple ratio; SAVI, Soil Adjusted Vegetation Index; EVI, Enhanced Vegetation Index; IPVI, Infrared Percentage Vegetation Index; DVI, Difference Vegetation Index; red and green (visible wavelengths); NIR (near infrared wavelengths). Coefficients (C1 = 6.0 and C2 = 7.5) and soil adjustment factor L =1.0.

2.4. Statistical Analysis

In this study, Band 1, Band 2, Band 3, Band 4 and vegetation indices obtained from Göktürk-2 satellite image as independent variables, and V, BA and N as dependent variables were used in stepwise regression analysis. Before the analysis, suitability of normal distribution of data sets was controlled with Kolmogorov-Smirnov test. All data sets were normal distribution ($p>0.05$). The regression analysis was performed using SPSS version 20.0 (SPSS 2011). Relationships between the stand parameters with reflectance values and vegetation indices of Göktürk-2 satellite image were modeled. Dependent variables were the stand parameters and independent variables were reflectance values and vegetation indices. The model was defined as follow:

$$SP = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \ldots + \beta_n * Xn + \varepsilon \qquad (1)$$

where *SP* is the stand parameters, stand volume, basal area and tree density, response variables, *X1, X2, ...,Xn,* are independent variable vectors corresponding to Göktürk-2 satellite image (spectral reflectance values and vegetation indices) and the combination variables, *β1... βn* represent model coefficients, and *ε* is the additive bias (Corona et al., 1998; Fontes et al., 2003).

2.5. Performance Criteria of Models

Three different performance criteria that include determination of coefficient (R^2), mean absolute error (MAE) and root mean square error (RMSE) were used comparisons of models. The determination of coefficient is a good indicator of explanatory power of the model and reflects predictive power of the model. The formula was defined as follow:

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$$R^2 = 1 - \left(\frac{\sum_{i=1}^{n}(Y_{measured} - Y_{predicted})^2}{\sum_{i=1}^{n}(Y_{measured} - Y_{mean\ of\ measured})^2}\right) \quad (2)$$

The accuracy was measured by MAE and RMSE defined as follow:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|e_i| \quad (3)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(e_i)^2} \quad (4)$$

where n, the number of data; ei, the residuals; $Y_{measured}$, observed stand parameters in sample plots; $Y_{mean\ of\ measured}$, the arithmetic mean of observed stand parameters in sample plots $Y_{predicted}$, the predicted stand parameters by regression analysis.

3. RESULTS AND DISCUSSION

In this study, stand volume (V), stand basal area (BA) and tree density (N) were predicted using stepwise regression analysis with reflectance values and vegetation indices generated from Göktürk-2 satellite image. Descriptive statistics of V, BA and N were presented in Table 2.

Table 2. Descriptive statistics of V, BA and N

	N	Min	Max	Mean	SD	Cv %	Skewness	Kurtosis
V (m^3/ha)	120	19.75	231.00	121.77	49.92	41.00	0.206	-0.763
BA (m^2/ha)	120	5.07	38.83	23.32	7.53	32.29	-0.130	-0.671
N (stems/ha)	120	63.00	1400.00	634.53	297.13	46.83	0.457	-0.363

Determination of coefficient (R^2), the standard error of model (Syx), the mean absolute error (MAE) and the root mean square error (RMSE) were used as a performance criterion to select the best model (Table 3). The stand volume and stand basal area were developed by Band 1, 2, 3 and 4 as independent variables. The tree density was developed by Band 1 and 2. The best model was obtained for stand volume (R^2=0.61, Syx=31.580, MAE=25.24 and RMSE=30.92 m^3/ha). Performance criteria of stand basal area and stem density were calculated with adjusted R^2=0.50, Syx=5.408, MAE=4.24, RMSE=5.29 m^3/ha and R^2=0.31, Syx=248.065, MAE=198.77, RMSE=244.94 m^3/ha, respectively.

Stand volume, stand basal area and tree density with vegetation indices showed the poor relations compared to reflectance values of Göktürk-2 satellite image (Table 4). However, two indices (IPVI and DVI) were only included as model parameters. The model parameters developed for stand volume and stand basal area was IPVI and DVI, for tree density was DVI. Performance criteria of stand volume, stand basal area and tree density were calculated with adjusted R^2=0.23, Syx=44.214, MAE=34.54, RMSE=43.66 m^3/ha; R^2=0.21, Syx=6.753, MAE=5.38, RMSE=6.67 m^3/ha and R^2=0.06, Syx=289.462, MAE=234.18, RMSE=287.04 m^3/ha.

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Table 3. The models and performance criteria of stand parameters that created based on the reflectance values with regression models

Model Group	**Model Description** Dependent Variables	Independent Variables	**Coefficient of Independent Variables**	**t statistics**	**p value**
Stand Volume (m^3/ha)	V	Constant	1931.535	13.287	0.000
		Band 1	-1.517	-2.479	0.015
		Band 2	5.023	3.975	0.000
		Band 3	-4.582	-11.213	0.000
		Band 4	0.160	6.225	0.000
R^2= 0.61	Syx= 31.580	MAE= 25.24		RMSE= 30.92 m^3/ha	
Stand Basal Area (m^2/ha)	BA	Constant	262.318	10.537	0.000
		Band 1	-0.460	-4.394	0.000
		Band 2	1.152	5.321	0.000
		Band 3	-0.671	-9.585	0.000
		Band 4	0.024	5.423	0.000
R^2= 0.50	Syx= 5.408	MAE= 4.24		RMSE= 5.29 m^2/ha	
Tree Density (stems/ha)	N	Constant	-2387.558	-4.559	0.000
		Band 1	-28.465	-7.261	0.000
		Band 2	49.417	6.887	0.000
R^2= 0.31	Syx=248.065	MAE= 198.77		RMSE= 244.94 stems/ha	

Table 4. The models and performance criteria of stand parameters that created based on some vegetation indices with regression models

Model Group	**Model Description** Dependent Variables	Independent Variables	**Coefficient of Independent Variables**	**t statistics**	**p value**
Stand Volume (m^3/ha)	V	Constant	479.698	6.153	0.000
		IPVI	-722.823	-4.692	0.000
		DVI	0.607	4.097	0.000
R^2= 0.23	Syx= 44.214	MAE= 34.54		RMSE= 43.66 m^3/ha	
Stand Basal Area (m^2/ha)	BA	Constant	80.476	6.759	0.000
		IPVI	-114.770	-4.878	0.000
		DVI	0.100	4.418	0.000
R^2= 0.21	Syx= 6.753	MAE= 5.38		RMSE= 6.67 m^2/ha	
Stem Density (stems/ha)	N	Constant	670.774	22.663	0.000
		DVI	0.400	2.718	0.008
R^2= 0.06	Syx=289.462	MAE= 234.18		RMSE= 287.04 stems/ha	

Regarding this, Kayitakire et al. (2006) applied panchromatic IKONOS image in the estimation of basal area and dominant height for homogenous Norway spruce stands and found a low relation for basal area (R^2=35%), but good relation for dominant height (R^2 ranges from 0.76 to 0.82). Özdemir (2008) investigated between stem volume and tree

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attributes generated pan-sharpened Quickbird image in mixed forest areas (R^2=0.67). In another study by Özdemir and Karnieli (2011) examined the relation between stand volume, basal area and tree density, and texture values obtained from WorldView-2 image in dryland forest region with R^2 values of 0.42, 0.54 and 0.38, respectively. The models developed by Mısır (2013) have indicated to estimate the stand volume using Landsat 7 ETM+ image and the R^2 values of 0.60 was found. In a study done by Şenyurt (2013) using Landsat 8 satellite images tried to estimate basal area, tree density and quadratic mean diameter and the R^2 values of 0.6545, 0.5833 and 0.4925 were found, respectively. Günlü et al. (2014) investigated the prediction of stand volume and basal area using band reflectance values and vegetation indices obtained from Pan-Sharpened IKONOS image and the R^2 values of 0.41 and 0.43 for band reflectance model, and R^2 values of 0.55 and 0.59 for vegetation indices model were found. Unlike the work performed by the Günlü et al. (2014), in this study the regression models developed with Göktürk-2 satellite image band reflectance values were able to estimate stand volume and basal area better than do the Göktürk-2 vegetation indices values. Another study conducted by the Günlü et al. (2015) showed that model including band reflectance and vegetation indices values predicted the stand volume and tree density using Spot-4 satellite image with R^2 values of 0.67 and 0.62, respectively.

4. CONCLUSION AND SUGGESTIONS

This study examined the possibility of Göktürk-2 satellite image in prediction of stand volume, basal area and tree density in Çankırı Forest Planning Unit in the Central Anatolia Region of Turkey. Stepwise regression analysis was performed, and models were developed using band reflectance values and VIs obtained from the Göktürk-2 satellite image. The results of our study showed that the models obtained from reflectance values were better predictor than models with vegetation indices in study area. It is concluded that the estimation of stand parameters using Göktürk-2 satellite image should be expanded in different forest ecosystems of Turkey.

5. ACKNOWLEDGMENT

We would like to thank to General Command of Mapping and General Directorate of Forestry for the supply of satellite images of Göktürk-2 and forest inventory data.

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EVALUATING DEPLOYMENT OF FIREFIGHTING TEAMS FOR TIMELY ACCESS TO PROTECTED AREAS: THE CASE OF ULUDAĞ NATIONAL PARK

Abdullah E. AKAY*, Ebru BİLİCİ, Hande E. KILIÇ

Bursa Technical University, Faculty of Forestry, 16330 Bursa, Turkey. Tel: +90 224 3003426
Fax: +90 224 3003429 E-mail: abdullah.akay@btu.edu.tr*

ABSTRACT

Quick response to forest fire areas is critical especially in environmentally sensitive areas because of their natural features, ecological functions, wildlife, aesthetic or historical values. Thus, it is very important to determine the optimum route that minimizes the total travel time of the fire fighters for timely access to protected areas. In this study, deployment of firefighting teams was evaluated using Geographical Information System (GIS) based decision support system that searches for the optimum route with minimum arrival time to the forest fire. The study area was Uludağ National Park which is one of the important protected areas in Turkey and it is specified as the first degree fire sensitive area. In the solution process, the network analysis methods under "Network Analyst" extension of ArcGIS 10 platform were used to evaluate available firefighting teams. The results indicated that new firefighting teams should be located in the regions in order to access whole area in critical response time. Besides, new roads should be considered to provide alternative shortest paths to fire areas. Moreover, current road standards should be improved to increase current transportation speed that might reduce travel time to fire areas.

Keywords: Forest fires, protected areas, shortest part, network analysis

1. INTRODUCTION

A variety of natural disasters (i.e. wild fires, storm damages, etc.) can have a great impact on forest resources. Among them, forest fire disaster can be the most detrimental factor affecting forest ecosystems. The forested areas of 5.5 million ha located along the Mediterranean coastline are highly sensitive to forest fires in Turkey (Akay and Kılıç, 2015). Approximately 10,000 ha of forested areas are affected by wild fires annually (Akay and Şakar, 2009).

In order to reduce the potential effects of forest fires, the firefighters should reach the fire area within the critical response time in which the probability of controlling the forest fires rises dramatically. Quick response to forest fire areas is very important especially in environmentally sensitive areas. The environmentally sensitive areas (EASs) are defined as sensitive sites which need special protection, strategies, and implementations because of its natural features, ecological functions, wildlife, aesthetic or historical value. ESAs also include native forests, high quality successional forests, wildlife reserves, national parks, etc. Thus, determination of the optimum route that minimizes the total travel time of the fire fighters for timely access to sensitive areas is critical in combating forest fires.

Geographical Information Systems (GIS) techniques have been effectively used in forestry studies (Akay et al., 2008; Gumusay and Sahin, 2009; Wing et al., 2010). GIS techniques

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have been used in forest fire related studies (Sağlam et al., 2008; Sivrikaya et al., 2014; Dindaroğlu et al., 2014). GIS based decision support system can be also used to determine the fastest access routes from firefighting headquarters to fire areas. The recent studies indicated that network analysis method integrated with GIS tools provides effective solutions for solving vehicle routing problems (Akay et al., 2012; Stergiadou, 2014; Drosos et al., 20104; Akay and Kılıç, 2015).

In this study, deployment of firefighting teams was evaluated for timely access to potential fires in Uludağ National Park in Bursa, Turkey. A GIS tool was used to search for the optimum route with minimum arrival time to the potential forest fires. In the solution process, the Network Analyst provided as an extension in ArcGIS 10 platform was used to evaluate available firefighting teams and existing road network.

2. MATERIAL AND METHODS

2.1. Study Area

The study area was Uludağ National Park which is one of the important protected areas in Turkey (Figure 1). Uludag National Park is located at 36 km south of the city of Bursa. Mount Uludağ (Great Mountain) is the highest point (2543 m) in the Marmara region of Turkey. The waterfalls and glaciers at the peak are the most interesting geographical features in Uludağ National Park. About 71% of the National Park is covered by forests, while 28% is meadowlands and rocky areas, 0.5% is covered by open areas and water, and rest is a residential area (URL-1, 2016).

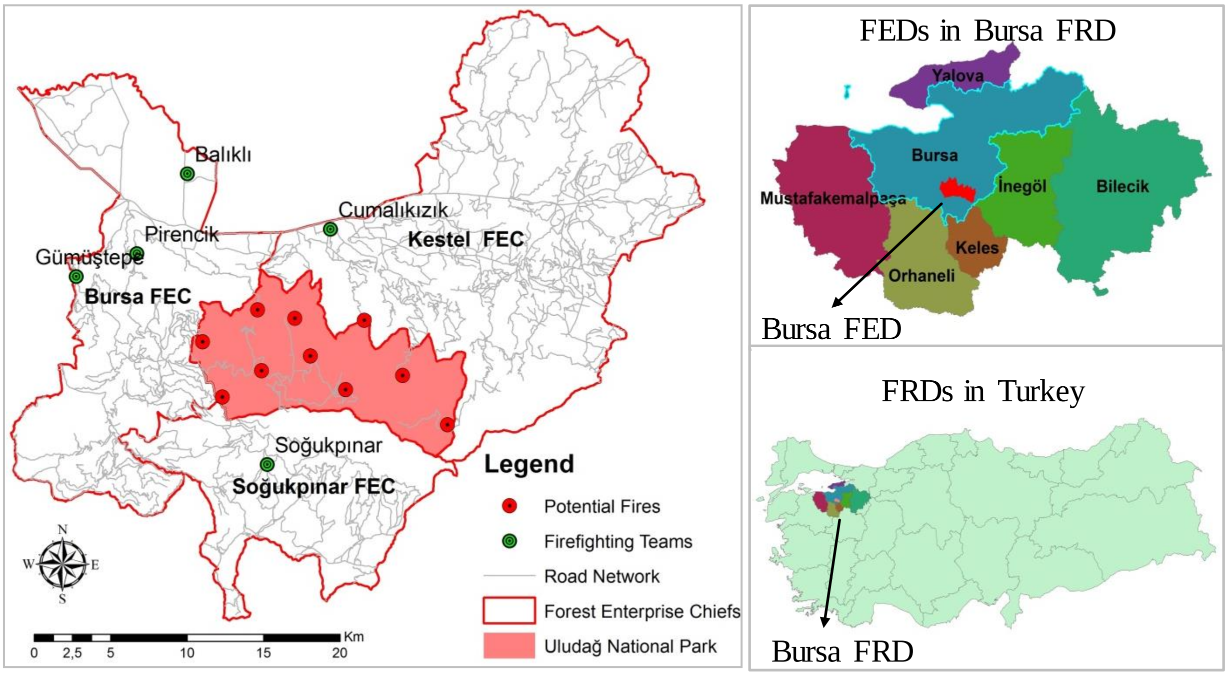

Figure 1. Firefighting teams around Uludağ National Park within Bursa Forest Enterprise Directorate

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Mount Uludağ was previously known as Olympos Misios in ancient times. During the Ottoman Empire, it was called as Kesis Mountain and it received current name of Uludağ in 1925. Its richness of flora and fauna has made Uludağ into a National Park and winter sports and summer activities are also very popular. Due to its proximity to large residential areas, the Park hosts very high numbers of campers and daily users (about 1,000,000 visitors per year). Thus, it is subject to high fire risk.

The Uludag National Park is located in Bursa Forest Enterprise Directorate (FED) which is specified as the first degree fire sensitive area. Bursa FED is in the border of Bursa Forestry Regional Directorate (FRD). Uludağ National Park is surrounded by three Forest Enterprise Chiefs (FECs) including Bursa FEC, Kestel FEC, and Soğukpınar FEC. There are five firefighting teams (Balıklı, Pirencik, Gümüştepe, Soğukpınar, Cumalıkızık) in the FECs. In this study, these teams are considered in selecting shortest route to potential forest fires (total of 10 fires) and determining accessible forest areas in critical response time.

2.2. Network Analysis

Network Analysis requires GIS database with accurate road network layer. Thus, road network layer was first developed based on 1:25000 topographic maps of Uludağ National Park. The average travel time of fire trucks was computed for each road section and added into the attribute table of the road network layer. Following formula was used to compute travel time based on road length and average speed of a fire truck that varies depending on road type:

$$t_i = \frac{l_i}{v_i} 60 \qquad (1)$$

t_i : travel time for road section i (minutes)
l_i : length of road section i (km)
v_i : average speed of fire truck for road section i (km/hour)
60 : used to convert the unit of travel time from hour to minute

The road types in the study area include asphalt, gravel, and forest roads. The average vehicle speeds for the road types are 60 km/hr, 40 km/hr, and 20 km/hr, respectively. The locations of firefighting teams and potential fires are also indicated on GIS database.

After generating GIS database, the Network Analyst extension of ArcGIS 10 was used to determine the fastest access routes to potential fire areas in Uludağ National Park. Network Analyst extension provides several methods including New Route, New Service Area, New Closest Facility, New OD Cost Matrix, New Vehicle Routing Problem, and New Location-Allocation (Figure 2). In this study, New Closest Facility and New Service Area methods were used based on network database where travel time as assigned to the each link in road network. New Closest Facility was used to find the fastest access routes from firefighting teams to the potential fire areas in the Park area. Then, the team with the minimum travel time to each potential fire area was determined. During the wild fires, some of road sections or forest units can be closed due to fire hazard risks. Considering these risks, some of the links located on the fastest access routes were excluded from the network system by locating barriers in the solution process (Figure 3).

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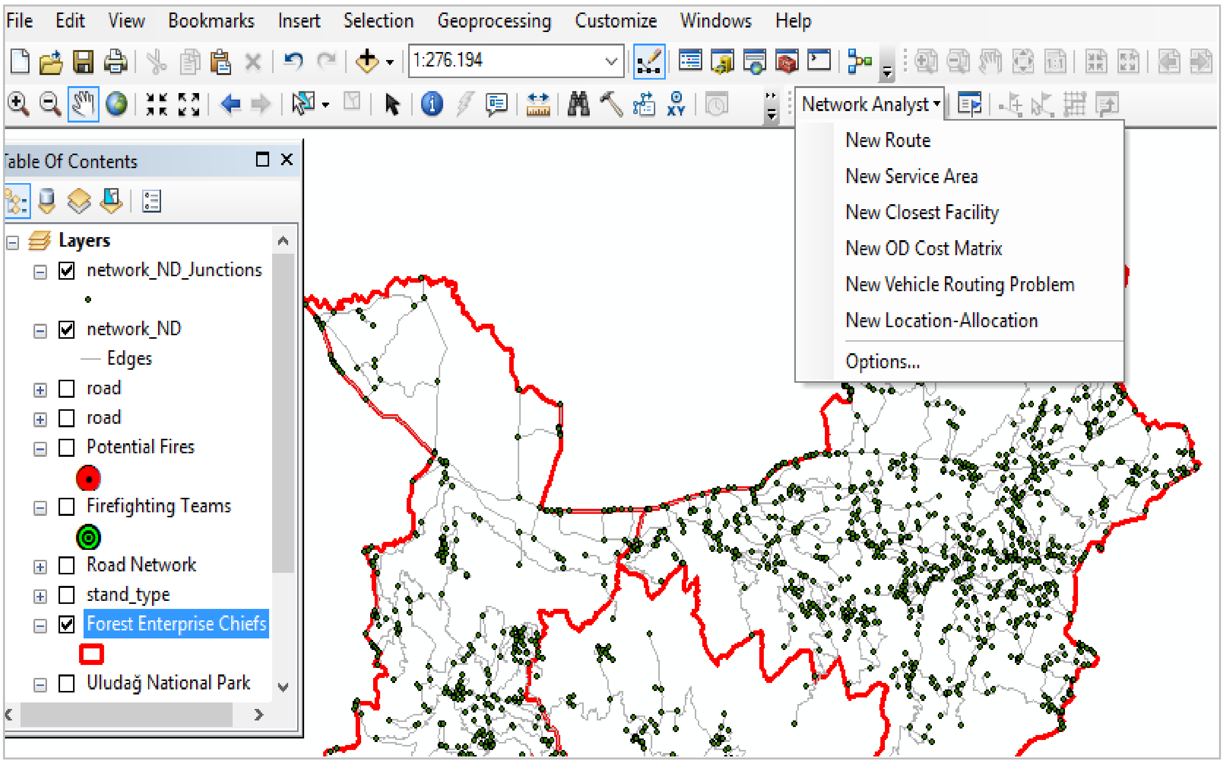

Figure 2. Network Analyst menu in ArcGIS 10

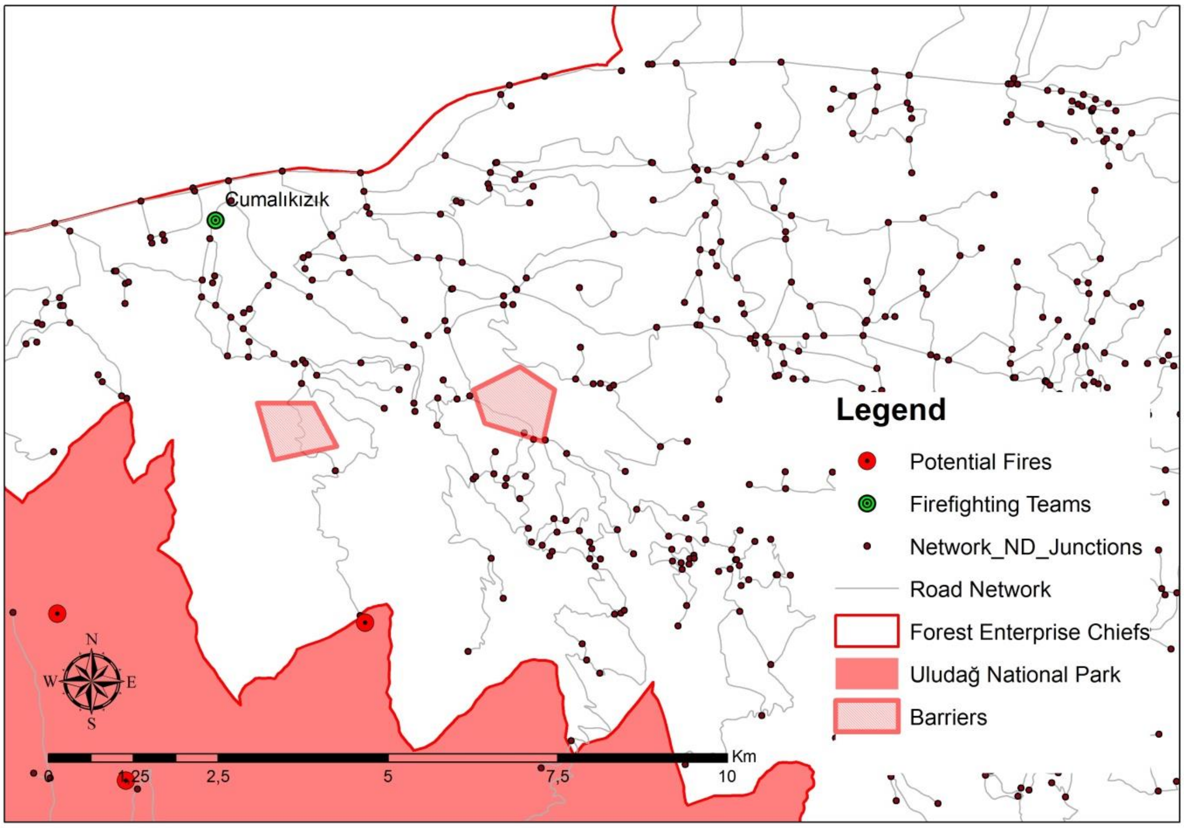

Figure 3. The areas of fire hazard risks excluded from the road network by the barriers

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The New Service Area method was used to evaluate accessible forest areas by the firefighting teams within the critical response time. The critical response time varies depending on the fire sensitivity levels (Table 1) (GDF 2008). The locations of the teams were considered as service area points and then the forest areas that can be reached within the critical response time were determined. Since the study area is sensitive to forest fires at the first degree, the critical response time was considered to be 20 minutes in this study.

Table 1. Critical response time to forest fires by fire sensitivity level (GDF, 2008)

	Fire Sensitivity Degrees				
	I	II	III	IV	V
Critical Response Time (min)	20	30	40	50	50

3. RESULTS AND DISCUSSION

The fastest access routes from firefighting teams to the potential fire areas in the study area were determined using the New Closest Facility method. The findings indicated that there is a correlation between the travel time and road type, as well as between travel time and road length. First, the firefighting teams that reached potential fire areas within the minimum arrival time were identified. Then, alternative routes were determined by considering fire hazard risks.

Figure 4 indicates the fastest access routes to the each potential fire area for the first scenario. The results indicated that, five of the potential fires were not accessible by the teams within the critical response time (Table 2). For the second scenario, barriers were placed on the road network to determine the safe access routes to the potential fire areas (Figure 5). It was found that the response teams that reached the potential fire areas within the critical response time were the same as in the first case, except the 6th and 7th fire areas (Table 3). However, the number of inaccessible fires within the critical response time increased to six fires (i.e. including fire number 7).

The forest areas that can be reached within a critical response time were determined by the New Service Area method. In solution process, the areas that can be reached by fire trucks through the road network within critical response time of 20 minutes were investigated. The results indicated that only 10.14% of the National Park can be reached by firefighting teams within 20 minutes (Figure 6). The results from methods strongly implied that new firefighting teams should be located in the study area in order to reach potential fire areas within the critical response time.

4. CONCLUSION AND SUGGESTIONS

A network analysis based GIS method was used to determine the fastest access routes from firefighting teams to potential fire areas in Uludağ National Park in Bursa, Turkey. The results indicated that available initial response teams in the study area cannot reach five out of 10 potential fire areas within the critical response time. When barriers were located in the National Forest, the number of inaccessible fires increased to six.

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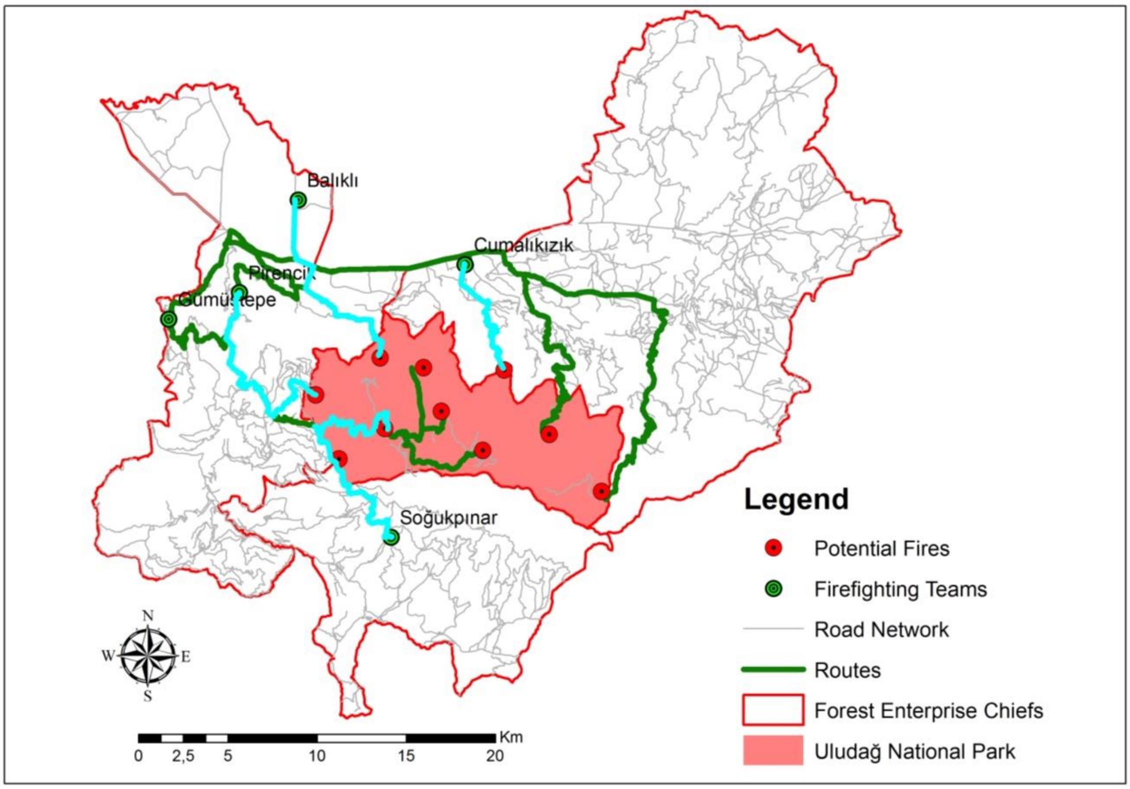

Figure 4. The fastest access routes to the each potential fire area at the first scenario

Table 2. The arrival time of initial response teams to potential fire areas in the first scenario

Teams	Potential Fire Areas									
	1	2	3	4	5	6	7	8	9	10
Balıklı	**19.44**	35.29	49.33	31.59	52.13	30.46	36.54	43.60	54.06	45.57
Pirencik	25.55	39.58	36.11	**18.37**	56.42	17.24	23.32	30.38	58.35	32.35
Gümüştepe	37.13	50.13	52.91	35.17	66.97	34.04	40.11	47.18	68.90	49.15
Soğukpınar	51.18	65.20	32.81	21.36	82.04	**8.39**	**18.01**	27.08	83.97	29.05
Cumalıkızık	28.91	**19.29**	54.40	36.66	39.51	35.53	41.61	48.67	41.44	50.64

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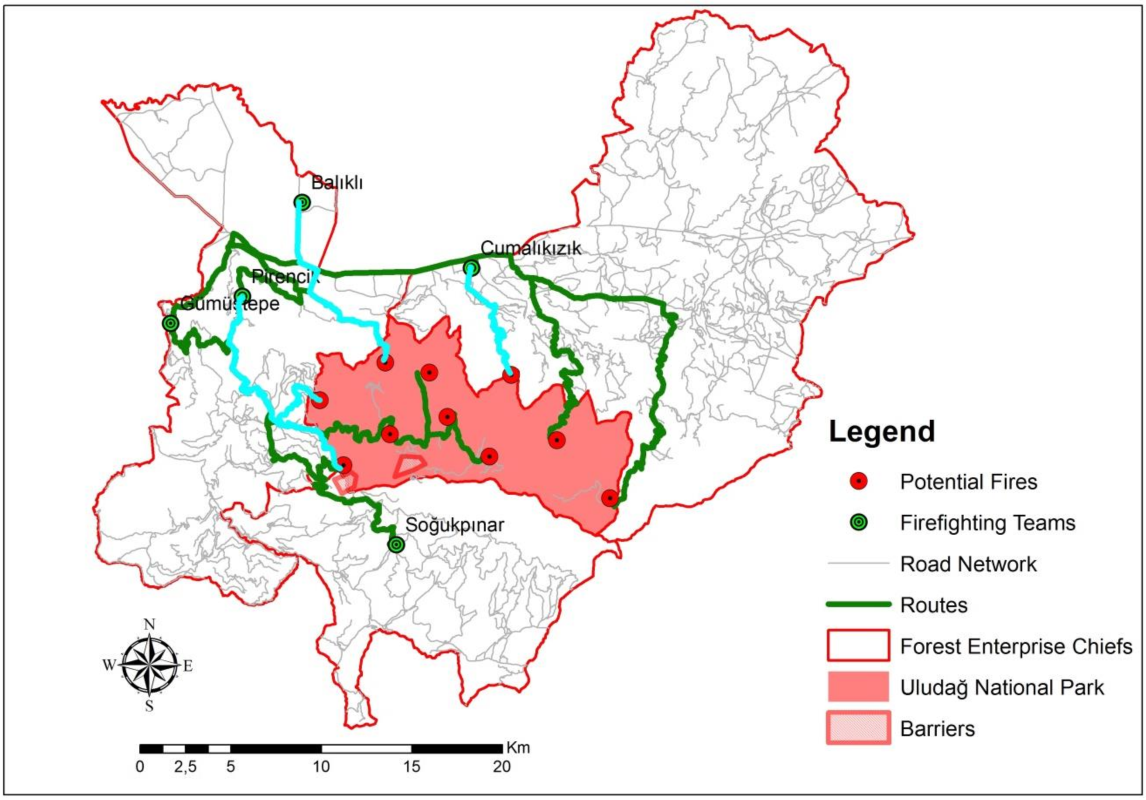

Figure 5. The fastest access routes to the each potential fire area at the second scenario

Table 3. The arrival time of initial response teams to potential fire areas in the second scenario

Teams	Potential Fire Areas									
	1	2	3	4	5	6	7	8	9	10
Balıklı	**19.44**	35.29	51.50	31.59	52.13	30.46	36.54	43.60	54.06	45.57
Pirencik	25.55	39.58	38.28	**18.37**	56.42	**17.24**	23.32	30.38	58.35	32.35
Gümüştepe	37.13	50.13	55.07	35.17	66.97	34.04	40.11	47.18	68.90	49.15
Soğukpınar	68.16	82.19	54.35	39.25	99.03	27.87	39.39	46.46	100.95	48.43
Cumalıkızık	28.91	**19.29**	56.57	36.66	39.51	35.53	41.61	48.67	41.44	50.64

ORAL PRESENTATION

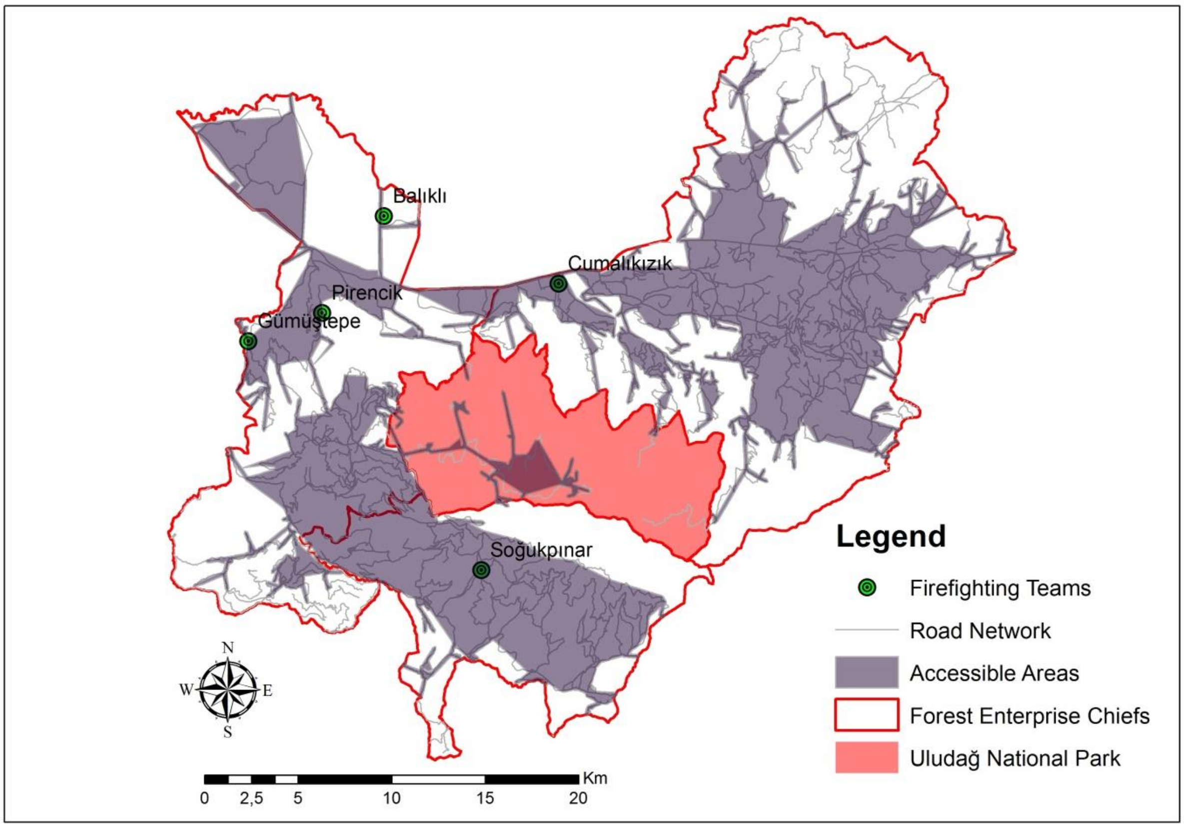

Figure 6. Forest areas accessible by firefighting teams within the critical response time

The forest areas that can be reached by firefighting teams within critical response time were also determined. It was found that 89.86% of the areas could not be reached by the response teams within the critical response time. The results indicated that new firefighting teams should be established in the region. Besides, road density should be increased by locating new roads. Moreover, road standards should be also improved to increase travel speeds and decrease travel time.

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EXAMINATION OF THE CHANGES IN WORK-RELATED HEALTH STATUS OF THE HARVESTING AND TRANSPORT WORKERS IN FORESTRY

Metin TUNAY*, Tuna EMİR, Kenan MELEMEZ

Bartın University, Forestry Faculty, 74100 Bartın, Turkey. Tel: +90 378 22351 70 Fax: +90 378 2235062 E-mail: mtunay@bartin.edu.tr*

ABSTRACT

Today labor protection is one of the most important issues of the working life. While forestry workers are at the limit value of the ergonomic pressures that a human organism can stand despite the technical progressions in recent years, legislation provisions fall behind the application due to the different features that the forestry sector has exhibited in terms of business life and the social security of the employees working in this sector cannot be provided completely. This situation hinders the forestry workers in showing the required sensitivity on health problems, and thus results in high level of health problems and affects productivity. The aim of this study is to reveal all the changes by performing all the physical examinations of the forestry workers who take charge in harvesting and transport operations in forestry such as measurement-logging, cutting with chainsaw, dragging with tractor and transportation with trucks within certain periods in the hospital environment, to detect the disorders occurring due to the work effect and to propose solutions. Within this scope, detailed information on general health status of a total of 12 forestry workers who are only taking charge in the relevant work segment, with each segment having a capacity of 3 workers, despite not having a certain distribution of work in forestry production and transport operations has been obtained upon comparing all the physical examinations of these workers to be made in 5-year periods (2011-2012 / 2015-2016 production years) and revealing the differences. Moreover, the work load that the forestry workers had within this period, their working methods and habits were also analyzed together.

Key words: Physical Examination, Worker Health, Forestry Worker, Social Security, Harvesting and Transport.

1. INTRODUCTION

Appearance of worker health, which is a social and economic problem, falls on the end of 18th century. Due to the fact that poor working conditions started to threaten the health of the employees and disease and accident rates increased, labor protection has gained importance. Worker health is a field aiming to maximize the physical, mental and social aspects of the employees in each job, to maintain this maximization, to prevent the factors that will spoil this order, to employ workers in the works that are suitable to their physiological and psychological abilities, and thus to adapt the work to the person and the person to the work. The object here is to provide maximum health capacity to the employees, to protect them from the negative aspects of the working conditions, and to provide the optimal harmony between the work and the worker (Dertli, 1999).

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Forestry works are the works performed under biological and physical conditions in order to meet different demands of people in forestlands. These works can be gathered around main points such as wood harvesting, forestation, plantation, road repair, and forest protection. Forestry works are included in heavy works due to high energy consumption, static workload density, frequent repetition of the movements such as lifting and carrying heavy loads, leaning, kneeling and standing, vulnerability to climatic factors such as extreme heat, high humidity, wind, snow and rain, negative technological effects such as noise, vibration, gas, dust, and chemicals, health disorders they create in the main systems of people such as central nervous system, skeletal system, cardiovascular system, and accident risks for all the organs of the body. These features of forestry works require the forestry workers to be strong, skilled and trained, thus the forestry has a different quality than the labor in many other business lines. Performing forestry activities timely and in accordance with the technique, and providing high productivity are primarily based on the employment of forestry workers who received a good education and whose living and working conditions are arranged (Engür, 2006).

Production works in forestry are composed of the processes such as cutting and toppling trees, cleaning the branches, girdling, classifying, wood extraction, loading, transporting, stacking and carrying the woods to the final storage. The peasants taking a production work from the forest administration perform these processes in periods of time that may take 1-5 months with the periods changing year by year. While on the one hand, they continue their working under hard land conditions; they perform cutting, dragging and carrying processes despite the harsh winter conditions (winter cutting) on the other hand. Compared to other sectors, forestry workers who are quoted in unit price in forestry generally work continuously and without resting in order to do a lot of work and earn more money by eating on the run and pushing their limits, and thus undesired situations such as fatigue and insomnia appear (Menemencioğlu, 2012). Forestry works generally performed in steep and rough areas far away from the main residential areas under various climate, vegetation and soil conditions increase the health problems of the forestry workers and thus the productivity. Moreover, working environments for forest-working are insufficient either technically or socially and are high-risk areas. For example, the risk increases considering the fact that the works performed manually and with chainsaw in the cutting process require physical power and energy. Therefore, in order to perform forestry works effectively, it is important to have experience and practical thinking as well as a healthy forestry worker (URL-1). In this scope, while the wageworkers depending on an employer are evaluated within Social Security Institution (SSI), social security of the self-employed (forestry workers) in the status of those who "make a production of goods and services on his/her own behalf without employing any employees" is provided by the Social Security Organization for Artisans and the Self-employed within the Law No. 2926, Law on Social Insurance for the Self-employed in the Agricultural sector (Tunay and Emir, 2015).

The aim of this study is to reveal all the changes by performing all the physical examinations of the forestry workers who take charge in production and transport operations in forestry such as measurement-logging, cutting with chainsaw, dragging with tractor and transportation with trucks within certain periods in the hospital environment, to detect the disorders occurring due to the work effect, to make comparative evaluation between the obtained results and the work performed by the forestry workers, and to propose solutions.

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2. MATERIAL AND METHOD

The forestry workers working in wood extraction continuously encounter various health problems due to the works they perform, the difficulty of different climate and land conditions. With this study, thanks to the medical check-ups to be made in the forestry workers who take charge in production and transport operations in forestry such as measurement-logging, cutting with chainsaw, dragging with tractor and transportation with trucks, it is projected that how their work-related disorders and the changes in their personal habits progress will be revealed with the measurements to be made within certain periods in the hospital environment and the changes will be detected and thus protective measures will be taken to provide the forestry production workers to work in a healthier environment.

The study will be conducted such that all the physical examinations to be made in 5-year periods (2011-2012 / 2015-2016 production years) in the forestry workers who are taking charge in different lines of work such as measurement-logging, cutting with chainsaw, dragging with tractor and transportation with trucks (3 workers in each line of work) in production and transport operation in forestry will be compared and the differences will be detected and detailed information on their general health status will be obtained. Moreover, the work load that the forestry workers have within this period, their working methods and habits will also be analyzed together.

To detect the health conditions of the workers attending the study, first, a questionnaire form was arranged in order to reveal the awareness for introductory information, social condition, personal habits and disorders of the forestry workers, and then their general examinations and necessary tests were made in a general health center. The processes made are divided into four sections as laboratory tests, *audiometric,* radiological and cardiologic examinations. Results of the examinations were compared with previous findings and the change in the health conditions of the workers was revealed. Thus, first general examinations of the patients were made by different specialist physicians, and then the study was maintained by demanding the relevant test results according to the general examination result. Within laboratory tests, biochemical (biochemical, hemogram, hematology and hormone tests, urinalysis and microbiological tests (sedimentation, serological tests), pure tone audiometry test for detecting the hearing loss were applied, for radiological tests bilateral wrist-ankle joint radiography, pelvic radiography, waters (sinus) radiography, lung radiography; for cardiologic tests echocardiography, effort and Holter tests were applied. The data obtained was evaluated by attending physicians.

3. RESULTS AND DISCUSSION

The study was performed on forestry workers (forest peasants) who take charge in different lines of work such as measurement-logging, cutting with chainsaw, dragging with tractor and transportation with trucks in the production and transport operations in forestry. While the forestry worker who takes charge in measurement-logging performs the processes of cleaning the branches, girdling, and classifying; chainsaw operator performs the processes of cutting, toppling and classifying the trees; the tractor operator performs the processes of wood extraction and stacking the products; and remote transportation (transportation with trucks) operator manages the processes such as loading and carrying the products to the final storage.

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Age and experience distributions of the forestry workers taking charge in different lines of work are given below (Figure 1). Accordingly, it is seen that the individuals with high average age (61) work in measurement-logging work that requires less energy and mobility than the other work segments, which is followed by the work segments such as cutting with chainsaw, remote transportation and dragging with tractor. Moreover, it is understood that the forestry workers taking charge in these work segments are experienced from their early ages (<20). Distribution of body mass index (BMI) of the forestry workers which is calculated by dividing the body weight (kg) and length into its square in meters is below (Figure 2).

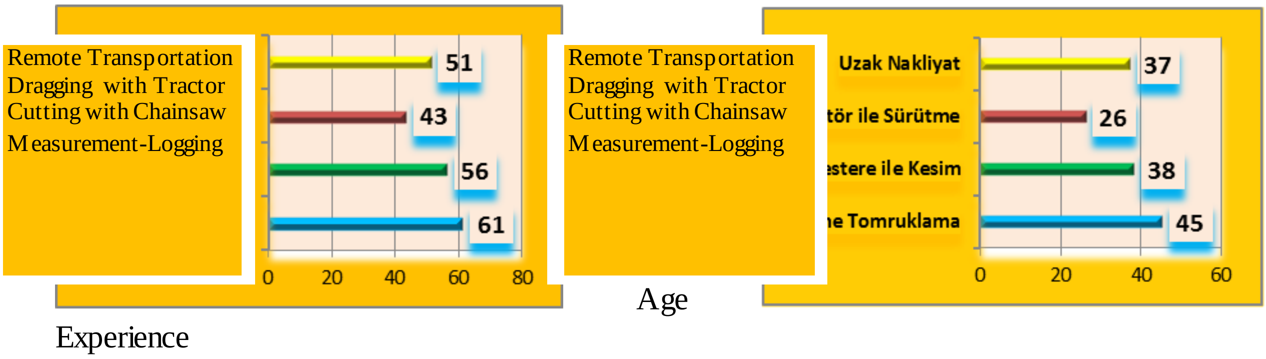
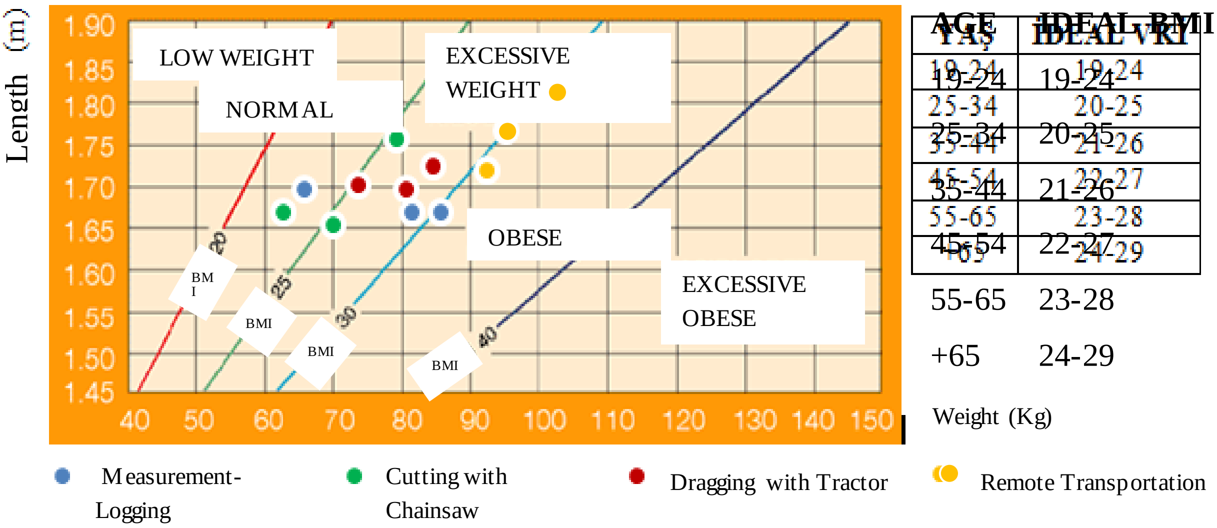


Figure 1. Age and Experience Distribution of the Forestry Workers Taking Charge in Different Parts of Work (Years).



AGE	IDEAL BMI
19-24	19-24
25-34	20-25
35-44	21-26
45-54	22-27
55-65	23-28
+65	24-29

Figure 2. Body Mass Index Distribution of the Forestry Workers in Different Parts of Work.

Annual production (working) amounts of each forestry worker taking charge in different parts of work, whose general health conditions are thought to be associated with the evaluation of the changes are given below (Table 1). The questionnaire form including awareness for the introductory information and social conditions, personal habits and disorders of the forestry workers who are all primary school graduates and attended the study was made again and the changes were examined. It is understood that a work accident occurred while the chainsaw operator was cutting the trees and another product rolled down and the operator got wounded in his feet which would lead to workday loss in a 5-year period, and generally the forestry workers are experienced in terms of security. It is seen that especially the forestry workers in

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Table 1. The Last 5-year Production (Working) Amounts of Each Forestry Workers (m^3)

Production Years	**Measurement-Logging**			**Cutting with Chainsaw**			**Dragging with Tractor**			**Remote Transportation**		
	1st worker	*2nd worker*	*3rd worker*	*1st worker*	*2nd worker*	*3rd worker*	*1st worker*	*2nd worker*	*3rd worker*	*1st worker*	*2nd worker*	*3rd worker*
2011-2012	342	75	198	341	342	294	421	98	103	258	418	201
2012-2013	-	339	676	463	361	341	192	107	146	170	201	58
2013-2014	289	161	289	161	289	229	161	161	161	156	161	114
2014-2015	312	422	360	422	312	310	422	124	422	376	422	252
2015-2016	385	140	385	140	385	294	170	140	140	361	478	250
TOTAL	1328	1137	1908	1527	1689	1468	1366	630	972	1321	1680	875

chainsaw and measurement-logging segment have a high level of drinking tea (>20 tea cups) and smoking. Moreover, it is detected that previous complaints of the forestry workers still continue, they do not need to go to the doctor except for routine disorders and they stated that stress factor is effective in the working environment.

While the patient was evaluated, patient history was examined through his/her anamnesis which was combined with the physical examination and necessary examinations were made, thereby true diagnosis could be provided (Figure 2).

Figure 2. Blood Sampling for Laboratory Tests and Physical Examination

Thus, it is stated by the physician that general views of the chainsaw (56), tractor (43) and remote transportation (51) operators are good and their body is quite youthful while age-related deformities are observed in the forestry workers working in measurement-logging (61) segment. Besides, it is understood that CK-MB value which is available in cardiovascular muscles and gives an idea in the diagnosis of the damage in heart (myocardial infarction) and other muscles was high in two of every three patients working in measurement-logging and in one of every three patients working in other work segments (Table 2).

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Table 2. CK-MB Paid Attention in the Diagnosis of Myocardial Infarction (Ref. Range: 0.3-4.0 ng/ml)

	Measurement-Logging		*Cutting with Chainsaw*		*Dragging with Tractor*		*Remote Transportation*	
	25.10.11	*25.03.16*	*25.10.11*	*25.03.16*	*25.10.11*	*25.03.16*	*25.10.11*	*25.03.16*
1st worker	3.7	3.4	3.6	6.2	1.2	4.3	0.9	1.2
2nd worker	3.2	5.4	1.7	3.1	1.2	1.7	2.1	3.3
3rd worker	5.2	7.3	3.4	3.6	0.9	1.6	5.4	5.5

■ Within reference values ■ Out of reference values

Among the potential causes, excessive smoking and alcohol consumption, age (40 and above in males), high blood pressure, fatness, ongoing stress and genetic factors as well as high muscle breakdown due to work-related difficult exercise conditions are regarded as effective factors and it is stated that it will be useful to evaluate it along with the detailed cardiologic examination results to be applied.

It is understood that cholesterol level (ref. range 140-200 mg/dl) and triglyceride levels (ref. range 50-160 mg/dl) were high in two of every three patients working in measurement-logging segment and in one of every three patients dragging with tractor and remote transportation segments. Moreover, low monocyte level (ref. range 0.15/0.70 10^3/µl), the role of which is to terminate the infected organisms, attracted the attention in all forestry workers taking charge in all lines of work. Considering that diseases and viruses such as flu, cough, chill, fever, thamuria as well as malaria, tuberculosis, and anemia can be seen, this condition was evaluated as an epidemic increasing in the seasonal shifts and antibiotics were advised for the treatment.

Through performing "pure tone audiometry" which determines the minimum intensity of sound (threshold of hearing) that both ears can hear in different frequencies (high and low pitch), hearing levels were measured as dB and air and bone conduction hearing levels were determined and hearing loss was revealed (Table 3).

Accordingly, hearing loss levels were evaluated, as a result of sensorineural (neural) decreases occurring in high frequencies (tone), while "mild hearing loss" was observed in the forestry workers cutting with chainsaw; "very mild hearing loss" was observed in the forestry workers performing measurement-logging (URL-2). Hearing aids or middle ear implants were offered as a solution to sensorineural hearing loss which is caused by the damage or absence of sensory cells (hair cells) and is generally permanent. When feature of the work is considered for the causes of this innate or acquired loss, long exposure to the noise resulting from chainsaws was presented as an effective cause.

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Table 3. Hearing Sound Level Changes (dB) of Each Forestry Worker in a 5-year Period

		Measurement-Logging				*Cutting with Chainsaw*				*Dragging with Tractor*				*Remote Transportation*			
		25.10.11		*25.03.16*		*25.10.11*		*25.03.16*		*25.10.11*		*25.03.16*		*25.10.11*		*25.03.16*	
		left	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*
1	*Air*	13	15	22	18	12	13	25	25	10	7	20	17	7	5	15	12
	Bone	12	10	18	12	10	10	20	20	5	2	10	8	2	2	8	10
2	*Air*	17	18	20	17	13	10	13	12	12	13	13	12	7	10	13	12
	Bone	12	15	18	12	5	5	10	8	7	10	12	10	2	5	10	10
3	*Air*	13	12	22	18	30	23	30	25	10	12	15	13	10	12	13	12
	Bone	12	10	15	12	25	22	28	25	2	5	7	10	5	7	7	10

In addition, long exposure to the noise resulting from chainsaws and presbycusis (age-related hearing loss) were evaluated together for the forestry workers (61) with a high average of age and working in measurement-logging segment. Hearing levels were normal (threshold average below 15 dB) in the forestry workers taking charge in dragging with tractor and remote transportation (Figure 3). It is understood that the workers did not pay attention to the condition as the loss was not that much and did not disturb them much.

Figure 3. Pure Tone Audiometry Test

With PA lung graphy, relationship of trachea with the middle line and the diameter thereof, main bronchial patency and potential mass following the same, cardiothoracic rate, heart configuration and potential size differences, calibration of aorta and pulmonary arteries, enlargement of both hila, mass and lymphadenopathy developments, control of mediastinal contours and potential mass-related enlargements, lung parenchymal areas, pleural thickening and especially calcifications were evaluated. With waters (sinus) graphy, maxillary and other paranasal sinus mucosal inflammatory (various microbial agents) pathologies and septum (a wall dividing the nose into two equal parts inside) and nasal concha (narrow and curled shelf of bone providing nasal secretions) were evaluated. Accordingly, opacity in the form of mucosal thickening was observed in the bilateral maxillary sinuses in at least one of the forestry workers taking charge in different lines of work, and sinusitis secondary to upper respiratory tract infections was diagnosed. Moreover, bilateral hilar fullness was observed and

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chronic bronchitis was diagnosed in at least one worker in the chainsaw operators. Diagnosis of sinusitis and bronchitis in all of the workers in the previous examinations was associated as the period (autumn) when the examinations were made and the seasonal changes. In addition, as a result of vertebral fatigue and strain of the ligaments occurring due to standing for a long time and chainsaw weight, scoliosis (curvature of the spine) was monitored in one of every three workers working in chainsaw and measurement-logging segment. Cardiothoracic rate giving an idea in the diagnosis of cardiac insufficiency in one of the workers taking charge in measurement-logging segment increased and aortic arch was prominently observed, and the other evaluations were studied at normal levels (Figure 4).

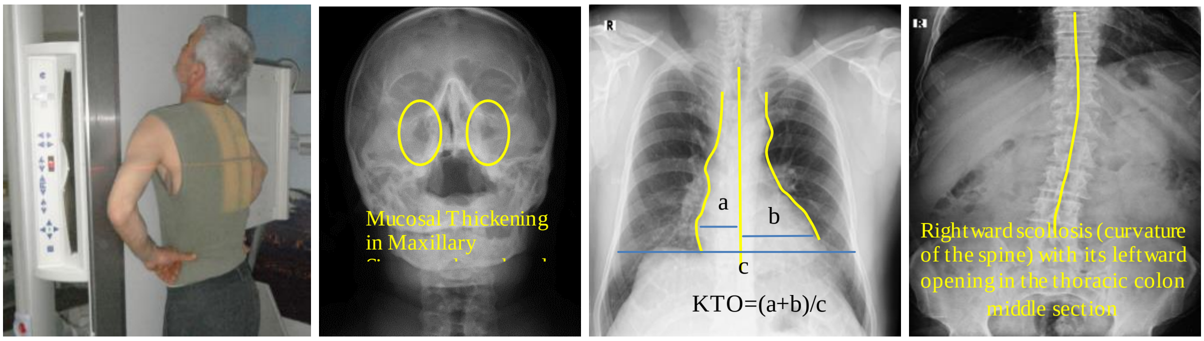

Figure 4. Waters (Sinus) and PA Lung Graphy and Their Interpretation.

To see the lumbar and hip disorders and the pathological conditions occurring in the wrist and ankle joints, first orthopedic examinations of the forestry workers were made, and then pelvic radiography, bilateral wrist and ankle radiography were taken, joint MRI was also performed due to the suspicion based on clinical laboratory data, and advanced imaging examinations were applied.

Accordingly, herniated disk disorder was monitored, in a respective order, in two of every three workers working in chainsaw and measurement-logging segment, in one of every three workers dragging with tractor and in all of the forestry workers working in remote transportation segment. Looking at the causes of this condition, in addition to a lot of factors such as lifting heavy, frequently performing sudden and repetitive movements, strains occurring as a result of the fact that the work requires physical strength, and standing for a long time; disk displacement due to the age-related loss of protective liquid content between the disks for the forestry workers with high average of age and working in measurement-logging segment, weight of the cutting with chainsaw for the forestry workers cutting with chainsaw, frequent repetition of the sudden movements for the forestry workers working in the segment of dragging with tractor and also weight for the forestry workers working in remote transportation segment were evaluated as effective factors.

As result of the complaints occurring based on age, structure and the environment in the forestry workers working in measurement-logging segment in time; while mild height loss was monitored in T10, T11, T12 (10, 11 and 12th dorsal vertebra) and L1 (1st lumbar vertebra) vertebra corpus anterior, spur formation (calcification) was monitored in vertebral corpus corners in T12, L1, L2, L3, L4, L5 vertebrae. Moreover, L5-S1 intervertebral disk height was also reduced. While mild height loss was monitored in T10, T11, L1, L2, L3, L4 vertebra corpus anterior in the forestry workers cutting with chainsaw, spur formation was

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monitored in vertebral corpus corners in L1, L2, L3, L5 vertebrae. Besides, grade I anterolisthesis (slight slipping of upper vertebral body forward onto the vertebra below) was seen in L5 vertebra. In the forestry workers working in remote transportation segment, however, bulging disc (protrusion of the disc outside the space it normally occupies between the vertebrae) in L2-L3, L3-L4 intervertebral disk levels, mild disk herniation (herniated disk) in L4-L5, L5-S1 intervertebral disk levels and degenerative changes were monitored. Furthermore, decrease in T10, T11 vertebra anterior and L4-L5 intervertebral disk height and straightening of lumbar lordosis (lumbar lordosis is straightened as a result of the spasm of thick muscles around the vertebra due to lumbar pain) were seen (Figure 5a). First, quality physiotherapy was advised with the use of a corset, and surgical intervention is found appropriate unless success cannot be achieved. It is understood from the previous examinations that the same forestry workers had complaints of lumbar disorders and due to the low pressure intensity in the initial stage necessary treatment was not applied and it showed progression in time.

As a result of bilateral wrist and ankle radiograph and joint MRIs; spur formation (cystic calcification areas and various damages in some anatomic regions) was monitored in a level of Achilles tendon joint in both calcanei (heel bone) in two of every three workers working in measurement-logging segment and in one of every three workers cutting with chainsaw, respectively, due to standing for a long time, and due to being above the ideal weight for those working in measurement-logging segment. Joint spaces were normal in the forestry workers working in the other lines of work and no pathologic opacity was detected in the visible soft tissues. In the wrist radiograph/MRIs applied, however, no fracture or lesion was detected in the bones examined, and the result was evaluated as normal wrist radiograph (Figure 5b). However, hand nerve compression (carpal tunnel syndrome) which manifests itself as hypokinesia during wrist movements, tingling and severe pain, loss of strength in the hands, electrification in fingers, pain spreading to the shoulder and elbow and increasing aches was detected in all of the workers working in cutting with chainsaw and measurement-logging segment that require excessive use of the wrist, application of surgical treatment that would require local anesthesia in which it is aimed to relieve the nerve cells by relaxing the median nerve was found appropriate.

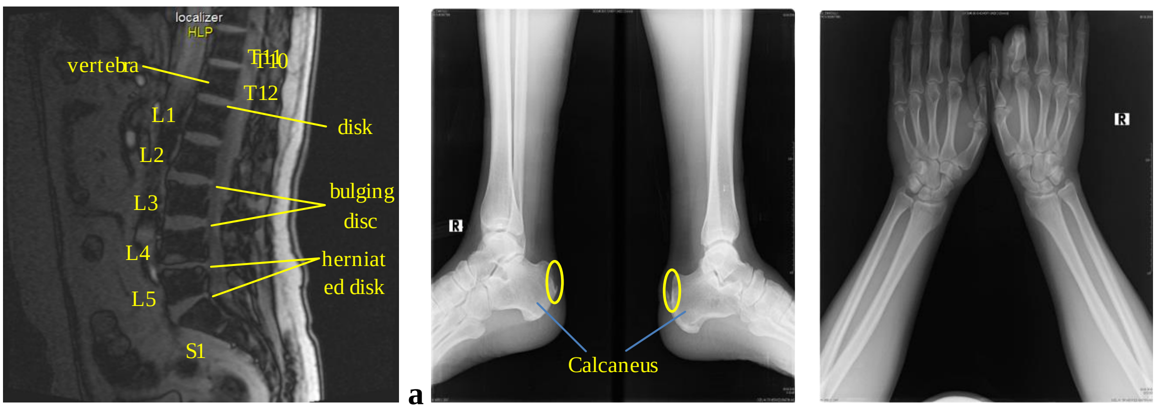

Figure 5 a. Lumbar Spine MRI (of the remote transportation operator), b. Bilateral Ankle and Wrist Radiograph (of the forestry worker working in measurement-logging segment).

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Finally, electrocardiography (ECG), through which cardiac electrical activity is measured, was performed in order to reveal the cardiovascular system related problems, application of the Holter test in which the heart beats are recorded throughout the entire 24 hours of the day to detect the short-term palpitations which are not seen during the examination but seen within the day and all the cardiac rhythm disorders such as feeling of fainting, and the effort tests aiming to detect transient ischemic symptoms that may appear in the myocard and revealing the disorders not seen in ECG performed during normal resting were provided (Figure 6).

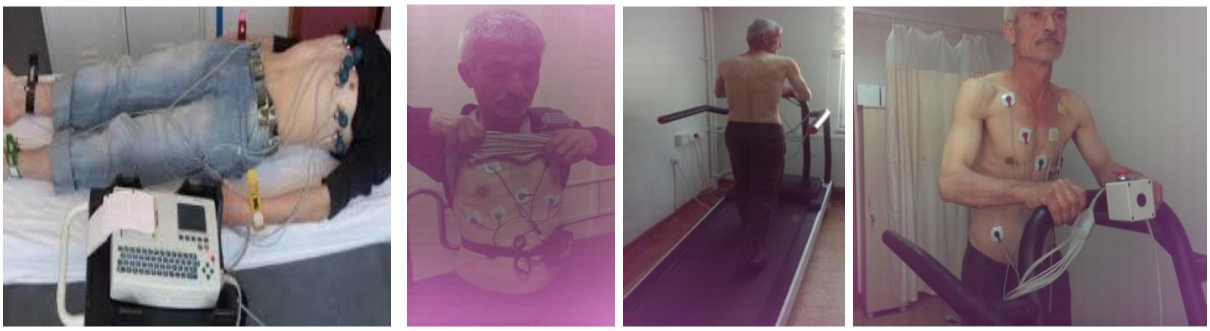

Figure 6. Application of ECG, Holter and Effort Tests.

According to the Holter test results, ventricular extra-systole was detected in at least 15 forestry workers taking charge in measurement-logging segment. Rare supraventricular premature beats were detected in the forestry workers working in the other parts of work. According to the effort test results, however, coronary vessels of the forestry worker (taking charge in dragging with tractor) whose effort tests applied in 2011 and 2016 were positive from the ischemic aspect (2 mm ST depression in d_{2-3}, avf and V_{4-5-6} derivations) were examined with coronary angiography, a diagnostic tool showing the structure of coronary vessels along with the first symptoms, and medical treatment was decided without any other process after coronary angiography. For the same forestry worker, the cardiologic test results performed in 2016 were described as suspicious positive effort test (due to genetic reasons and working environment (stress)) after the evaluation thereof with the previous tests and continuation of the medical treatment was found appropriate. Besides, the new effort test was evaluated as positive (>2 mm ST depression in d_{2-3}, avf and V_{4-5-6} derivations) from the ischemic aspect in the forestry worker taking charge in measurement-logging segment and having negative effort test result in the previous tests, and thus a stent (steel case) was applied to the vascular occlusion (Figure 7).

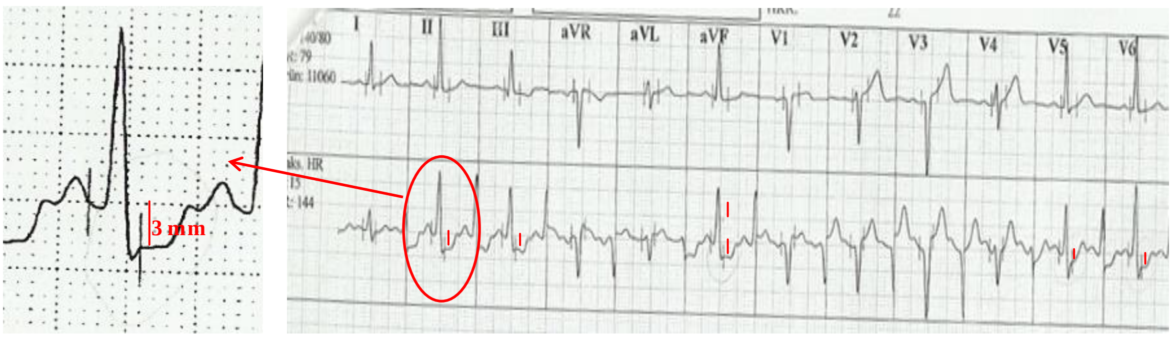

Figure 7. ST Segment Depression of the Forestry Worker Working in Measurement-Logging that was revealed by Effort Test.

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4. CONCLUSION AND SUGGESTIONS

It is understood that the forestry workers experienced in terms of work accidents and taking charge in measurement-logging (61), chainsaw (56), tractor (43) and remote transportation (51) segments failed in showing the same success in terms of worker health; although their previous complaints still continue, they do not need to go to the doctor except for the epidemics (upper respiratory tract infections, chill, fever, thamuria, etc.) increasing in the seasonal shifts and the stress factor is effective in the working environment. Likewise, it is understood that in addition to work-related difficult exercise and working environment conditions, excessive cigarette consumption, age, weight, ongoing stress, nutritional conditions and genetic factors, etc. are the factors affecting the health conditions.

When the hearing loss levels are evaluated, in the forestry workers who perform the processes of cutting with chainsaw and are exposed to the noise from the chainsaws for a long time, mild hearing loss was evaluated while in the forestry workers (61) with a high average of age and working in measurement-logging segment, long exposure to the noise resulting from chainsaws and presbycusis (age-related hearing loss) were evaluated together.

In line of orthopedic examinations, as a result of vertebral fatigue and strain of the ligaments occurring due to standing for a long time and chainsaw weight, scoliosis (curvature of the spine) was monitored in one of every three workers working in chainsaw and measurement-logging segment. Moreover, herniated disk disorder was monitored, in a respective order, in two of every three workers working in chainsaw and measurement-logging segment, in one of every three workers dragging with tractor and in all of the forestry workers working in remote transportation segment. Looking at the causes of this condition, in addition to a lot of factors such as lifting heavy, frequently performing sudden and repetitive movements, strains occurring as a result of the fact that the work requires physical strength, and standing for a long time; disk displacement due to the age-related loss of protective liquid content between the disks for the forestry workers with high average of age and working in measurement-logging segment, weight of the cutting with chainsaw for the forestry workers cutting with chainsaw, frequent repetition of the sudden movements for the forestry workers working in the segment of dragging with tractor and also weight for the forestry workers working in remote transportation segment were evaluated as effective factors. According to the cardiologic examination results, ventricular extra-systole was detected in at least 15 forestry workers taking charge in measurement-logging segment. Rare supraventricular premature beats were detected in the forestry workers working in the other lines of work. Medical and life changing treatment of the forestry worker who is working in the segment of dragging with tractor and whose effort tests were positive (due to genetic reasons and working environment (stress)) from the ischemic aspect in the previous examination was made. Besides, the new effort test was evaluated as positive (due to age and weight and working environment) (>2 mm ST depression in d_{2-3}, avf and V_{4-5-6} derivations) from the ischemic aspect in a forestry worker taking charge in measurement-logging segment and having negative effort test result in the previous tests, and thus a stent (steel case) was applied to the vascular occlusion.

While the wage workers depending on an employer are evaluated within Social Security Institution (SSI) in the Occupational Health and Safety Law No. 6331, social security of the self-employed in the status of those who "make a production of goods and services on his/her own behalf without employing any employees" is provided by the Social Security Organization for Artisans and the Self-employed within the Law No. 2926, Law on Social Insurance for the Self-employed in the Agricultural sector. Due to the fact that seasonal quality of working in the sector is dominant and the employment statuses are transitive with each other, a lot of problems preventing the establishment and management of the insurance appear, and social security of the employees working in the forestry sector cannot be provided completely. In order to provide the social security of the employees working in this sector completely with the regulations to be made, underwriting opportunities for the forestry workers covering the periods they work for the General Directorate of Forestry and even the opportunity of integrating these premiums with the optional insurance application should be provided. Above all, those who are structurally convenient should be employed and those who are employed should be followed with periodic controls. It is quite important to establish mobile service systems that will provide the fastest and the most effective access to provide health services. Moreover, within the framework of the protocols to be made between Ministry of Forestry and Water Affairs and Ministry of Health in order to enforce the Law No. 6331 in the production works, opportunities of performing routine health examinations of the forestry workers in certain periods should be evaluated. This will provide the peasants to approach the circumstance more consciously and will lay the way open for professional forestry workers.

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HIGH RESOLUTION DIGITAL TERRAIN MODEL GENERATION FROM UAS-BASED POINT CLOUDS

Cigdem SERIFOGLU*, Volkan YILMAZ, Oguz GUNGOR

Karadeniz Technical University, Engineering Faculty, 61080 Ortahisar, Trabzon, Turkey. Tel: +90 462 3772805 Fax: +90 462 3257499 E-mail: cigdemserifoglu@ktu.edu.tr*

ABSTRACT

Digital Terrain Models (DTM) have been widely used in many forestry applications, especially in determining the stand parameters. Generally, LiDAR (Light Detection and Ranging) point clouds have been used to generate DTMs, since LiDAR technology is able to provide multiple returns, which is very useful to separate the ground surface and non-ground objects such as trees, buildings etc. However, LiDAR technology generally requires a high cost and this, of course, has a negative effect on the use of LiDAR point clouds. In this study, the DTM of the study area was generated by means of the point cloud extracted from the aerial images taken from a UAS (Unmanned Aerial System). As a first step, the UAS-based point cloud was filtered to separate the points belong to the ground and non-ground objects. Thereafter, the filtered point cloud was interpolated to obtain the DTM of the study area. Finally, field measurements were conducted by using Real-Time Kinematic GPS (Global Positioning Systems) measurement technique to evaluate the accuracy of the produced DTM. Accuracy evaluations revealed that it is possible to generate high-resolution DTMs by using UAS-based point clouds.

Key words: Point Cloud, Ground Filtering, Unmanned Aerial System, Digital Terrain Model, Forestry

1. INTRODUCTION

DTM is a mathematical surface calculated by using the position and elevation information to generate the 3D elevation model of the surface of the earth. A DTM does not contain elevation information of above ground objects such as vegetation, building and lamppost etc. Instead, it includes information relating to the bare land surface (URL-1). Digital Surface Model (DSM) represents the land surface with above ground objects.

There are several methods to acquire 3D information (i.e. point cloud) of the surface of the earth, which can be in either raster (pixel) or vector (TIN-Triangulated Irregular Network) format. LiDAR, stereo aerial or satellite imagery, radar interferometry and field measurements are some of these methods. Accuracy of the acquisition method directly affects the accuracy of the DTM (URL-1). Since a DTM represents the bare earth surface, there is a need to remove the points belong to the non-ground objects, which is called ground filtering. Ground points are then interpolated to generate the DTM. In the literature, many algorithms have been reported to filter the point clouds to obtain ground points. Montealegre et al., (2015) compared the performances of six interpolation algorithms to generate DEMs having 1 m and 2 m spatial resolutions. They investigated the effects of the spatial resolution on the accuracy of the produced DTM. Besides, the effects of the slope of the study area, land cover

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and density of ground points on the interpolation error were also examined. They used 55 check points, whose 3D positions were measured using GPS technique, to assess the accuracy of the interpolation algorithms. It was concluded that the Inverse Distance Weighted (IDW) algorithm gave the best root mean squared errors in both 1 m (37.10 cm) and 2 m (40.60 cm) DEMs. One of the main conclusions drawn by the authors was that the increase in the spatial resolution of the DEM leads to a decrease in the root mean squared error of the interpolation algorithms. Guo et al., (2010) investigated the effects of the topographical variety, point cloud density, used interpolation algorithm and spatial resolution on the accuracy of the produced DEM. They found out that the Natural Neighbor (NN), IDW and TIN interpolation algorithms are successful in producing DEM from LiDAR data. Kwak et al., (2007) used LiDAR data to detect individual trees and estimate the heights of trees. They computed the Digital Canopy Model (DCM) by subtracting the DTM from DSM. To detect the tree tops, they applied extended maxima transformation of morphological image analysis methods to the computed DCM. Examination of the studies in the literature reveals that the majority of the studies in which 3D elevation models have been produced use LiDAR point clouds. This is because LiDAR data results in multiple returns such as first return, last return etc. Laser beams are able to penetrate through the vegetation (unless the vegetation is not too thick) and reach the ground. This is the main reason that LiDAR data is very efficient in modelling the bare earth surface. However, LiDAR sensors are affected by bad weather conditions. In addition, increase in the acquisition range decreases the strength of each signal, which affects the position accuracy of the LiDAR data adversely. Besides, the acquisition and processing of LiDAR data is still expensive. For this reason, the use of LiDAR data is not prevalent in Turkey. As an alternative for LiDAR data, stereo aerial photos can be used to generate point clouds. The use of stereo aerial photos allows to generate point clouds for large-scaled areas with a less cost.

3D elevation models have been used in many forestry applications. Determination of stand parameters and growing stock, and analyzing the effects of a natural disaster (such as erosion, flood, avalanche etc.) are some of the leading applications in which 3D elevation models are used. Koç (1996) indicated that the accurate slope information should be known to decide whether a forestation study is conducted mechanically or by labor force. Slope information is also very efficient to decide appropriate agricultural crops (Koç, 1996). The aim of this study is to generate a high-resolution DTM, which can be used for various forestry applications as a base, by using a point cloud extracted from the aerial photos taken from a UAS. Multiquadratic method was used to interpolate the point clouds to generate the DTM. The accuracy of the produced DTM was investigated using terrestrial measurements.

2. MATERIAL AND METHODS

In the study, the DTM was interpolated by using the Multiquadratic interpolation technique. This technique represents the land surface with a single function by using all control points at the same time. The most common equation of the Multiquadratic interpolation algorithm is;

$$z_0 = \sum_{i=1}^{m} C_i[Q(x_0, y_0, x_i, y_i)] + z(x_0, y_0) \qquad (1)$$

In the Multiquadratic algorithm, a trend surface is first generated by using m control points in conjunction with an n-degree polynomial (Hardy, 1971). Leberl (1973) stated that a 1-degree

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or 2-degree polynomials are adequate for many applications. Unknown coefficients of the *n*-degree polynomial are determined with respect to the least squares technique. Then, x_i and y_i values of the control points are placed in the equation and z_{trend} values, which are the elevations of the control points, are calculated. Residuals of the elevations (Δz_i) are determined by subtracting the z_{trend} values from the elevations of the control points (z_i).

$$\Delta z_i = z_i - z(x_i, y_i) = z_i - z_{trend} \tag{2}$$

Residual of an elevation at any interpolation point (x_0, y_0) (x_0, y_0) is calculated as;

$$\Delta z_0 = z_0 - z(x_0, y_0) = z_0 - z_{trend} \tag{3}$$

Calculation of the unknown Δz_0 with respect to the Multiquadratic technique results in the elevations of the interpolation points (z_0) (Yiğit, 2003). According to Equation 1, z_0 can also be obtained as;

$$\Delta z_0 = \sum_{i=1}^{m} C_i [Q(x_0, y_0, x_i, y_i)] \tag{4}$$

C_i coefficients, which are determined from the residual elevations of the control points (Δz_i), specify the slopes and signs of the 2nd degree terms (Hardy, 1971; Güler, 1983; Çakır, 2012). Hardy' s multiquadratic surfaces vary between each other. These are;

Circular hyperboloid of two sheets (CHTS);

$$Q(x_0, y_0, x_i, y_i) = [(x_0 - x_i)^2 + (y_0 - y_i)^2 + \delta^2]^{1/2} \tag{5}$$

Circular paraboloid (CP);

$$Q(x_0, y_0, x_i, y_i) = [(x_0 - x_i)^2 + (y_0 - y_i)^2 + \delta^2] \tag{6}$$

Circular right cone (CRC);

$$Q(x_0, y_0, x_i, y_i) = [(x_0 - x_i)^2 + (y_0 - y_i)^2]^{1/2} \tag{7}$$

Placement of these equations in Equation 4 leads to multiquadratic surfaces as (Güler, 1985; Yiğit, 2003);

Summation of the series of the circular hyperboloid of two sheets;

$$\Delta z_0 = \sum_{i=1}^{m} C_i [(x_0 - x_i)^2 + (y_0 - y_i)^2 + \delta^2]^{1/2} \tag{8}$$

Summation of the series of the circular paraboloid;

$$\Delta z_0 = \sum_{i=1}^{m} C_i [(x_0 - x_i)^2 + (y_0 - y_i)^2 + \delta^2] \tag{9}$$

Summation of the series of the circular right cone;

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$$\Delta z_0 = \sum_{i=1}^{m} C_i \left[(x_0 - x_i)^2 + (y_0 - y_i)^2\right]^{1/2} \tag{10}$$

x_i, y_i and Δz_i values, which are determined with the control points, are used to calculate C_i coefficients. In case where Equation 7 is selected as the multiquadratic surface, m linear equation systems are formed depending on the control points to compute C_i coefficients;

$$\begin{matrix} C_1 a_{11} & + & C_1 a_{12} & +\cdots+ & C_m a_{1m} & = & \Delta z_1 \\ C_2 a_{21} & + & C_2 a_{22} & +\cdots+ & C_{m1} a_{2m} & = & \Delta z_2 \\ \cdots & + & \cdots & \ddots & \cdots & = & \vdots \\ C_m a_{m1} & + & C_m a_{m2} & +\cdots+ & C_m a_{mm} & = & \Delta z_m \end{matrix} \tag{11}$$

This equation system can be shown in matrix format as;

$$AC = \Delta z \tag{12}$$

where, A stands for the coefficients matrix with a size of mxm, C is the vector of the unknowns with a size of $mx1$, and Δz is the vector (a size of $mx1$) of the residual elevations. Unknown C_i coefficients are calculated as;

$$C = A^{-1} \Delta z \tag{13}$$

z_0 elevation value of any interpolation point (x_0, y_0) is computed as;

$$z_0 = z(x_0, y_0) + \sum_{i=1}^{m} C_i \left[(x_0 - x_i)^2 + (y_0 - y_i)^2\right]^{1/2} \tag{14}$$

δ^2 in Equation 5 and 6 is a constant value and known as geometric parameter. Equation 7 is obtained by setting the δ^2 in Equation 5 as 0. Table 1 shows a few formulaic suggestions for determination of the δ parameter (Franke, 1979; Hardy, 1990; Fasshaurer, 2002).

Table 1. Suggestions for determination of the δ parameter

Proponent	**Formula**
Hardy	$\delta = 0.815s$
Franke	$\delta = 1.25\ D/\sqrt{m}$
Fasshaurer	$\delta = 2/\sqrt{m}$

The s parameter in Table 1 represents the average distance between the control points and their neighbors, D is the diameter of the smallest circle covering all control points, and m is the number of control points (Çakır, 2012).

2.1 Study Area

A small part of the Karadeniz Technical University (KTU) campus was chosen as the study area. The campus is situated in the city of Trabzon, which is located on the northeast of Turkey. The study area, whose dimensions are 178 m x 410 m, includes non-ground objects such as building, tree and a store. The elevation of the study area ranges from 18 m to 83 m. The study area can be seen in Figure 1.

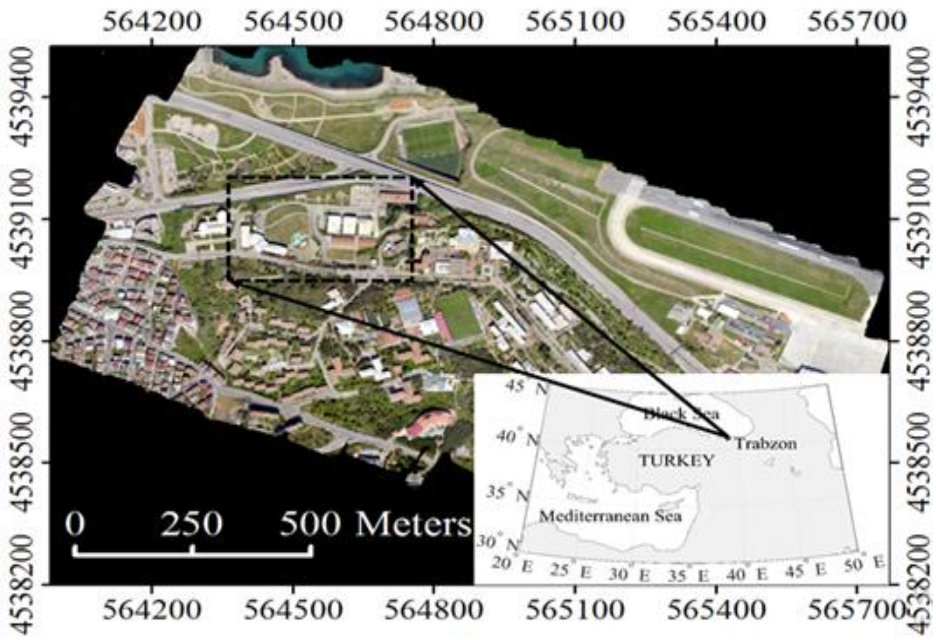

Figure 1. Study area

In April 2013, 256 aerial photos were taken along 9 lines with RICOH GR DIGITAL IV digital camera, which was mounted to the Gatewing X100 UAS. 12 ground control points (GCP) were established before the flights to use them for georeferencing. It should be noted that extra attention was paid to distribute the GCPs evenly over the study area. The aerial photos were then processed and the point cloud (a density of 61.1 point/m^2) was generated by using the Agisoft PhotoScan Professional software. As a final step, a 25 cm orthophoto image was produced.

2.2 DTM Generation

The produced point cloud was filtered with the Adaptive TIN (ATIN) algorithm to remove the points belong to the objects on the ground. The ground points were then interpolated in MATLAB environment by using the Multiquadratic interpolation technique to generate the DTMs. Whole point cloud was used as input in interpolation process. A matrix, with the size of the 25 cm orthophoto (703x1638), was generated and point cloud coordinates were assigned to related pixel positions in this matrix. At this stage, affine transformation was used to convert the land coordinates into the pixel coordinates. Since the interpolation of all ground points is a time and system source consuming process, interpolation was conducted using a sliding window to ease the process. Interpolation was done within the area corresponding to the window.

Bi-linear surface was chosen as the trend surface when conducting the Multiquadratic interpolation algorithm. Multiquadratic circular right cone, circular paraboloid and circular hyperboloid of two sheets surfaces were used as Q surfaces. The unknowns (a_0, a_1, a_2, a_3) of

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the bi-linear surface were solved with the least squares technique. z_{trend} elevation is calculated for each control point in the surface equation. Δz_i elevations of the control points were computed with Equation 2. Δz_0 residual elevation at a given x_0, y_0 interpolation point was calculated with Equation 3. Equation 10, used to determine the Δz_0 residual elevations, is obtained by substituting the right cone equation (Equation 7) with the Q surface function in Equation 4. C_i unknown coefficients in Equation 10 are solved with Equation 13. The trend surface of the interpolation points are obtained by substituting x_0, y_0 values into the bi-linear equation. Distances, the only unknowns in Equation 14, represent the distances between the interpolation points and control points. After calculation of these distances, z_0 elevations of the interpolation points are computed. In the study, the equation proposed by Fasshaurer was used for δ parameter.

2.3. Accuracy Assessment

Accuracy of the produced DTM was investigated by means of the test points established in the study area. These test points were established in flat areas (test site 1), sloping areas (test site 2) and the areas in the vicinity of the above-ground objects (test site 3). Elevations of these test points were measured by RTK (Real Time Kinematik) GPS technique. 87, 163 and 129 test points were measured for test site 1, test site 2 and test site 3, respectively. For each test site, measured elevations and the DTM elevations of the test points were used to calculate the Root Mean Squared Error (RMS), Standard Deviation of Differences (SDD), Mean Absolute Error (MAO) and Mean Error (ME) metrics. Minimum (MinH) and maximum (MaxH) elevation errors were also calculated (see Table 2). The equations of the RMS, MAE and ME metrics are given as (Montealegre et al., 2015);

$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(M_{zi}(x,y) - DTM_{zi}(x,y)\right)^2}$$

$$SDD = \sqrt{\frac{\sum_{i=1}^{n}(M_{zi}(x,y) - DTM_{zi}(x,y)) - \overline{M_{zi}(x,y) - DTM_{zi}(x,y)})^2}{n-1}} \tag{15}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left(\left|M_{zi}(x,y) - DTM_{zi}(x,y)\right|\right)$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}\left(M_{zi}(x,y) - DTM_{zi}(x,y)\right)$$

where, M_{zi} stands for the measured elevation of a given test point, DTM_{zi} is the elevation of the same test point on the DTM and n is the total number of test points (Montealegre et al., 2015).

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3. RESULTS AND DISCUSSION

In this section, the results of the interpolation algorithms were investigated for each test site. Table 2 shows the RMS, SDD, ME, MAE, MinH and MaxH results of the multiquadratic interpolation techniques. As seen in Table 2, interpolation algorithms gave similar RMS results in test site 1 (flat areas) and test site 2 (sloping areas). RMS was determined as 5 cm for test site 1 and as 18.4 cm for test site 2. Circular right cone algorithm gave the best RMS result (19.2 cm) in test site 3.

Circular hyperboloid of two sheets algorithm follows the circular right cone algorithm with an RMS of 19.8 cm. Circular paraboloid algorithm yielded the worst RMS result (28 cm) in test site 3. Circular right cone algorithm yielded the best SDD result with 14.4 cm in test site 3. Circular hyperboloid of two sheets algorithm is the second most successful one in test site 3 with an SDD result of 16.4 cm. In test site 3, circular paraboloid algorithm gave the worst SDD result with 27.3 cm. For test site 3, circular paraboloid algorithm gave the best ME result (6.6 cm); whereas the same algorithm yielded the worst MAE with 16.9 cm. It can also be inferred from the table that the circular hyperboloid of two sheets algorithm performed best with a MAE result of 15.1 cm. In test site 3, MinH results were found to be similar to each other (around 0.1 cm). Circular hyperboloid of two sheets algorithm also yielded the highest MaxH result with 53.8 cm (see Table 2).

The results shows that the circular right cone and circular hyperboloid of two sheets algorithms are more successful in representing the topography, compared to the circular paraboloid algorithm. The produced orthophoto was draped over the results of the circular right cone, circular paraboloid and circular hyperboloid of two sheets interpolation algorithms and given in Figure 2, Figure 3 and Figure 4, respectively.

Table 2. RMS, SDD, ME, MAE, MinH and MaxH results of the multiquadratic interpolation techniques

		Test site 1						Test site 2						Test site 3					
	Inter p. Algor.	RMS	SDD	ME	MAE	MinH	Max H	RMS	SDD	ME	MAE	MinH	Max H	RMS	SDD	ME	MAE	MinH	Max H
Radial Basis Functions	CRC	5.2	4.6	2.5	3.8	0	16.3	18.4	16.5	8.2	14.1	0.4	73.6	19.2	14.4	12.6	15.3	0.1	49.5
	CP	5	4.3	2.6	3.9	0.1	16.3	18.5	16.9	7.9	14.2	0.3	76.3	28	27.3	6.6	16.9	0.1	51.1
	CHTS	4.9	4.4	2.5	3.8	0.1	16.3	18.5	16.7	8.2	14.6	0.2	76.3	19.8	16.4	11.1	15.1	0	53.8

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Figure 2. The result of the circular right cone algorithm

Figure 3. The result of the circular paraboloid algorithm

Figure 4. The result of the circular hyperboloid of two sheets algorithm

4. CONCLUSIONS

UAV images provide high-resolution base maps for a wide variety of forestry applications. DTMs produced with UAV images are favorable when extracting morphological features such as crown diameter, tree heights etc. Deformation monitoring in forest roads, generating base products for forest management plans, inventory collection in small or large-scaled areas, gathering information for topographic plans and forestation are only a few of the application areas in which UAV-based DTMs can be used effectively. Compared to LiDAR

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data and satellite imagery, acquisition and processing of UAV images is cheaper, which makes the use of UAV-based point clouds more prevalent (Akgül et al., 2016).

In this study, the filtered UAV-based point cloud was interpolated with Multiquadratic functions. Accuracy evaluation results indicated that the Circular right cone algorithm represented the study area best. The main conclusion drawn from the evaluation results is that UAV-based DTMs can be used in the applications requiring high 3D accuracy.

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ORAL PRESENTATION

EFFECTS OF ROADS ON WILDLIFE IN AZDAVAY / KARTDAĞ WILDLIFE RESERVE AREA

Ahmet ARPACIK*, Alptuğ SARİ, Ebubekir GÜNDOĞDU, Şağdan BAŞKAYA

Karadeniz Technical Univiversity, Faculty of Forestry, Department of Wildlife Ecology and Management, Trabzon. Tel: +90 462 3772805 Fax: +90 462 3257499
E-mail: ahmtearpacik@ktu.edu.tr

ABSTRACT

The roads, deterioration habitats of wild animals or vehicles collision and poaching are known to various negative effects. But, depending on the subject are almost no studies in Turkey. In this study, effects of roads on wildlife where the target species are Red deer (*Cervus elaphus*) and 11494 hectares in Kartdağ Wildlife Reserve Area (WRA) were studied. This study was achieved by intensive field works, especially when the areas development plan was performed between 2010 and 2012, and the later individual field works. In these researches, it was used the results of indirect observations like tracks, signs, dead and injured wild animals and direct observations which was performed monthly, 3-4 days and night and during the day. While the asphalt-covered roads between north and east districts of the area were passing, the other parts of area were covered by forest and rural roads. Road density in the area 24 m/ha and this figure is the core zone in the field of 17 m/ha. In this area, which has high density of road for the country, the main negative effects of the roads on wildlife are determined as well as habitat deterioration; the increasing of poaching; the increasing of transportation, outing and travels; disturbance (noise, vehicle lights); vehicle collision; barrier effect created by the steep and unsuitable road slopes; becoming easy prey to predators; livestock grazing; increasing intensive forestry practices and pollution. To minimize these negative effects, it is necessary to take measures as well as closing some forest roads, instruction of the suitable road slopes and passages for wildlife, carefully using of the roads on planed times.

Key Words: Wildlife, Road, Negative Effect, Kartdağ Wildlife Reserve Area, Azdavay.

1. INTRODUCTION

Roads are a global threat to biodiversity and roads have a significant impact on wildlife world-wide (Polak, et al., 2014). The roads have the negative effect known direct; mortality, indirect; as degradation on habitat of wild animals (Saunders, et al., 2002; Ree, et al., 2011), fragmentation (Andrews, 1990; Saunders, et al., 2002; Bissonette, 2002; Rico, et al., 2007), conversion (Saunders, et al., 2001), loss (Andrews, 1990; Kerley, et al., 2002; Saunders, et al., 2002; Bissonette, 2002), and as well as vehicle collision (Kerley, et al., 2002; Trombulak and Frissell, 2000) and poaching (Kerley, et al., 2001). Of these effects, direct mortality is the most significant and widespread effect of roads on wildlife (Polak, et al., 2014).

Road construction and timber harvest activities increase habitat fragmentation across large areas, the populations of some species may become isolated, increasing the risk of local extirpations or extinctions (Watson, 2005). In the Russia, roads may be one of the primary factors for the dramatic decline of tiger population because the species most sensitive to roads tend to be large carnivores that rely on large movement ranges and have low reproductive rates (Salisbury, 2012). In the United States, automobiles vehicles are annual mortality estimated to cause approximately 80 million bird fatalities each year (Erickson et al. 2005). An estimated one million vertebrates are killed daily on roads in the United States (Forman et al. 2003).

In Turkey, it is seen that, especially for the big mammals, enlarging their habitats aside, even the existing habitats of many species cannot be protected and many species face with the risk of extinction every day. One of the main reasons for this is the structures such as unplanned roads and art structures leading to habitat deterioration.

Over 19 million vehicles use the 236.671 km network of public roads that currently exist in the Turkey (Anonymous, 2016). In Turkey, the number of accidents occurring by hitting a domesticated or wild animal was reported to be 533 for the year 2014 (Anonymous, 2015). But, the number of wild animal deaths caused by vehicle crash is believed to be higher. In Turkey, there is no system recording the vehicle crashes to wild animals. No detailed study on the effects of roads on wild animals has been carried out in Turkey.

With this study, as a result of our direct and indirect wild animal observations on the roads within the site during the preparation process of 2010-2012 management plan of Kartdağ Wildlife Reserve Area, the effects of roads on wildlife were revealed, and some solution offers were proposed.

2. MATERIALS AND METHODS

Azdavay / Kartdağ Wildlife Reserve Area (WRA) is located within the administrative borders of Azdavay and Şenpazarı district of Kastamonu city (Figure 1). The air distance of area from the city center of Kastamonu is approximately 50 km. The site was registered as Kartdağ Wildlife Reserve Area on 7th of September 2005 for the protection of Red deer (*Cervus elaphus*) among endangered species.

Kartdağ WRA is one of the hot points hosting the natural forest of Europe that should be immediately protected, and is located in buffer zone of Küre Mountains Natural Park that is very rich in biological diversity (Anonymous, 2011).

Kartdağ WRA is an area located in northwestern region of the country, covered with needle and broad-leaved and mixed forests, away from the residential areas, and hosting large mammalians such as Brown bear, Gray wolf, Lynx, Roe deer, and Wild boar and important bird species such as Golden eagle, Black vulture, and Goshawk (Anonymous, 2011). In this area, 66 mammal species, 233 bird species, 20 reptile species, 10 amphibian species (Başkaya, 2010), and at least 25 fresh water fish species live (Anonymous, 2011).

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Figure 1. Kartdağ Wildlife Reserve Area

Total surface area of Kartdağ WRA is 11,495 ha general road density 24 m/ha and the road density in strict protection area with 1,187 ha of surface area is 17 m/ha As a result of Red deer counting in year 2010, it is estimated that there are 19 Red deer in this area (Anonymous, 2011). There are public and private property areas in Kartdağ WRA. Since 87% of the area consists of state-owned forests, the public use has significant dominance in this site. As private property areas, 12.3% of the site is agricultural lands and 0.7% is residential area (Anonymous, 2011).

In this study, the effects of forest roads on the wild animals in Kartdağ WRA between the years 2010 and 2012 were examined. During the researches, the topographical maps, various models of binoculars, cameras, video cameras, and GPS devices were utilized.

Between the years 2010 and 2012 throughout the preparation of Management and Development Plan, all of the roads were visited on foot and with vehicle, and the data were obtained regarding the traces and signs of wild animals, and injured and dead bodies of those animals. The wild animals using these roads were determined through observation and utilizing the traces and signs pointing the wild animals. Moreover, all of the roads were assessed from the aspect of suitability for wild animals.

3. RESULTS AND DISCUSSION

3.1. Road Density

Kartdağ WRA Management and Development Plan is made up many parts of the area are used for the purpose of forestry activities. The basis of production in forestry is based on a well-planned forest road network. Road density value forest areas in Turkey are not calculated according to the intensity with the aim of ensuring the opening of the forest. In forests where the wealth is 250 m^3 or over per hectare, the planning should be done as to have a road density of 20 m/ha with road spaces of 500 m, while in forest areas where the wealth is under 250 m^3 per hectare, a road density of 10 m/ha with road spaces of 1000 m should be tried to be realized (Demir, 2007). However, these values are quite high for protected areas. This field is not separately determined value for a road density.

Large mammals were shown to move their home range and avoid areas within 100–200 m from roads and 500 - 1000 m from settlements, which reduces suitable habitat area. Additionally, human activities generally occur near the residential area within a radius of 500 m. (Wu et. all., 2016). A road density of approximately 0.6 km/km^2 appears to be the maximum for a naturally functioning landscape containing sustained populations of large predators (Forman and Alexander, 1998). Deer of all species regularly cross minor roads

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(narrow roads of relatively low traffic volume) during routine daily movements around an established home range. Although deer are neither strictly crepuscular nor nocturnal, all species are shy of human disturbance and thus shun open areas during the hours of daylight (Putman, 1997)

Over 19 million vehicles use the 236.671 km network of public roads that currently exist in the Turkey (Anonymous, 2016). The general road density of Turkey was calculated to be 6.55 m/ha. Total length of the roads in Kartdağ WRA is 275.32 km, and the road density is 24 m/ha. The road constituting the northern and northeastern border of the area is an express way and 19 km in length. Other roads in and around the area are stabilized, village and forest roads. The transportation to villages is generally provided via minibuses and private vehicles. The locations of villages concentrate on northern and southeastern parts of the area.

The area is divided into 3 protection areas according to the Management and Development Plan (Figure 2). In Strict Protection Area, which is the most important protection area, the road density is 17 m/ha. This is a very high density of an area that is being strictly protected (Table 1).

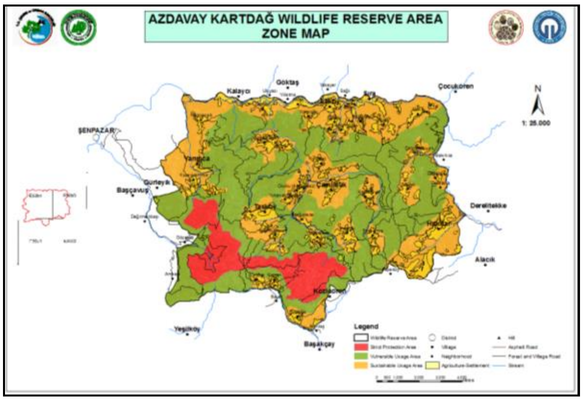

Figure 2. Kartdağ WRA zone map (Anonymous, 2011)

Table 1. Road density in Kartdağ Reserve Area protected zone

Protection Areas	Area (ha.)	Road (km)	Road Density (m/ha)
Strict Protection Area (Red area)	1187.34	20.6	17
Vulnerable Usage Area (Green area)	5594.21	121.12	21.7
Sustainable Usage Area (Yellow area)	4713.43	133.6	28.3
Total	11494.98	275.32	24

The road effect zone can be substantial for species that either travel long distance or are vulnerable to predation by species introduced along road corridors (Boarman and Sazaki, 2006). According to various scientific studies on road effect zone; for large mammals species 600 m (Gagnon et a., 2007), for sensitive birds species 1000 m. (Forman et al., 2002), for amphibian species 1200 m (Eigenbrod et al., 2009) are detected for roads.

The asphalt express roads linking the districts pass from northern side of Kartdağ WRA, and their total length is 19 km. The effect areas of this express road are demonstrated on the map

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by the species in WRA. Especially the road on eastern side has effects on many species in vulnerable usage area (Figure 3).

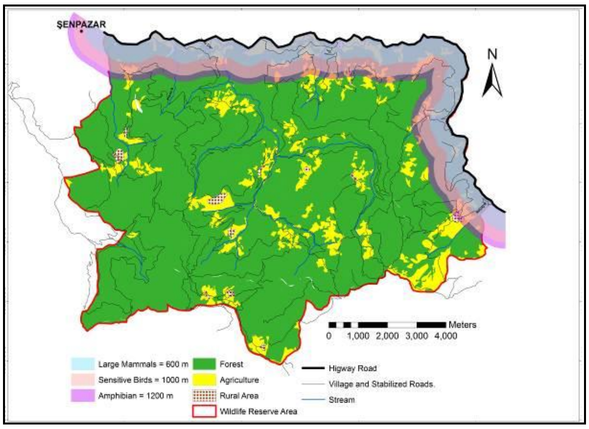

Figure 3. Road effect distance values from the literature on Kartdağ WRS

3.2. Vehicle-Caused Mortality

Estimates of road kills based on measurements in short sections of roads tell the annual story: 159.000 mammals and 653,000 birds in The Netherlands; 7 million birds in Bulgaria; 5 million frogs and reptiles in Australia. An estimated 1 million vertebrates per day are killed on roads in the United States (Forman and Alexander, 1998).

The roads ease the access to many regions of Kartdağ WRA. The increased vehicle traffic, especially due to the guest workers coming to the villages in summer season, leads to death of many wild animals as a result of hitting vehicle. In this area, there is neither speed reducing traffic sign related with the wild animals nor ecologic art structures constructed for the transition of wild animals. The road network within the area, which developed alongside the forestry activities and continues developing, and the loss of cover ease the poaching activities and leading to excessive hunting. Under favor of the roads in area, the illegal hunters can easily access many regions of the area. The numbers of injured and dead wild animals we found during our field survey in Kartdağ WRA are presented in table (Table 2).

3.3. Noise

Road noise has a variable effect on animals. The most significantly impacted by road noise are those species that incorporate sound into their basic behavior, such as birds. There may be a varying effect of road noise on animals as determined by time of day or season of the year, depending on the daily and life cycle patterns of that animal (Coffin, 2007). Noise likely causes reductions in population densities that have been reported for several bird species that are present near roads (Kociolek et. al., 2010).

The vehicle traffic Kartdağ WRA, which increases in summer as a result of the arrival of summer house vacationists having vehicles, the use of many roads including those used for forestry besides the main roads for the purpose of short-cut and tour lead to high level of noise in this area. As a result of our inventory study, it was determined that the Red deer, which is the target species of the field, doesn't come close to the road due to the increased road traffic.

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Table 2. Injured and dead wild animals of our field survey in Kartdağ WRA.

English Name	Scientific Name	English Name	Scientific Name
Mammal Species			
Southern white-breasted hedgehog	*Erinaceus concolor*	Brown bear	*Ursus arctos*
European hare	*Lepus europaeus*	Pine marten	*Martes martes*
Caucasian squirrel	*Sciurus anomalus*	Beech marten	*Martes foina*
Asia minor ground squirrel	*Spermophilus xanthoprymnus*	European badger	*Meles meles*
House mouse	*Mus musculus*	Wildcat	*Felis silvestris*
House rat	*Rattus rattus*	Lynx	*Lynx lynx*
Gray wolf	*Canis lupus*	Wild boar	*Sus scrofa*
Golden jackal	*Canis aureus*	Red deer	*Cervus elaphus*
Red fox	*Vulpes vulpes*	Roe deer	*Capreolus capreolus*
Birds Species			
Common buzzard	*Buteo buteo*	Great spotted woodpecker	*Dendrocopos major*
Long-legged buzzard	*Buteo rufinus*	Eurasian jay	*Garrulus glandarius*
Black kite	*Milvus migrans*	Black-billed magpie	*Pica pica*
Eurasian sparrowhawk	*Accipiter nisus*	Carrion crow	*Corvus corone cornix*
Chukar	*Alectoris chukar*	Eurasian blackbird	*Turdus merula*
Common quail	*Coturnix coturnix*	Field fare	*Turdus pilaris*
Rock pigeon	*Columba livia*	Song thrush	*Turdus philomelos*
Stock dove	*Columba oenas*	Mistle thrush	*Turdus viscivorus*
Common wood-pigeon	*Columba palumbus*	Common starling	*Sturnus vulgaris*
Eurasian collared-dove	*Streptopelia decaocto*	House sparrow	*Passer domesticus*
European turtle-dove	*Streptopelia turtur*	Eurasian chaffinch	*Fringilla coelebs*
Reptile Species		Amphibian Species	
Spur-thighed tortoise	*Testudo graeca*	Common toad	*Bufo bufo*
Slow worm	*Anguis fragilis*	Green toad	*Bufo viridis*
European blind snake	*Typhlops vermicularis*	European tree frog	*Hyla arborea*
Smooth snake	*Coronella austriaca*		
Ring-headed dwarf Snake	*Eirenis modestus*		

Especially the June-August period, when high number of guest workers comes, corresponds to the birth season of Red deer and mating and birth season of Roe deer. The intense traffic and the high level of noise in mating and birth season of wild animals scare the wild animals and lead to miscarriage. The noise pollution during April-June season affects the bird species in this region especially from the aspects of mating, incubation and feeding.

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Disobeying the speed limitations on the roads, sounding the horn, and listening to music at high level of sound scare the significant species during their spawning period. The wood production and transportation during mating and spawning periods of wild animals lead to noise pollution, and the intensive use of the area disturbs the wild animals. The forestry activities in this field and intense use of truck and construction equipment during the transportation of wood products affect the wildlife negatively.

3.4. Chemical pollutants

Total of 16 villages in and around WRA, 3 villages are completely and others with one or more of their neighborhoods are located within the field. Approximately 1715 people live in the field. Besides that, the people named "guest workers" and living in metropolitans such as İstanbul, Ankara, and Bursa and people living in centers of Kastamonu city and Azdavay or Şenpazar district have started to frequently come to these villages for summer vacation, especially in summer holiday of schools. In recent years, the number of these persons restoring their houses or constructing a new house gradually increased, even slightly.

The lack of planned structuring in residential areas and the solid and liquid wastes alongside the road in those regions, especially those thrown into the rivers along the road, have significantly negative effects on the wild animals. Accumulation of the domestic waste alongside the road draws the mammals such as Brown bear, Gray wolf, Golden jackal and Red fox near the road and they can be easily prey by illegal hunters.

3.5. Barrier effect

Of the indirect threats of roads, the barriers to movement roads present may have the greatest effect on vertebrates (Kociolek et. al., 2010). Nonetheless, the barriers caused by roads may be a simple function of the width of the gap they create in the surrounding habitat, unless the roads are also noisy or are associated with tall features such as power lines (Kociolek et. al., 2010). The physical obstructions, which have been created in the excavations and filing during the construction of roads in some regions of the field, divide the habitat of wild animals, and it was observed that wildlife passages have not been involved while planning the roads. During our night surveys, it was determined that, when the mammal species such as European hare, Brown bear, Wild boar, Gray wolf, Golden jackal and Red fox meet with a vehicle, they run for meters to escape from the vehicle but couldn't find any outlet to run into the forest. Forest roads, just like glades in forests, draw the attention of mammal species such as Red deer, Roe deer and Wild boar because of their grass content. But this situation prevents the wild animals from escaping from the road (due to the slopes on the forest roads), and lead them to become easy-prey for predator animals.

4. CONCLUSION AND SUGGESTIONS

Within the borders of Wildlife Reserve Area, it is required to make the necessary arrangements to meet the fundamental, daily and recreational needs of the local people and visitors in harmony with the status and values of the protection area, and to realize the field activities determined in Management and Development Plan. Especially in strict protection zone of the field, it is required to take necessary measures in order to minimize the negative

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effects. By organizing the use of field roads, it is required to ban the use of many roads, including the roads constructed for forestry but except for the main roads, even for touring or short-cut transportation. The necessary measures should be taken in order to protect the wildlife from drivers and pedestrians.

Warning, speed-limit, and stop traffic signals regarding the species such as Red deer, Roe deer, Spur-thighed tortoise and Common toad must be placed near the roads and at the remarkable locations. Moreover, also the road signs for not sounding horn, not listening music at high levels of sound, and warnings regarding the main species of the field and interaction with the wild animals are also required. Mainly on the old roads to be improved and used actively, the warning and informative tables regarding the wildlife reserve area and its resource values should be placed.

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ORAL PRESENTATION

DETERMINING UNOFFICIAL FOREST ROADS BY USING GOKTURK II IMAGES (ILGAZ SAMPLE)

Ender BUGDAY [*], Kayhan MENEMENCIOGLU

Çankırı Karatekin University, Faculty of Forestry, Çankırı, Turkey.
Tel: +90 376 2122757 Fax: +90 376 2136983
E-mail: ebugday@karatekin.edu.tr

ABSTRACT

Almost all of the forests (99.9%) are state forests in Turkey and they are managed by Turkish Ministry of Forestry and Water Affairs, General Directorate of Forestry. Forest roads are regulated with the notification number 292, which contains planning, construction and maintaining technics of forest roads. Forest road network plans and maps contain existing and planned roads, but it is possible to encounter some unofficial roads in the forests. Map revisions are known as time consuming and expensive activities, so, we purposed to identify unofficial forest roads with remote sensing by using Gokturk II images in Ilgaz in this study. We extracted all existing roads from aerial image and then superposed and matched existing roads with forest road network map. The results show that there is a significant amount of unofficial forest roads in the study area and mapping unofficial forest roads is possible in this wise.

Key words: Road extraction, road detection, forest road network, aerial image

1. INRODUCTION

The existence and distribution of forest roads, according to the technical necessities of forestry activities and to be carried out entirely the year is an important component. According to 2014 annual reports of General Directorate of Forest (GDF), 282.000 km forest road construction planned in order to perform the various forestry activities and 177,000 km of the forest road have been made to date. Total road length with the located in the forest village road and highway has reached nearly 243,000 km that can be utilized in forestry activities.

The planning, establishment and maintenance of forest roads are regulated with the notification number 292 in Turkey (Anonymous, 2008). Forest road network plan includes in the existing roads and planned roads for the future periods. There are also forest roads (paved, unpaved) uncoded as official which located in the forest road network plans but appeared in forestry operations for a variety of necessities (Brandão and Souza, 2006). This unofficial roads must be digitized in for demonstrate of the current road existence and to enable information to practitioners and make a decision during the planning of forestry activities.

Various techniques are used to update the existing road network plan for identification of forest roads. Identifying objects by via satellite which offering images of temporal and spatial

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assessment, and mapping is a widely used method by GIS applications (Boggess, 1993; Geman and Jedynak, 1996; Hu et al., 2000; Peteri and Ranchin, 2003; Zhu et al., 2005; Amo et al., 2006; He et al., 2009; Muli, 2013; Beck et al., 2015).

One of the major constraints affecting the quality of data on the evaluation of satellite imagery and analysis to spatial resolution. Satellite images are used with many different spatial resolution (15m, 8m., etc.) obtained from various satellites in the world (Ergin, 2006). Gokturk-II satellite, with the support of TUBITAK developed, launched into space in late 2012 in Turkey. Gokturk II with high-resolution satellite image of public institutions in our country needs can be met. Gokturk II images, 4-day temporal resolution of 2.5 meters by 5 meters in panchromatic and multispectral (red, blue, green and near-infrared) can provide images in panchromatic and multispectral bands (Küpçü et al., 2014).

Turkey's earth observation characteristics of satellite systems and various areas (Teke and Yardımcı, 2016) in terms of availability of forestry mentioned can be used as an economical and effective Gokturk II satellite images and data acquisition in GIS environment it is reliable, a key base that can be used in data processing and evaluation (Çoban, 2016). Satellite images, depending on the desired properties of the costs are higher images (Zhou et al., 2005; Leloğlu et al., 2010; Yıldırım, 2016). However Gokturk II images in our country see interest by academics working in the field of remote sensing, especially because it put free of charge to researchers. In this study, Gokturk II as a base to transfer the detection of unofficial forest roads and GIS, satellite imagery has been used. The length of the existing roads (village, official and unofficial) of Hızardere Forest Subdistrict are determined, it was calculated general and nominal road density and the percentage of opening up the forest.

2. MATERIAL AND METHODS

This study was carried out in Hızardere Forest Subdistrict that covers approximately 9000 ha in a north central region of Anatolia. Two satellite images were obtained for the study area. Gokturk II Images defined to UTM (Universal Transverse Mercator) coordinate system and mosaic were combined by the ArcGIS 10.3^{TM} software. All visible roads in the images set and they have been digitized. Official forest road network plan was transferred to the same digitized platform and unofficial roads have been identified (Figure 1).

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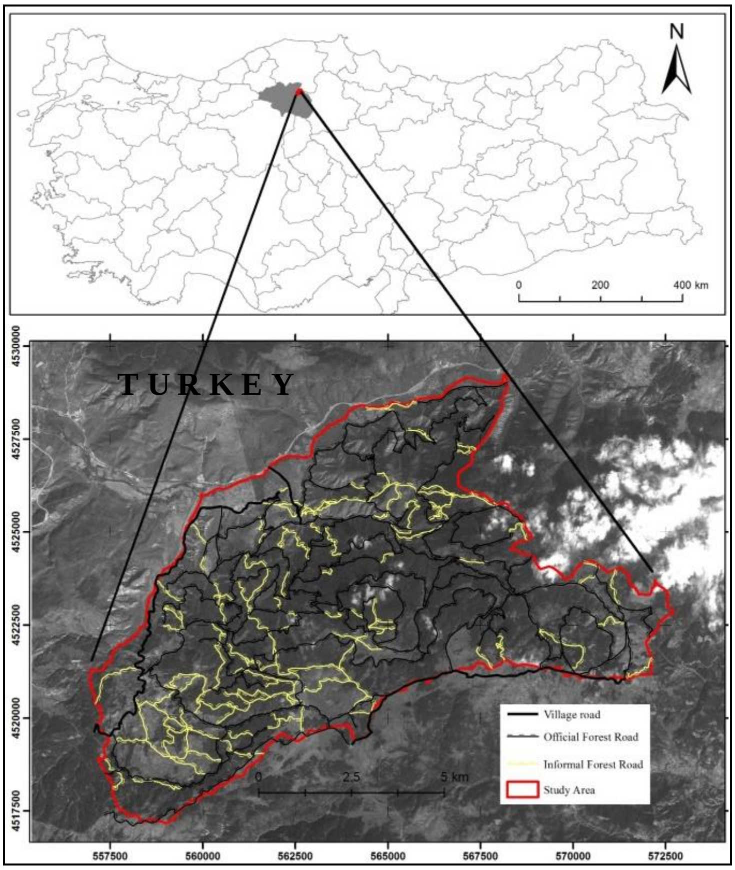

Figure 1. Location of study area

Forest roads and satellite imagery in 1: 5000 scale was defined. The roads have been made visible in dense forest lands and gaps. We have defined two types of forest roads. They are official and unofficial forest roads (Figure 2). Official roads: It has been digitized by the management. Unofficial roads, constructed by management but the roads are not registered.

3. RESULTS AND DISCUSSION

Hızardere Forest Subdistrict forest road network have been transferred to a computer with existing officially registered forest roads in the plan and Gokturk II satellite images compared existing roads which have been identified through and unofficial roads have been identified and confirmed all of this enables the road. Forest road network plan that works on all available roads mapped the route has been determined according to the methodology presented. Unofficial accuracy for mapping roads, meticulously carried out and information was mapped by the method presented in this study. A total of 316.40 km of roads have been mapped. These roads have been identified as 206.36 km official roads and 110.04 km unofficial roads. Unofficial roads showed more intensity in the southwest and northern of the subdistrict. Especially, the longest unofficial road existence is centered southwest to 56.03 km. These roads have the largest share in the access to densely forested lands.

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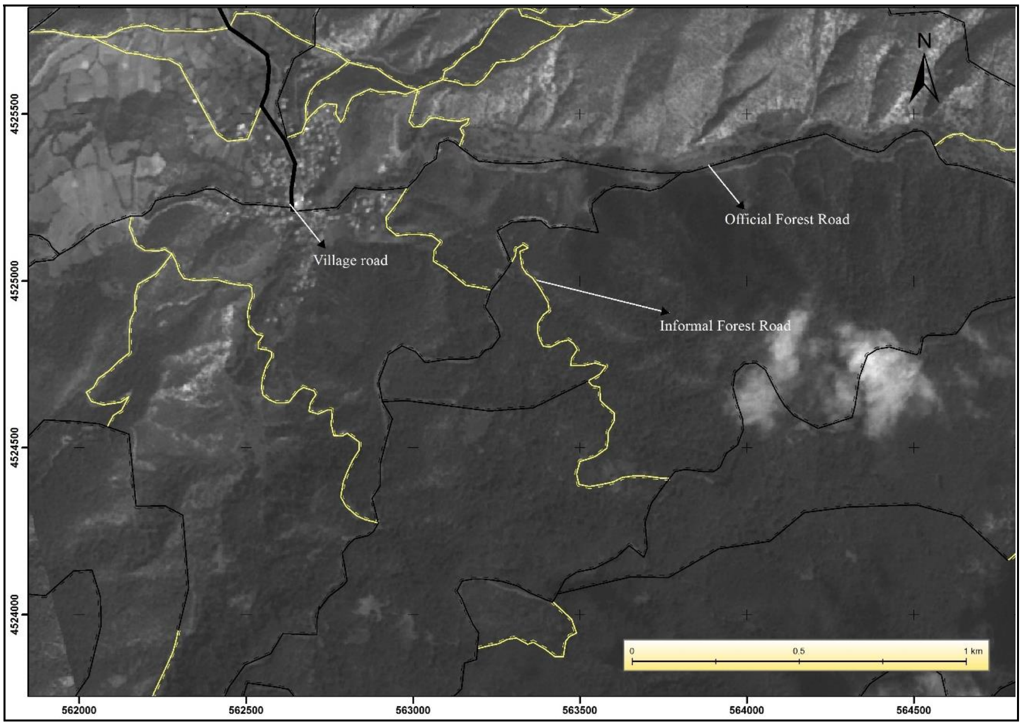

Figure 2. Sample of the road types defined in Gokturk II satellite image

According to current forest road network, general road density was 22.96 m/ha, nominal road density was 26.18 m/ha, the ratio of exploited forest area was 61.57%. When the existing road network is considered the unofficial forest roads, general road density was 35.20 m/ha, nominal road density was 41.86 m/ha, the ratio of exploited forest area was 98.05%. When the unofficial forest roads are included in the current forest road network plan all of forested lands (7019.20 ha) have been identified to be exploited forest of 6882.32 ha area. General road density, nominal road density and the ratio of exploited forest area of Hızardere Forest Subdistrict is calculated (Table 1).

Table 1. Forest road density and ratio of exploited forest area

		Road (m)	Area (ha)	Road Density (m/ha)
General road density	Official	206360.0	8988	22.96
	Unofficial	316396.1	8988	35.20
Nominal road density	Official	183760.0	7019.2	26.18
	Unofficial	293800.0	7019.2	41.86
Ratio of exploited forest area		**Road area (ha)**		**Ratio of exploited forest area (%)**
	Official	4321.5	7019.2	61.57
	Unofficial	6882.5	7019.2	98.05

Determination of the existing forest road network can be done easily with the help of Gokturk II satellite images. However, the spatial resolution of these images of forest roads has been

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shown to be insufficient compared to other high resolution satellite imagery to determine standards.

4. CONCLUSION AND SUGGESTIONS

In this study, it has been concluded Gokturk II satellite images and GIS technology is usable to map of forest roads. Current unofficial forest roads of Hızardere Forest Subdistrict are determined as 110.04 km. These roads are more important in an orderly manner to meet the needs of road to be used in the conduct of forest operations activities and to attract the desired level of exploited forest area in the study.

To move rapidly in relation to any fires and can be given effective decisions support, in terms of increasing the availability of high quality information and get in the decision-making process in planning the preservation and production of forest unofficial roads, the application to transfer the proper technical features to the database are determined by the units and kept up to date is extremely important.

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ARTIFICIAL NEURAL NETWORK FOR PREDICTING STAND CARBON STOCK FROM REMOTE SENSING DATA FOR EVEN-AGED SCOTS PINE (*Pinus sylvestris* L.) STANDS IN THE TAŞKÖPRÜ-ÇIFTLIK FORESTS

**İlker ERCANLI[1*], Alkan GÜNLÜ[1], Muammer ŞENYURT [1], Ferhat BOLAT[1]
Aydın KAHRIMAN[2]**

[1]Çankiri Karatekin University, Faculty of Forestry, 18200 Çankiri, Turkey.
Tel: +90 376 2122757 Fax: +90 376 2136983 E-mail: ilkerercali@karatekin.edu.tr*
[2]Artvin Coruh University, Faculty of Forestry, 08100 Artvin, Turkey.

ABSTRACT

Carbon storage in forest biomass and soil organic carbon are important elements of global carbon cycle, and the changes of their accumulation and decomposition directly affect directly forest ecosystem carbon storage and global carbon balance. Accurate estimation of stand carbon stocks are essential to forest managers and practitioners in decision making process. Modern technology such as Remote Sensing Data and Geographical Information Systems (GIS) provide new opportunities for the predictions of stand carbon stocks in forest inventory. Also, artificial neural network applications offer the ability to implicitly perceive complex and nested relationships between input and output variables, which are very helpful in stand carbon predictions from remote sensing data. In this study, Applications of Artificial neural networks (ANNs) were carried out to predict the relationships between stand carbon stock and remote sensing data including reflectance values and vegetation indices calculated from Landsat TM. The data were measured from even-aged and pure Scots pine stands located in Taşköprü-Çiftlik Forests, Kastamonu, Northern Turkey. The individual tree carbon predictions will obtained by using the carbon equations developed by Yavuz et. al. (2010). Applications of ANN was carried out using MATLAB-nntool module including the development data set that was further subdivided into three subsets for ANN training (75%), verification (15%), and testing (10%). The ANN applications, including vegetation index based on the reflectance values as input variables, will trained to provide the lowest errors of stand carbon stock as target variable. When these predictions are obtained by ANNs, different neural networks such as the feed-forward backprop, Elman backprop, Layer Recurrent and NARX will be carried out and the predictive acquirement of these networks will compared by using criterion values. Therefore, the stand carbon stock predictions based Artificial Neural Network (ANN) may present an important tool in forest management planning and site quality evaluations of these studied stands located in Turkey.

Key words: Artificial neural networks, Stand carbon stock, Network types, Landsat TM

1. INTRODUCTION

Carbon storage in forest biomass and soil organic carbon is the consequence of a cycle between different carbon pools and its concentration in the atmosphere has improved by 31% since the beginning of the industrial period, from 280 to 360 ppm (IPCC, 2007). These improvements in carbon emissions have a role to play in mitigating climate change, because climate affected with carbon by absorbing sunshine when deferred in the atmosphere or when

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deposited on the Earth's surface (Ruiz-Peinado et. al., 2012). Then, carbon release the energy absorbed to more temperature and underwrites to atmospheric warming and the accelerated transpiration and evapotranspiration. As alternative solution, improving Carbon storage by improving forest areas can present chances to decrease atmospheric carbon and hereby the obstruction of global warming (Watson, 2000; Zhou et. al., 2010).

Therefore, the estimation of forest carbon stocks has increased distinction due to the role of forests in the qualification of global climate change through carbon storage in biomass and soil in recent years. In traditional forest inventories, the carbon storage that is correlated to the dendrometrical properties of trees, which are relatively easy to measure (i.e., the diameter at breast height and total height) is commonly assessed by using carbon equations that were developed by using regression analysis. Nevertheless, the acquiring of such prediction by forest survey and inventory is very costly in terms of money, time and energy for forest management planners and other forest users (Hyyppa et. al., 2000). In this regards, there is an evident need to quick and cost-effective methodologies for forest inventories which allow for both the prediction of the total stand variables and for forest management practices (Leckie and Gillis, 1995; Chubeyve et. al., 2006). Methods of using satellite data are consequently an appreciated methods of for predicting forest attributes that are linked to relevant spectral responses (Steininger, 2000; Foody et al., 2003). Lately, satellite images have been broadly practical to evaluate and predict the carbon storage over larger areas (Goetz et al., 2007; Gallaun et al., 2010). These studies have used the regression analysis including some equations predicting the relationships between remote sensing data such as vegetation index values calculating these band values and stand carbon storage. However, these regression models have been frequently used in literature about this subject, these statistical models require some assumptions about the form of a fitting function such as that the data are independent, normally distributed, and homoscedastic with uniform residual variance. Inappropriately, these assumptions are often not fulfilled owing to the inherent variability structure in forestry data (Peng, 2000; Weiskittel et al., 2011).

Artificial neural network models have gained popularity as a prevailing and efficient tools for fitting data obtained from forest area as a remarkable technique, which is not the case of statistical regression analyze where a suitable regression models must first be established. Artificial neural networks (ANNs) are a sort of artificial intelligence system similar to human brain, having a computational capability which is attained through knowledge (Braga et. al., 2003). Artificial neural networks (ANNs) form a subclass of artificial intelligence, which has the possible ability to model compound and nonlinear connections of natural systems without encoded model functions (Atkinson and Tatnall, 1997). Although several studies have developed the model providing some prediction and forecasting in a number of areas, including finance, power generation, medicine, water resources and environmental science, the studies predicting the relationships between carbon storage and vegetation index values originating from remote sensing data are limited by using Artificial neural network modeling approach. The objectives of this study are therefore: (1) to evaluate various Artificial neural network type such as the feed-forward backprop, Elman backprop, Layer Recurrent and NARX network type, and (2) to compare these neural networks with classical regression model based on some statistical fitting criterions for Scots pine stands in the Taşköprü-Çiftlik forests of Northern Turkey.

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2. MATERIAL AND METHODS

2.1. Material

The data used in this study were obtained from even-aged and pure Scots pine (*Pinus sylvestris* L.) stands located in the Çiftlik Planning Unit, Taşköprü Forest Enterprise, Kastamonu Forest District Directorate, Northern Turkey. Çiftlik forests are one of essential distribution areas for natural Scots pine stands in this region. Çiftlik forests cover 7852 ha, including 6818 ha of productive forest area and 1034 ha of degraded area, with important Scots pine stands.

In the even-aged Scots pine stands, 150 sample plots were selected to represent various stand conditions such as site quality, age, and stand density. These sampled pure Scots pine stands were naturally regenerated and uniformly stocked (60-90% tree layer cover), with no historical evidence of damage caused by fire or storms. During the sampling of the plots, plots were carefully investigated for evidence of intensive silvicultural treatments or clear-cutting. The size of circular sample plots ranged from 400 to 800 m2 to include a minimum of 30–35 trees in sample plots; the number of trees was dependent on the stand crown closure. In each sample plot, DBH was measured to 0.1 cm precision using calipers for every living tree with a DBH > 8 cm.

2.2. Methods

2.2.1. Carbon Storage Estimations

The carbon values of individual trees were directly calculated by using the species-specific and regional allometric equations developed by Yavuz et. al. (2010) for Scots pine trees obtained from Northern of Turkey. The four equations for estimating the stem, branch, needless, and bark carbon of individual trees are based only on DBH and are single entry carbon equations (Yavuz et. al., 2010):

$$Carbon\ values\ of\ tree\ stem = -33.726 + 0.383 \cdot dbh^2 \quad (1)$$
$$R^2 = 0.963, S.E. = 40.96$$

$$Carbon\ values\ of\ tree\ branch = 0.131 + 0.011 \cdot dbh^2 \quad (2)$$
$$R^2 = 0.647, S.E. = 4.37$$

$$Carbon\ values\ of\ tree\ needless = 25.152 - 2.002 \cdot dbh + 0.042 \cdot dbh^2 \quad (3)$$
$$R^2 = 0.759, S.E. = 4.12$$

$$Carbon\ values\ of\ tree\ bark = -2.174 + 0.414 \cdot dbh \quad (4)$$
$$R^2 = 0.648, S.E. = 3.10$$

The total aboveground standing carbon values (called as carbon storage) of each sample plots were obtained by summing the carbon values of all individual trees in sample plots and converted to per hectare based on the size of sample plots.

2.2.2. Digital processing of Landsat TM

Landsat TM satellite image was acquired on 27 August 2010 (path/row 176/31). The six bands (TM1, TM2, TM3, TM4, TM5 and TM7) of Landsat TM with 30 m spatial resolution were used. The Landsat TM satellite image was georeferenced to UTM WGS 84 Zone 36.

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Using 25 control points taken from Google earth map, a root square mean error of 0.5 pixels was obtained. Data processing, interpreting and analysis were performed using Erdas Imagine 9.1^{TM} version (Erdas, 2002). The UTM coordinates of the sample plots determined by GPS. However, the GPS points have positional errors, which normally average to ±4m. Therefore, it is difficult to correctly locate each sample plot on the center of the 30 m grid of Landsat TM pixels. Therefore, many researchers used a moving window, such as a 3 x 3 pixel (Makela and Pekkarinen, 2004; Labrecque et al., 2006). Similarly, we used a moving window to average the reflectance values in the neighboring pixels and, the band reflectance values and vegetation indices were calculated for each sample area on the Landsat TM satellite image. In this study, total eight vegetation indices (NDVI, SR, DVI, SAVI, ND53, ND54, ND57, ND32, ND73, TVI, NLI, NDWI, IPVI) were used.

2.2.3. Artificial neural network modeling approach

In the neural network model building, both training, verification and testing data sets that randomly partitioned into training (75% of all data), verification (15% of all data) and test (the remaining 10% of all data) data sets were used for capturing general patterns between input variables (independent variables in regression analysis) and target variable (dependent variables in regression analysis). The types of training of ANNs selected for evaluation are the feed-forward backprop, Elman backprop, Layer Recurrent and NARX with training function of Levenberg-Marquardt and transfer function of hyperbolic tangent sigmoid. In ANNs training process, the number of neurons is used as 10 with number of layers of 2 owing to fact that these parameters are the most frequently chosen values in ANNs. In these networks, stand carbon storage calculated from sample plots are reserved as target variable and input variables are vegetation index values from satellite data. All these applications for ANN was carried out using MATLAB-nntool module. Also, these artificial neural networks (ANNs) structures such as the feed-forward backprop, Elman backprop, Layer Recurrent and NARX were compared based on evaluations of the magnitudes and distributions of models' residual and four goodness-of-fit statistics: Akaike's information criterion (AIC), Root Mean Square Error (RMSE) and Adjusted Coefficient of Determination (R^2_{adj}).

3. RESULTS AND DISCUSSION

3.1. Results

The goodness-of-fit statistics, including AIC, RMSE and R_{adj}^2, for the ANNs and regression model including some vegetation indices, such as ND53, ND73 and DVI that provided best predictive results, are given in Table 1. The AIC was between 627.21 and 703.43, RMSE between 7.930 ton and 10.224 ton, and R^2 between 0.425 m and 0.654 m in all tested methods. On the basis of the goodness-of-fit statistics, the Artificial neural network based on feed-forward backprop showed better fitting ability with AIC (627.21), RMSE (7.930), R^2 (0.654) than the linear regression model and the other studied ANNs. Fitting results in the ANN based feed-forward backprop accounted for more than 65 % of total variance in stand carbon storage and vegetation indices from satellite image data.

Table 1. The goodness-of-fit statistics for Prediction Method including the ANNs and regression model

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Prediction Methods including the ANNs and regression model	AIC	RMSE	R_{adj}^2
ANN based on feed-forward backprop	627.21	7.930	0.654
ANN based on Elman backprop	669.32	9.126	0.542
ANN based on Layer Recurrent	686.01	9.648	0.488
ANN based on NARX	675.02	9.301	0.524
Linear Regression	703.43	10.224	0.425

The residuals versus fitted (predicted) values for the ANN based on feed-forward backprop are given in Figure 1. These residuals of this ANN indicate that there are no observable patterns in Figure 1 and thus, there are no serious violations of the assumption of constant variance, such as homoscedasticity. Precisely, the appropriate features of the residual pattern emphasized the statistical acceptability for the ANN as statistical prediction method with no bias prediction results (Fig. 1). However, the residuals of regression model indicate that there are increasing noticeable patterns in Figure 2, thus it may be biased for predicting stand carbon storage by using regression model.

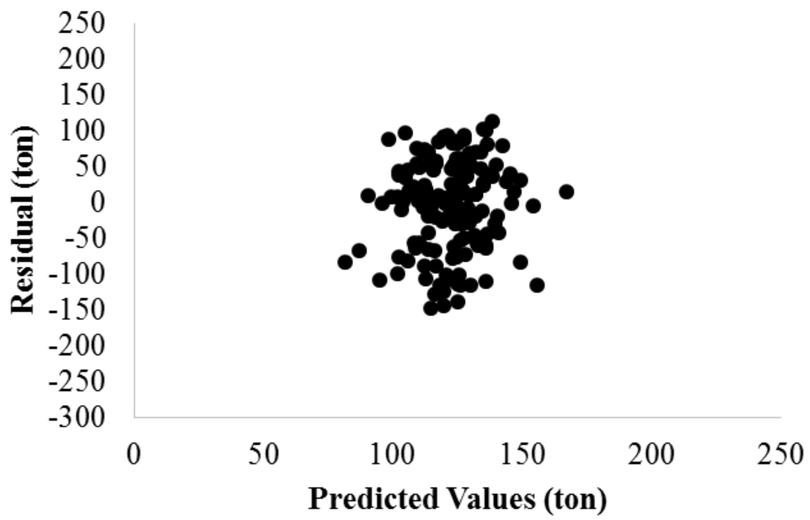

Figure 1. Residuals versus predicted carbon storage values from the ANN based feed-forward backprop network type.

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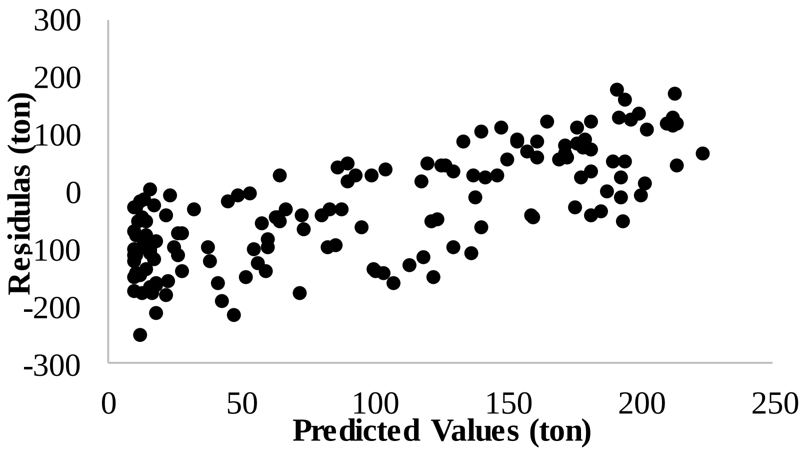

Figure 2. Residuals versus predicted biomass values from multiple regression model

3.2. Discussion

Some artificial neural network modeling technique based on different network type such as the feed-forward backprop, Elman backprop, Layer Recurrent and NARX has been successfully carried out for predicting carbon storage of Scots pine (*Pinus sylvestris* L.) stands located in the Çiftlik forests. The results show that the ANN models are able to predict stand carbon storage from some vegetation indices based on satellite data image, and to generate more accurate predictions than multiple linear regression approaches. In ANN, target variable is stand carbon storage calculated sample plots, input variable are some vegetation indices such as DVI, ND57 and ND73 that have significant relationships with stand carbon values.

In nowadays, artificial Neural networks are becoming a widespread prediction method, because of the unnecessary of some statistical assumptions that are important for accurately predicting regression models that may fit the observed data. Also, such complexity and nonlinearity that overlooked by the traditional statistical models can be modelled by the architecture of an ANN by allowing highly correlated inputs to be used to enhance the modelling capability. Thus, ANN analysis techniques have potential for more accurately modelling carbon storage using remote sensor data. It may produce unbiased carbon predictions using different ANN structure in specific sample plots. This method will help forest planners and silviculturist to obtain stand carbon storage in Scots pine stands. In this study, we emphasized the ability of the ANN based on feed-forward backprop predicting the relationships between carbon storage and vegetation indices from satellite image. The ANN models may present an important tool in forest management planning and stand carbon storage evaluations of these studied stands located in Turkey.

4. ACKNOWLEDGMENT

We would like to thank to for support to the Head of Forest Management and Planning Department, General Directorate of Forestry, Republic of Turkey.

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A METHOD STUDY TO DETERMINE BUFFERING EFFECT OF THE FOREST COVER ON PARTICULATE MATTER AND NOISE ISOLATION

Burak ARICAK[1*], Korhan ENEZ[1], Çiğdem ÖZER GENÇ[1], Hakan ŞEVİK[2]

[1]Kastamonu University, Faculty of Forestry, Department of Forest Engineering, Kastamonu, Turkey. Tel: +90 366 2801707 Fax: +90 366 2152316
E-mail: baricak@kastamonu.edu.tr*
[2]Kastamonu University, Faculty of Engineering and Architecture, Department of Environmental Engineering, Kastamonu, Turkey.

ABSTRACT

Noise and air pollution come in the first place among environmental pollution types that have negative effects on the quality of the environment we live in currently and human health. Particularly, settlements close to motorways are adversely effected from particulate matter (PM) and noise pollution arising from the traffic. Method of study to be conducted for determination of the buffering effect of the forest cover, which act to isolate the PM and noise pollution in motorways will be explained here. With this method study, criteria for isolating the PM and noise pollution, which will have adverse effects on settlement areas and wild life, depending on the characteristics of the forest cover around the highway can be established. Determining these criteria, the area sufficient to ensure PM and noise pollution isolation based on the leaf type, closure and forest stand age characteristics of the forest cover adjacent to the highway can be determined.

Keywords: Noise pollution, Particulate Matter, Forest Cover, Highway

1. INTRODUCTION

Air and environmental pollution is one of the factors that affect the comfort and living conditions of individuals. The environmental pollution factors include the elements such as temperature, humidity, noise, light pollution and malodor particularly that can be sensed with 5 sensory organs as well as the chemical gases and the PM rate in air.

The quantity and period of presence of the said pollution elements, rather than their mere presence, are the basic factors that determine the extent of nuisance. For example, the noise of a wedding celebration in high level and terminating within a few hours is considered less irritating than that of the permanent sound of water with a lover level. Therefore, elimination of the continuous nuisance factors that affect the comfort conditions of the people is much more important.

The developing technology in the world of the twenty-first century has brought forth mane problems, and factors that event the existence were not taken into consideration in the previous century have become the most important problems of our times. Light pollution, noise pollution, household wastes, radioactive substances and similar can be given examples of these problems. Noise and PM pollution are facts that should be evaluated in this scope in today’s world.

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Noise, which is defined as unwanted and disturbing sounds, adversely affects the wild animals as well as it affects humans adversely (Guidelines for the Assessment of Environmental Noise, 2011). Sound pressure level unit is decibel, and is shown as “dB”. Hearing limit of human ear is 0dB,and this rate increases logarithmically depending on the sound intensity. The pain limit for humans is 120-130 dB level. Human behaviors against the effects of noise are divided into two groups. The first is the psychological discomfort that can only be determined with the explanation of emotions and senses, and the second is the physiological discomfort that can be determined with several measurement methods. Classification of noise according to effects on humans is given in Table 1.

Table 1. Noise risk levels and effects on humans (www.rshm.saglik.gov.tr)

Risk Level / Noise Level (dBA)	**Effect**
1st Level Noise 30-65 dBA	Irritation, Discomfort, Feelings of Boredom, Anger, Impairment of Concentration and Sleep Disorders
2nd Level Noise 65-90 dBA	Heart rate changes, Acceleration of Breathing, Decrease in intracranial pressure
3rd Level Noise 90-120 dBA	Headache
4th Level Noise 120-140 dBA	Impairment in the inner ear
5th Level Noise 140<dBA	Tearing of the eardrum

According to the International standard ISO 1999 and American National Standard ANSI S 3-1, hearing losses are classified as follows:

0-26 dB(A) Normal hearing,
27-40 dB(A) Very slight hearing loss,
41-55 dB(A) Slight hearing loss,
56-70 dB(A) Medium-level hearing loss,
71-90 dB(A) Serious hearing loss,
91-< dB(A) Very serious hearing loss (Çetin, 2000).

“Various sources of noise and maximum noise levels allowed from these sources” in the Regulation Related to Noise Control, article 6/1 are given in Table 2. According to the noise control regulation, operation, putting into service and use of devices emitting noise in levels higher than those indicated is prohibited.

Buffering the noise originating from the highways and doing this in an easy, esthetic and unproblematic way with low expenses and also ensuring continuity constitute a problem. This buffering process is carried out with solid materials in many countries of the world; however, although the material used was functional, it is expensive and get reactions of the highway users because it is not esthetic.

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Table 2.Various sources of noise and maximum noise levels allowed from these sources

Vehicles	Upper limit of noise (dB)
Automobile	75
Bus (urban transport)	85
Bus (long distance)	80
Slow moving vehicle (within the driver's cabin)	85
Truck (at 80km/h speed)	85
Railway engine (with diesel engine, operating at full power and load, speed 80 km/h and windows closed	85
Electric trains and railway engines	80
Within the cars	70

The most effective method for buffering the noise originating from highways is possibly the plant cover. Planting on the sides of highways in regions where the climatic and soil conditions allow it is a easy, inexpensive, effective and esthetic solution for PM and noise isolation. Planting works on the sides of highways also make important contributions to the ecosystem of the cities and air quality. Studies for determining the air quality have significantly increased with the establishment of the effects of air quality on human health. Loss of air quality directly affects performances and health of humans (Şevikand Kanter, 2011).

One of the most important parameters of air quality is the "particulate matter quantity". While the excessive amounts of particulate matter (PM) causes discomfort in every individual and animal, it can cause serious problems in individuals with upper respiratory tract diseases, and in the elderly and children.

Particulate matter is defined as the suspension of fine solid or liquid substances within the gas that originate from wind, sea or volcano, and is referred as "aerosol" in the literature. PM10(gross particles) and PM2,5 (fine particles) represent the small particles with aerodynamic diameters smaller than 10 and 2,5 µm, respectively. Sources of PMs in nature and their compositions are rather complex. A significant portion of PM in the troposphere is of human origin and contains sulfate, ammonia, nitrate, sodium, chlorine, trace elements, carbon-containing substances, earth elements and water (Özdemirand others, 2010).

Limit values of PM concentration have been determined in regulations in many areas in the world, including the countries of the European Union, because of their potential effects on health and environment. Increase in the number of studies on PM is notable in the recent years because of its dangerous effects on human health and the adverse effects on environment including the effects on climate and ecosystem. Studies have shown that PM2,5and PM10concentrations have reached critical values; however, the previous studies are not sufficient (Özdemirand others, 2010).

Particulate matter quantities were investigated in our country studies carried out in Aydın (Başarand others, 2005) BüyükçekmeceBasin (Karaca, 2008), Izmir (Doğanand Kitapçıoğlu, 2007; Yatkınand Bayram, 2007) and in Malatya(Eğriand others, 1997) and various evaluations have been made. Particulate matter quantity was assessed also for the Kastamonuprovincial center. The mean lowest values for measurements made in seven points

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in Kastamonu were 412.943 for particles 0,3 µm in size, 126.300 for particles 0,5 µm in size and 327 for particles 5 µm in size. The mean lowest values were estimated to be 92.643 for particles 0,3µm in size, 7633 for particles 0,5 µm in size and 27 for particles 5 µm in size. Based on the mean values of measurements, it has been calculated that particle number for particles 0,3 µm in size is 243.261,while the particle number for particles 0,5 µm in size is 34255 and particle number for particles 5 µm in size is 102 (Şevikand others, 2013).

As regards the mean values of the measurements made in Kastamonu, the highest values were measured in Telekom Cul-de-sac for particles 0,3 µm in size (345444 particles) and particles 0,5 µm in size (66017 particles) and in Cumhuriyet Square for particles 5 µm in size. The lowest values for particles 0.3 µm in size were measured in DadayJunction (172127 particles) in Kışla Park for particles0,5 µm in size (16017 particles), and in Kışla Park (57 particles), Telekom Cul-de-sac (57 particles) and Narsullah Square (58 particles) for particles 5 µm in size (Şevikand others, 2013). However, studies on PM and noise are still very, very insufficient. Particularly, number of studies on the methods to diminish noise and particulate matter pollution is next to nothing.

Method of study to be conducted for determination the buffering effect of the forest cover on noise and PM pollution originating from highways, which are continuous noise and PM sources will be explained here, and an easy, inexpensive, effective, ecologic and continuously esthetic solution for noise and PM pollution can be determined based on the results of the study.

2. MATERIAL AND METHOD

In study, steel measuring tape, GPS, sounding-level meter, air horn, particulate matter measuring device and SPSS software to analysis will be used. The planned study will be carried out on suitable highways running through different forest stands within the boundaries of Kastamonu Regional Forestry Directorate. PM and noise measurements will be made on highways with suitable characteristics in the frame of the project.

During the measurements, forest areas that will function as barriers will be assessed in eight different land class alongside the roads. Furthermore, the open areas without forest cover will be determined as the ninth class to show the distance that effects of PM and noise can reach. Classification of lands with forest cover will be formed by taking the leaf types, closure and development ages into consideration. Characteristics of the land groups created based on closure, type and forest stand development ages are given in Table 1.

As seen in Table3, forest covers are divided into “Broad leafed” and “coniferous” according to leaf types, and as “areas with intense forest closure 3 to 4 (70% or higher closure)”, “areas with sparse forest closure 1 to 2 (closure between 0 to 70%)”, and “clearings within the forest with no closure and no intense forest plant cover”.

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Table3. Classification of forest stands to be used as PM and noise barrier

Land Class	Crown Closure	Type	Age Class
1	0	-	-
2	3-4	Broad leafed	a-b
3	3-4	Coniferous	a-b
4	3-4	Broad leafed	c-d
5	3-4	Coniferous	c-d
6	1-2	Broad leafed	a-b
7	1-2	Coniferous	a-b
8	1-2	Broad leafed	c-d
9	1-2	Coniferous	c-d

With the purpose of obtaining statistically significant results from land surveys, PM and sound measurements in maximum numbers (at least 30 from each) will be carried out from each land class that the highway runs through. At least 270 measurements (9 classes x 30 repeats) are planned for the particulate matter, and at least 270 measurements (9 classes x 30 repeats) are planned for noise measurements. However, the number of measurements will be increased to the extent possible, and 50 measurements will be targeted for each land class. Points for both PMand noise measurements will be selected from areas that are not inclined to the extent possible.

The noise level emitted to the environment by automobiles is stated in A weighted sound power level as stated in ISO 6393 standards. During the pass of vehicles on the highway for each land class determined,

1. At the side of the road (sound source)
2. 10 m to the road
3. 25 m to the road
4. 50 m to the road

Simultaneous noise measurements will be made in dB (decibel) with noise level measurement devices. This way, the distance that noise falls to 68 dB according to the article 21(b) of environmental noise criteria in highways and to 30 dBlevel, which is the limit for effects including irritation, discomfort, feelings of boredom will be determined for each land class.

Air horns that generate sound up to 100dB will be used to represent the sounds of traffic. The sound measurement device will be kept at a height of 1.5m from ground (at ear level). Measurements will be made under daylight, when there is no wind and at a noise level of 90 dB to represent the passing of vehicles, and the highest value of the 30-second measurement shall be accepted. Since measurements are planned to be made under similar meteorologyconditions, air temperature and wind speed will also be recorded. Measurements will not be made when the wind speed exceeds 5 m/sec. Wind speed will be measured with hand-hold anemometerand temperature will be measured with a thermometer.

For the measurement of particulate matter, lime will be laid on the road on an area 5m long and 2m wide on the highroad passing inside each land class, and particulate matter (size 3 to 100 microns) will be measured after passing on this coat with a vehicle. This particulate matter will be observed during the passage of vehicles with bus/truck characteristics and preliminary measurements will be made to determine the distances that measurements should be made. The time intervals for the PM measurements will also be determined with the preliminary measurements (unlike sound, particulate matter does not move with high speed, and the raised particles with the passage of the vehicles move away from the road with a lower speed. Therefore, the amount of the particulate matter originating from the pass of the vehicles moves away from the road after a certain period of time. The value of this time will be determined with preliminary measurements). During the preliminary measurements, simultaneous measurements will be made at certain points, the movement in air of the lime laid on the road will be traced to determine the measurement points and times.

Particulate matter in 3 different sizes will be measured suing the particulate matter measurement device. This way, the distance and rate of falling of the particulate matter will be determined. The amount of falling PM depending on distance will be determined separately for each land class.

Distances that both noise and particulate matter levels drop to acceptable levels will be modeled for each of the 9 land classes that the study will be carried on will be modeled using the SPSS software. The use of forest cover as a barrier against PM and noise based on the leaf types, forest stand development age and closure will thus be determined. The regression equations thus obtained will be used to determine the minimum widths of the forest cover to be planned for each of the nine land classes.

3. CONCLUSIONS

As a result of study by the method described, the type and extent of the buffering effect in PM and noise isolation of the forest stands located closely to the highways in young (ages (a) and (b)) and old (ages (c)and (d)) according to closure and the leaf types (coniferous and Broad leafed) can be introduced. Therefore, forest cover classes with eight different characteristics affecting the quality of being a barrier against PM and noise isolation have been determined. Also the surface area sufficient and criteria for the creation of natural forest cover curtains to be used as a buffer against PM and noise pollution for settlement areas and wild life will be determined with study method.

This study to be carried out will naturally have the qualities to form the background for the planning of the forest cover to be created on sides of highways to function as a curtain against PMand noise. The curtaining effects of different forest cover types against PMand noise will be established. Since the extent of reducing noise and PM pollution by the forest cover will be determined based on the results of the study depending on the characteristics of the forest cover to which width, significant contribution will be ensured for the planning of the highways running close to settlement areas. At the same time, important information will be provided for the owners of operations located close to highways to help to reduce the noise level under the provisions of relevant regulations.

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GIS-DERIVED SITE INDEX MODEL OF ORIENTAL BEECH STANDS IN GÖLDAĞ FOREST PLANNING UNIT

Alkan GÜNLÜ[1*], İlker ERCANLI[1], Emin Zeki BAŞKENT[2], Ferhat BOLAT[1] Muammer ŞENYURT[1]

[1]Çankırı Karatekin University, Faculty of Forestry, 18200 Çankırı, Turkey.
Tel: +90 376 2122757 Fax: +90 376 2136983 E-Mail: alkangunlu@karatekin.edu.tr*
[2]Karadeniz Technical University, Faculty of Forestry, 61080 Trabzon, Turkey.

ABSTRACT

The accurate prediction of forest site index is important to effective forest management and useful for stratifying forest areas into productive classes. Traditionally, these forest site index estimations have been obtained through national forest inventories at sample plots. Although this method provides highly accurate measurements of forest stand parameters, it is very timewasting. However, the applications of Geographical Information System (GIS), seems to be more promising and practical, since the model can be easily applied to great forest areas. Especially, the topographic variables that can be obtained from GIS provided better information for decision making in the management of forest resources, and is likely to fulfill the needs of field foresters in assessing productivity as a measure of site potential when suitable site trees are not available in forest areas. In this study, some GIS- derived variables, including altitude, slope and aspect were regressed with site index values that could be measured in each sample plots. This study was performed in pure oriental beech (*Fagus orientalis* Lipsky) stands located in the Göldağ planning unit located in the central Black Sea Region, Turkey. In this study, multivariate regression analysis was used to model the relationship between stand site index values, as dependent variables, and the GIS-derived variables, aspect, slope and altitude as independent variables. The regression model that used aspect, slope and altitude showed the performances of the site index (R^2=0.576, Sy.x=2.6131).

Keywords: GIS-derived variables, Site index, Regression analysis

1. INTRODUCTION

The precise forecasts of forest site quality is essential to operative and effective forest management (Clutter et al., 1983), and also these estimations are an significant input variable for forest growth and yield models (Husch et al., 1972). In forest areas, these forest quality estimations have been conventionally achieved by national forest inventories at sample plots. To obtain forest site quality estimation, "the site index, defined as the average height of dominant or co-dominant trees at a specified index age, has been commonly used as a measure of site quality in both pure stands" (Carmean, 1972). A fundamental characteristic of dominant and co-dominanat height is independence from stand density and it's not being affected by thinning in silvicultural applications (Clutter et al., 1983; Monserud, 1984). GIS approach can be joint with remote sensing data to obtain improve (Menemencioğlu et al., 2013) and easily site index estimations, which was then used to predict forest quality for forests areas. In nowadays, because of the development and popularization of the geographic information system (GIS), many site quality models including some GIS-derived variables

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based on digital terrain analysis have been proposed (Iverson et al., 1997; Chen and Abe, 1999; Mitsuda et al., 2001; Sturtevant and Seagle, 2004; Minowa et al., 2005). The objective of this study is to evaluate the use of GIS derived variables (aspect, slope and altitude) obtained from topographic map (1/25.000 scale) to predict the site index values, indicator of forest quality, for pure oriental beech stands in Göldağ forest planning unit located in the central Black Sea Region, Turkey.

2. MATERIALS AND METHODS

2.1. Study area

The research area was the Göldağ forest planning unit located in the central Black Sea Region, Turkey (647000-650000 E. 4629000-4632000 N. UTM ED 50 datum Zone 36 N, Figure 1). Elevation ranges from 500 m to 970 m. The research area is situated on a steep terrain, topographic surface with a slope ranging from 10% to 60%. Average annual temperature reaches a maximum of 27.6^{o}C in the summer and a minimum of 13.8^{o}C in the winter. Average annual precipitation in the research area is 677.3 mm (Anonymous, 2005). The research area is covered with unmanaged, even-aged, pure stands of oriental beech (*Fagus orientalis* Lipsky.) (Günlü et al., 2008).

2.2. Ground measurements

In this research, 70 sample plots were established with 300 x 300 m grids and classical timber inventory measurements (stand age and height) were carried out in each sample plot. In each sample plot, height and age were measured in free-growing dominant and co-dominant trees. Site index was calculated for each stand at the reference age of 100 years by site index curves developed by Carus (1998) for *Fagus orientalis* Lipsky.

2.3. Determining topographic factors

In this study, digital topographic map at 1/25.000 scale used to estimate the aspect, slope and altitude. Digital Elevation Models (DEM) contains the elevation of the terrain over a specified area, usually at a fixed grid, displaying slope, aspect and altitude. The source of the DEM data (at 10×10 m pixel resolution) comes from the contour line map with 10 m intervals digitized from digital topographic map, registered with 6–8 m root mean square (RMS) error with 3D modeling in GIS. The aspect, slope and altitude maps were produce using GIS. Then, using developed maps from GIS were determined the slope, aspect and altitude of each sample plot.

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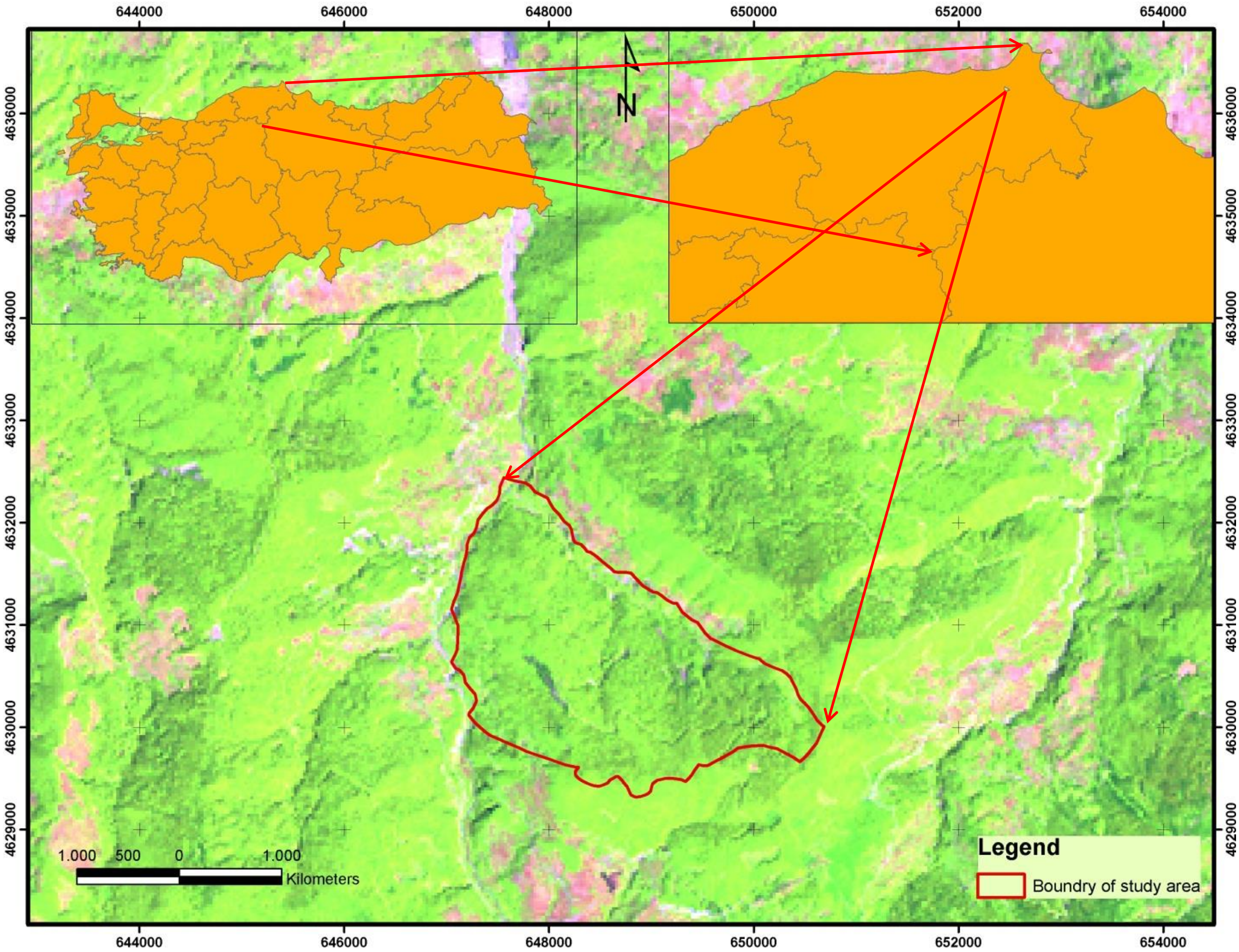

Figure 1. Location of the study area

2.4. Statistical analysis

The multiple stepwise regressions analysis was performed using PROC REG procedure of the SAS/ETS V9 software in this study. The stepwise variable selection technique was used to choice the predictive variables with p values equal to or less than 0.05 for the best the highest adjusted R^2 values. The multiple stepwise regression analysis was performed using SPSS version 15.0 (SPSS, 2007). The structure model used in this study was listed below.

$$\text{Site index} = \beta + \beta X_1 + \beta X_2 + \ldots\ldots\ldots + \beta_n X_n + \varepsilon \qquad (1)$$

X1, X2,……..Xn, are independent variable (i.e. the aspect, slope and altitude), β1… βn represent model coefficients, and *ε* is the additive bias (Corona et al., 1998; Fontes et al., 2003).

3. RESULTS AND DISCUSSIONS

In this study, the regression model, accuracy statistics such as coefficients of determination (R^2) and the standard error of model (Sy.x) of site index is presented in relation to the aspect, slope and altitude values in Table 1. In addition to, Figure 2 shows the scatterplots of residuals versus predicted biomass values.

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Table 1. Parameters of the regression model of site index based on the aspect, slope and altitude values.

Independent Variables	Coefficients of Independent Variables	S. E. of Variables	t-statistics	p-value
Constant	39.6468	2.9645	13.374	0.000
Altitude	-0.01119	0.0037	-2.9921	0.005
Aspect	-0.02154	0.0030	-7.1613	0.000
Slope	-0.1006	0.02555	-0.4065	0.000
R^2=0.576	Sy,x=2.6131			

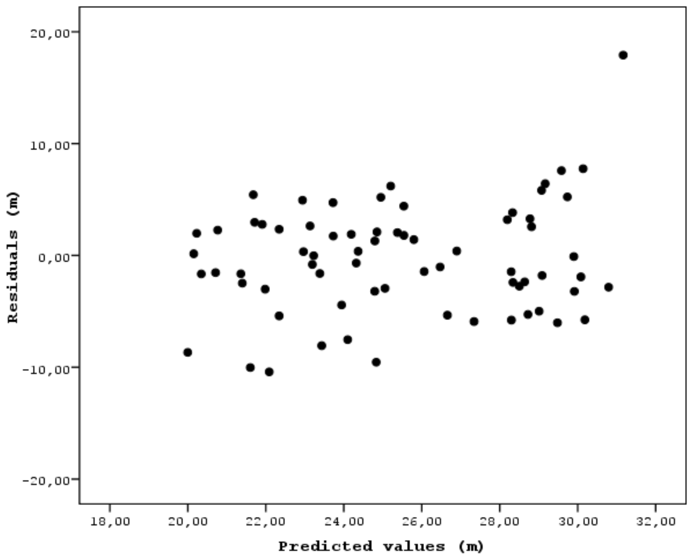

Figure 2. Residuals versus predicted site index values from multiple regression model

When examining Table 1, the site index model was developed based on the topographic factors of aspect, slope and altitude as independent variables, and this model performance was calculated and adjusted with R^2=0.576, and Sy.x=2.6131. In the model, negative relationship between the dependent variables with the independent variables were observed. Compared with other studies in the literature this study, similar relationships were indicated. For example, Ercanlı et al. (2008) found that site index was negative correlated with aspect, slope and altitude (r=-0.44), (r=-0.58) and (r=-0.39) respectively, in pure *Picea orientalis* (L.) stands. In the same study, the site index model developed using topographic factors (aspect, slope and altitude) and this model result was calculated and adjusted with R^2=0.656, and Sy.x=1.283. In another study, Socha (2008) showed the negative correlated between site index and altitude for *Picea abies* (L.) (r=-0.61).

In the model with topographic variables, the aspect, slope and altitude were showed negative effects on site index. The negative relationship between aspect (according to azimuth angles) and site index was found. Because, in the northern hemisphere, northern aspects are normally cooler than south aspects and have more rainfall with less evaporation and more soil moisture than southern aspects as supported by (Cepel et al., 1977), Eruz (1984) and Dasdemir (1992). Similar to, because of low sunlight exposure time and intensity, more surface flow of precipitation, higher soil skeleton content, reducing soil depth, aggravations of nutrients and water budget, slope was negatively related with site index as also presented Fontes et al. (2003).

In addition to, the altitude was negative effects on site index, because increasing altitude caused negative effects of physical and chemical attributes of soil. However, Louw and Scholes (2006) found positive correlation between topographical factors and site index of *Pinus patula* (L.) (r= 0.56). However, Korkalainen and Laure´n (2006) found low relation between the site index of *Picea abies* (L.) and topographical variables such as aspect, slope and altitude.

4. CONCLUSIONS

This study examined the relationship between topographic factors such as aspect, slope and altitude obtained from topographic map using GIS and site index, using multivariate regression analyses. The model including aspect, slope and altitude as independent variables was predictor of site index (R^2=0.576, and Sy.x=2.6131). The aforementioned topographic factors can be easily obtained from digital topographic maps using GIS. Therefore, finally, we commend that GIS-derived technique to predict site index can be applied in the other forest ecosystems areas.

5. ACKNOWLEDGMENT

This work was supported by the Karadeniz Technical University Project Department, Project No: 2005.113.001.3.

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EFFECTS OF GREEN ROAD ON WILDLIFE IN EASTERN KARADENIZ MOUNTAINS

Alptuğ SARİ*, Ahmet ARPACIK, Şağdan BAŞKAYA, Ebubekir GÜNDOĞDU

Karadeniz Technical University, Faculty of Forestry, Deptartment of Wildlife Ecology and Management, Trabzon. Tel: +90 462 3773247 Fax: +90 462 3257499
E-mail: alptugsari@ktu.edu.tr*

ABSTRACT

In this study, the effects of green road on wildlife, which has been planned for connection of high plateaus and for increasing the potential of tourism in the scope of Eastern Karadeniz Project, were studied. The green road of totally 2600 km long provides the transportation between the highlands to provide a separate road to beach and it is formed by new methods as an improvement over current roads. The roads potentially have a negative effect on habitats of wild animals such as degradation, fragmentation, conversion, loss, and as well as vehicle collision and poaching. In order to find out the effects of green road on wildlife, researches and studies have been done on the construction part of the road in Uzungöl, İkizdere and Kaçkar Mountains in 2014 and 2015. As a result of these studies, the main negative effects of green road on wildlife habitat were deteriorations, increased poaching, unsuitable and unnecessary barrier effect caused by the retaining wall, lack of appropriate vents and access areas to the passage of wild animals, and increased vehicle collision. This project is to minimize these negative effects not only from the aspects of tourism and transportation but also aspects of wildlife habitats in accordance with the wishes of wild animals.

Key words: Green Road, Wildlife, Negative Effect, Tourism, Eastern Karadeniz Region

1. INTRODUCTION

Turkey, surrounded from three sides with seas of different ecological characteristics, with altitudes ranging from sea level to above 5000 meters resulting in a variety of climatic conditions through the country, has a rich biodiversity. Several different ecological characteristics provide nesting and breeding areas for thousands of fauna and flora species. Eastern Karadeniz region, where include these studying areas, is one of the most important areas of Turkey for biodiversity.

Habitat in roadless areas is generally less fragmented and better-connected than in roaded areas of similar size (Reed et al., 1996). By far, the largest single threat to biological diversity worldwide is the outright destruction of habitat, along with habitat alteration and fragmentation of large habitats into smaller patches (Meffe et al., 1997). Roads are a major contributor to habitat fragmentation because they divide large landscapes into smaller patches and convert interior habitat into edge habitat. As additional road construction and timber harvest activities increase habitat fragmentation across large areas, the populations of some species may become isolated, increasing the risk of local extirpations or extinctions (Noss and Cooperrider, 1994).

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There are, of course, numerous benefits in having roads and access, although most of these benefits are social or economic rather than environmental. Some benefits of this roads, including access for protection of wildlife from illegal hunting, recreation and commodity extraction. In addition, resource roads facilitate public transportation, land and resource administration (e.g., research, monitoring) and traditional uses (e.g., plant or fruit gathering) (Burnett, 2001).

Roads are a global threat to biodiversity and roads have a significant impact on wildlife world-wide (Polak, et al., 2014). The roads have the negative effect known direct; mortality, indirect; as degradation on habitat of wild animals (Saunders et al., 2002), fragmentation (Andrews, 1990; Saunders, vd., 2002; Bissonette, 2002; Rico et al., 2007), conversion (Saunders et al., 2001), loss (Andrews, 1990; Kerley et al., 2002; Saunders et al., 2002; Bissonette, 2002), and as well as vehicle collisions (Kerley et al., 2002; Trombulak & Frissell, 2000) and poaching (Kerley et al., 2001). Of these effects, direct mortality is the most significant and widespread effect of roads on wildlife (Polak et al., 2014).

Furthermore, an estimated one million vertebrates are killed daily on roads in the USA (Forman et al. 2003). Greenroad is the natural corridors, such as river banks, ridges or valleys, and linear corridors joining the canals along railway routes used for recreational purpose, scenic roads or parkways, as well as areas of natural reserve, cultural characteristics and historical places (Little, 1995).

A greenroad is a linear open space established along either a natural corridor, such as a riverfront, stream valley, ridgeline or overland along a railroad right-of-way converted to recreational use, a canal, a scenic road or other route or alternatively an ‘open space connector linking parks, nature reserves, cultural features or historic sites with each other and with populated areas’ (Arslan, 1996).

The green road, planned by Eastern Karadeniz Development Agency (DOKAP), is a tourism project which links major tourism centers and 40 plateaus of 8 cities such as Samsun, Ordu, Giresun, Gümüşhane, Bayburt, Trabzon, Rize and Artvin. This project’s purposes are; to increase the tourism potential by linking tourism areas and plateaus and to increase the income of local peoples who transhumance (URL-1, 2016). With this study, as a result of our direct and indirect observations on the Green roads, the effects of roads on wildlife were revealed and some solution offers were proposed.

2. MATERIAL AND METHOD

The effects of green road on wildlife, researches and studies took place the stated construction part of the road in Uzungöl, Ikizdere and Kackar Mountains in 2014 and 2015. Three work areas in the Eastern Karadeniz Region were connected eachother on Green Road Project (Fig. 1). 1. came from Araklı Borders to Çaykara Plateaus 2. from Uzungöl Borders to İkizdere Plateaus, 3. from İkizdere Borders to Kaçkar Plateaus. The sampling primarily occurred from the inventory studies conducted, technical trips for students and individual studies from 2014s to 2015, but extended to earlier years for some regions.

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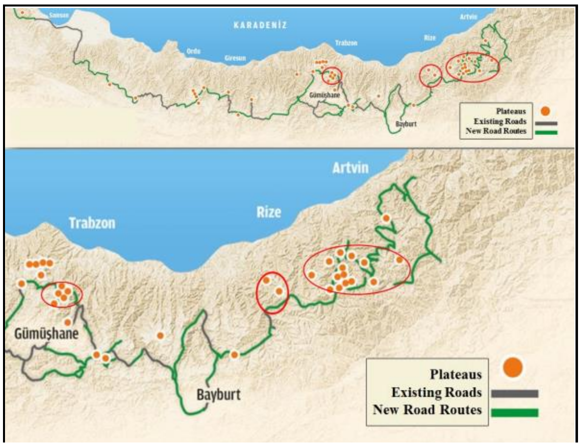

Figure 1. Green road's routes in study areas (Anon., 2016a).

Observations and studies were made by using topographic maps, various brands of binoculars, telescopes, cameras, video cameras and global positioning device (GPS). Especially in some field works camera-traps were used intensively to take photos of animals besides direct observations. Using road wild animals were determined by direct observation or indirect observations (all track and sign animal tracks, feces, spaw, scrape, urine, feathers, horns, food remains, dead animals etc.)

3. RESULT AND DISCUSSIONS

According to DOKAP, Development planned route is about 2600 km length. But, about 1000 km of this road is existing road in responsibilitiy of General Directorate of Highways. 500 km of Green road was improved after 2002 year. In the remaining parts of Green roads (1100 km), existing roads will be improved. The roads will be constructed in 7 meters width. Paths will be followed in roadless areas. New roads will not constructed (Anon., 2016b). But the opposite was observed during our reserches that in some places new roads were constructed and road width exceeded 7 meters.

Hosting thousands of species forest ecosystems are important habitats in terms of biodiversity. Alpine zones, part of forest ecosystems, host to most importants habitats for wild animals that are under threatened. Therefore, any application to be made in the forest that could important effect on living organisms.

Green road passes from average 2000 meters altitude above sea level. High mountain sections are hosting the best shelters for important wildlife areas in the region. Green road was effected a lot of animals and plants. Effected most of wild animals, using high altitude were especially Leopard (*Panthera pardus*), Lynx (*Lynx lynx*), Gray wolf (*Canis lupus*), Brown bear (*Ursus arctos*), Chamois (*Rupicapra rupicapra*), Wild goat (*Capra aegagrus*), Caspian snowcock (*Tetraogallus caspius*) and Caucasian black grouse (*Tetrao mlokosiewiczi*) (Başkaya, 2000; Başkaya and Bilgili, 2004; Başkaya, 2007; Anon., 2014). All these animals had trophy values for hunters, too. So, illegal hunters could easily taken to these areas with the help of these routes.

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In some instances, there are environmental benefits; for instance, road edges create habitat suitable for some flora and fauna species. It was observed that roadside plants were choosen for food by wild animals such as Caucasian black grouse (Figure 2). Roads can also provide travel routes for some species (e.g. Brown bear, Lynx, Gray wolf). So, this species can become easily accessible prey for illegal hunters and due to increased traffic on the roads many wild animals, choosed to walk in easy roads, would have been killed by hitting vehicles. In addition, transportation structures can actually provide habitat (e.g., retaining wall, bridges may become bird and reptiles nesting sites).

Figure 2. A male Caucasian black grouse (*Tetrao mlokosiewiczi*) on road edge in Soğanlı Mountains. (Photo by Şağdan BAŞKAYA)

Pollution from roads extends beyond just chemicals, as light and noise pollution from roads can be detrimental as well. Noise from cars can impact animals by disrupting their communication and interfering with warning signals, leading to animals' population declines in the proximity of roads. In addition to decreasing the numbers of animals, road noise can alter the community composition of animals as certain species are differentially excluded.

Unnecessary and inappropriate retaining walls were constructed in most places. Even, rear side of the retaining walls was made in hard or rocky ground. There was no ecological structures and speed cutter marks for wild animals in this area. Especially, due to increased traffic on the roads of expats coming to villages and plateaus in summer, as a result of, many wild animals would have been killed by hitting vehicles.

It was pay attention by the research time when there was a big support to the Green Road project from local people of study areas. There was only objection to the 5 kilometer portion of the project in Hemşin, Rize. Because, local people beleived that the local economy would develop by potential increasing tourism thanks to the green road.

As a result of studies, the main negative effects of green road on wildlife; habitat fragmentations, the increasing poaching, steep and unsuitable road slopes, unsuitable and unnecessary barrier effect created by the retaining wall, lack of appropriate vents and access areas the passage of wild animals, the increasing vehicle collision, pollution beyond chemicals as light and noise pollution from roads, disturbance has given the increased traffic were determined.

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4. CONCLUSION AND SUGGESTION

Green road will undoubtedly contribute the economic development of this local areas by improving the region's tourism potential. It should be known important areas for animals, ecology and biology of the species in these areas. Green road routes must be determined as far away as possible the habitat of wild animals. Road construction works in nearby important habitats must be quick and quiet. Excavation waste materials from road contruction works mustn't be dumped indiscriminate. Road constructions should be completed in a short time and even road should be closed completely for all using in important areas for animals especially in mating seasons and birth times.

All these animals, which use alpine zones of Green Road's routes for habitat, have trophy values for hunters. So, strict protection measures must be taken against illegal hunting by relevant public institutions and local people of this areas. Warning signs associated with wild animals should be placed to the roadside. Disposal of garbage to the roadside must be prevented. Especially at the time of mating and birth noise pollution must be prevented.

Retaining walls, higher than 1,5 meters, should include suitable structures in terrace type with ladder for going ups and downs of wild animals easyly. The green road is referred 7 meters width in the project, but in practice it was observed that width of roads were exceeded in some places. Wide road constructions should be discouraged by cunstructing mobile pocket roads.

Roads and retaining walls act as barriers by impeding animal movements and restricting space use. Understanding factors that influence barrier effects is important to discern the impacts of habitat fragmentation and to develop appropriate mitigations. Wildlife crossings structures, the most effective solution to animal-vehicle collisions and animal movement needs, must not be forgotten on structures such as retaining walls, bridges and culverts.

Instead of going parallel peaks of the mountain range in everywhere, the green road should do twists in some places and should be a path that has not stopovers at all locations in areas constituting shelter areas for wildlife. Green road will have, of course, some social or economic benefits for local people. Despite some protests, green road project continues and it is envisaged to be fully completed in a few years. So, it must be provided the least harm to wildlife and nature as soon as possible by taking necessary measures. Perhaps most important solution is the education of public officials and local people. Information educations about important animals and their habitats must be done for public officials, local people and tourists by authorities with written and visual materials. Including all stakeholders to all protection and control system will minimize the effect of green road to nature and wildlife.

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PLANNING RESPONSE TIMES OF FIRE-FIGHTING VEHICLES TO FOREST FIRES ON ACTIVE FIRE PROTECTION ORGANIZATION

Metin TUNAY[1*], Tuna EMİR[1], Murat YILDIRIM[2]

[1]Bartın University, Forestry Faculty, 74100 Bartın, Turkey.
Tel: +90 378 22351 70 Fax: +90 378 2235062 E-mail: mtunay@bartin.edu.tr*
[2]Kütahya Forest Enterprise Directorate, 43000 Kütahya, Turkey.

ABSTRACT

Our country has a sensitive nature in terms of forest fires due to its vegetation and climate. This situation has a vital importance for fire squads and fire-fighting vehicles to arrive at fire scene within the shortest time (critical response time - 15 minutes). In our country, there are several practices of overland and aerial response to forest fires, and various tools and equipments are used. Accordingly, there are fire-fighting vehicles in various numbers and features for the risk and sensitivity of the fire within each Forest Enterprise Directorates or Forest Sub-District Directorates. In this study which is aimed to improve efficient organization techniques of responding to forest fires and to minimize the fire damage by reducing response time to fire, distance coverage (km) of each of the suitable fire-fighting vehicles (sprinkler truck and first responder vehicle) on each road within the critical response time (15 min.) on the condition of launching vehicles from the station (fire operation center) have been measured and the remotest points where they reached have been marked. These points, then, have been introduced as areas, where each of the fire-fighting vehicles can respond within the critical response time, by means of combining them on GIS (Geographic Information Systems). Finally, measures that must be taken have been introduced by doing planning with respect to responding to fire efficiently within the frame of opportunities provided by advancing technology.

Key words: GIS, Critical Response time, Forest fire, Fire-fighting vehicle

1. INTRODUCTION

Forest fire is a fire that tends to spread and grow freely and that also burns inflammable matters in the forest like brushes, dry and thin branches, dry logs, leafs and trees alive in a certain extent since forests have an open surroundings (Bilgili, 2014). Apart from natural fires and fires caused by unknown reasons, situations such as accidents (power lines, sparks generated by machines and vehicles etc.), negligence (stubble, cigarettes etc.), arson (terrorism and land opening incidents) and rekindle incidents constitute major causes for forest fires (Figure 1).

Forest fires are one of the primary natural disasters that concern all countries due to their effects in the globalizing world and their results. Fires are an extremely serious threat causing millions of hectares of forest sites burn every year all around the world, fire-fighting expenses phrased with quadrillions and loss of life and property. Each year, approximately 2 millions of hectares of zone are falling into ruin on the Earth due to forest fires. 550 thousand hectares of this amount are located in countries (Turkey, Greece, Italy, Spain, Portugal, and France)

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Figure 1. Forest Fire.

around Mediterranean (OGM, 2014). 12,5 million hectares part of our country, which is starting from Hatay and reaching out to Istanbul through coastal regions of Mediterranean and Aegean and corresponding to almost 60% of our country's forests, constitutes the most dangerous area in terms of fires (OGM, 2007).

When considered generally, it is seen that more than half of our forests are ranging through fire-sensitive areas (Akay et. al, 2014). 70% of the fires outbreak in forests consisting of pine tree species, 6% of the fires outbreak in forests consisting of oak and rest outbreak in chestnut tree and beech tree forests. Especially when compared to Mediterranean countries located in the same climate zone, it is seen that Turkey leads forest fire extinguishing rate in Europe, considering rate of ruined forest sites and country forests of Mediterranean countries in last 10 years (2003-2012) (OGM, 2013).

The combustible causing natural forest fires is the living cover (weed fire) consisting of herbaceous or thin inflammable materials such as needle-leaves, branches and chopping remnants which are usually described as dead inflammable matters. However, in case that the fire continues and grows, the energy grows due to long brushes and saplings catching fire, and, in time, tops of trees blaze and it turns into a treetop fire which is hard to extinguish. In addition, at this stage, there emerges a situation which is hard to contain since barks, leaves and pine cones, which are burning due to the effect of unstable weather conditions, spread through kilometers away of main fire line and since it cannot be predicted where fire would spread. From this point of view, responding to the fire and containing it before it grows and turns into a treetop fire are of vital importance. Within this scope, in order to minimize the damages caused by forest fires, it is necessary to take fundamental (preventive) measures and to establish an effective fire protection and fighting organization.

As a preventive measure, along with weather forecasts and fuel status information, a model (Meteorological Early Warning System (MEUS) executed everyday for 3 days) has been developed with the thought that risk estimation could be conducted for forest fires meteorologically based on the relation between meteorological factors (air temperature, relative humidity rate, direction and velocity of the wind, precipitation-drought, atmospheric pressure etc.) and forest fires (Figure 2).

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Figure 2. Meteorological Early Warning System (MEUS)

With this model, possible start risk for fire is determined by inquiring under certain criteria in terms of relative humidity, temperature, and direction and velocity of the wind; and increasing or decreasing risk classification of these values are performed according to topography and aspect. Fire risk analysis is sent to fire operation center of General Directorate of Forestry (OGM) by highlighting it with green, yellow, orange and red on both map and Google Earth (URL-1). Upon these data, with protective and precautionary measures taken before the fire outbreak, relevant departments can accomplish successes on areas where fire grows fast and is hard to respond.

Also, semi-arid climate and arid climate conditions, a long summer aridness, various landforms, and physical and physiological features of forests, which are dominant factors in our country located in subtropical zone, draw attention as factors causing disadvantage in the beginning, developing and extinguishment stages of fire (Şahin and Sipahioğlu, 2002). 97% of forest fires in our country occur in between June and October when summer aridness taking place. In our country, 88% of the fires break out in daytime and 12% of the fires break out at nighttime period (Doğanay and Doğanay, 2003). When outbreak hours of forest fires in Turkey are observed, it is understood that fires outbreak mostly between 11:00 and 20:00. Because, in this time period, depending on the sunshine duration, temperature increase is at its highest rate and relative humidity is at its minimum level (Figure 3). Human activities being at maximum level and massive socio-cultural behaviors in this time period can be pointed as unnatural causes, and precautionary measures are taken accordingly (URL - 1). Despite all, it is not possible to completely prevent fires although there are wide precautions taken in order to protect forests against fire.

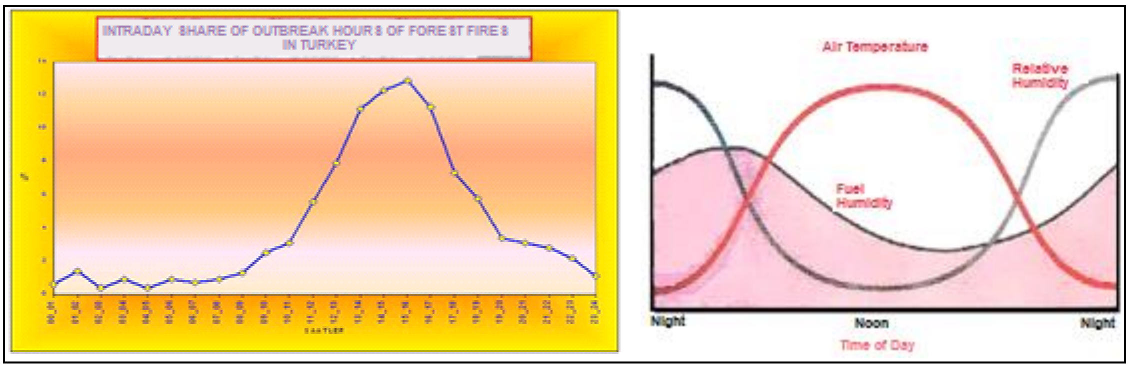

Figure 3. Intraday Share of Outbreak Hours of Forest Fires in Turkey (MGM - General Directorate of Meteorological Services)

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On the other hand, fighting activities against forest fires require an efficient planning as if it was a war, organizing teams and equipments utilized at best, and working coordinately. The important matter is to prevent and respond at the beginning. Tactic to be executed depends on characteristics of the area, topographical structure, air conditions, situation of roads and road network, equipments existing, and number and training level of the personnel (URL-2). Activities of fighting against forest fires are urgent and extraordinary and require a professional organization. Therefore, extinguishing forest fires is a practice that takes expertness, tactic and strategy.

Although number of fires has increased in Turkey recently compared to many countries such as Italy, France, Portugal, Greece and Spain, more effective and successful practices have been conducted on extinguishing and controlling forest fires. At this stage, it is extremely important to respond to the fire at the beginning with effective organization measures. According to records of OGM (2013), while response time to forest fires in our country had been 40 minutes in 2002, this time has been reduced to 18 minutes in 2012. Establishment of fire-fighting organization and early warning systems have played great role on reducing this time. Also, it has been stated that 2015 objective (Fighting Against Forest Fires Action Plan) is to reduce first response time to forest fires to 15 minutes (OGM, 2015).

To be able to employ all measures taken in order to extinguish forest fires is primarily based on the forest fire to be seen and located. In order to be able to see the fire, all forest is definitely ensured to be observed during the whole fire season. Observation is conducted by utilizing fixed watchtowers, aerial observation, mobile dispatch-teams, local residents and other sources. To be able to extinguish the fire, transportation has also a major importance. Forest roads constitute the most important land route transportation unit that teams can use to respond to fire breaking out at any spot of the forest. Forest roads providing the shortest time to arrive at all spots of the forest and the network of fire safety roads and lines are important factors in success of fire-fighting by reducing the respond time to fire (Mol and Oymen, 1988). Along with the transportation of forestry products, fire sensitivity conditions of forest sites should also be considered especially while planning forest roads at fire-sensitive areas (Ateşoğlu et. al, 2015).

At the organization of first response to fire, it is ensured for fire to be responded by using vehicles which can arrive at the field within the shortest time (planes, helicopters, sprinkler truck, first responder vehicle, fire extinguisher tank, fire extinguisher motorcycle and fire squads of district governments etc.) by considering fire-sensitivity of the fire site in question, specific location if any and also meteorological values that would affect especially the fire present to grow. In addition, number and location of vehicles used at fire-fighting in our country are determined by the directorate by considering the level of risk and sensitivity of fire. This case is mostly practiced in the way of installing fire-fighting vehicles located at all of the forest sub-district directorates in regions being important in terms of fire, and located at a shared operations base that is equidistant to all sub-district directorates within the forest departments in regions that are not constituting major importance.

In this study, in order to minimize damages of forest fires, it has been aimed to do an efficient planning for fire-fighting land vehicles used against forest fires in Turkey to respond fires in critical response time to forest fires, and efficient response areas have been revealed for each

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vehicle (sprinkler truck and first responder vehicle) by determining borders of transportation network required for early response to forest fires by using geographical information systems techniques. Finally, necessary measures required in fire-fighting within the frame of an effective organization have been offered.

2. MATERIALS AND METHOD

To be able to perform an efficient response to forest fires, arrival time of sprinkler truck and ground squad employed in fire-fighting at fire site should not exceed the critical response time when the possibility to contain the fire at the starting stage, especially in first degree fire-sensitive areas (Akay and Şakar, 2009). This study, where the planning to be done to be able to respond to the fire in the critical response time (first-respond success to flames) by using the fire-fighting vehicles, which are employed in fire-fighting and located at current equipment pool of forestry sub-district directorate, in the most efficient way, are revealed, have been performed in activity year of 2014-2015 in the borders of Kütahya Regional Forest Directorate, Simav Department of Forestry and Söğüt Sub-District Forest Directorate which possess the first degree fire-sensitive forest sites among our forests (Figure 4).

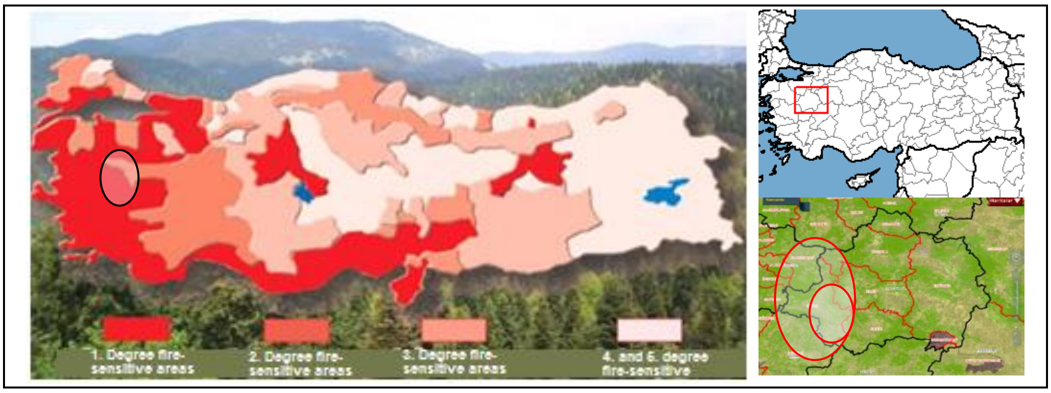

Figure 4. Location of Protected Areas Being Forest Fire-Sensitive (General Directorate of Meteorology) and Sub-District Forest Directorate.

At the first phase within the scope of the study, technical features of the vehicles employed in fire-fighting within the borders of the sub-district directorate and road network have been analyzed, and routes and status of all forest roads located within the borders of the directorate and forming infrastructure of entire forestry activities. Then, distance coverage of each of the fire-fighting vehicles (sprinkler truck and first responder vehicle) within the critical response time (15 min.) have been measured and the remotest points where they reached have been marked, on the condition of moving them on the each different routes predetermined by the station (fire operation center) These points, then, have been introduced as areas, where each of the fire-fighting vehicles can respond within the critical response time, by means of combining them on GIS (Geographic Information Systems). For the areas where cannot be reached in the critical response time, in order to be able to take precautions until the professional team arrives at the site, it has been planned to locate fire extinguisher tanks (water truck) in enough numbers and different alternatives have been evaluated. By this way, fire-fighting risk planning of the directorate has been done and necessary suggestions have been offered.

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3. RESULTS AND DISCUSSION

Total area of Söğüt Forest Sub-District Directorate which is the field of study is 21455.00 hectares and total forest land is 14719.50 hectares. Condition of the roads and presence of forest area within the borders of the sub-district directorate have been given below (Figure 5).

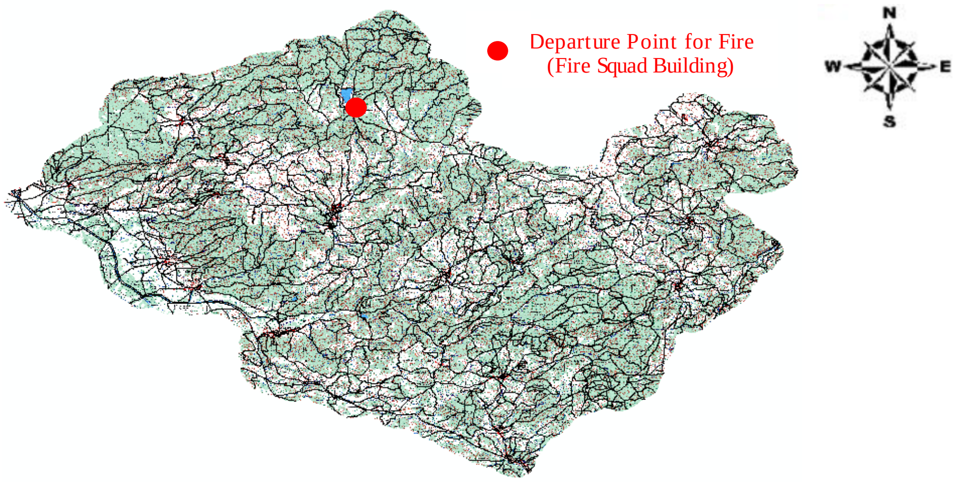

Figure 5. Present Road Network of the Forest Area within the Borders of Sub-District Directorate

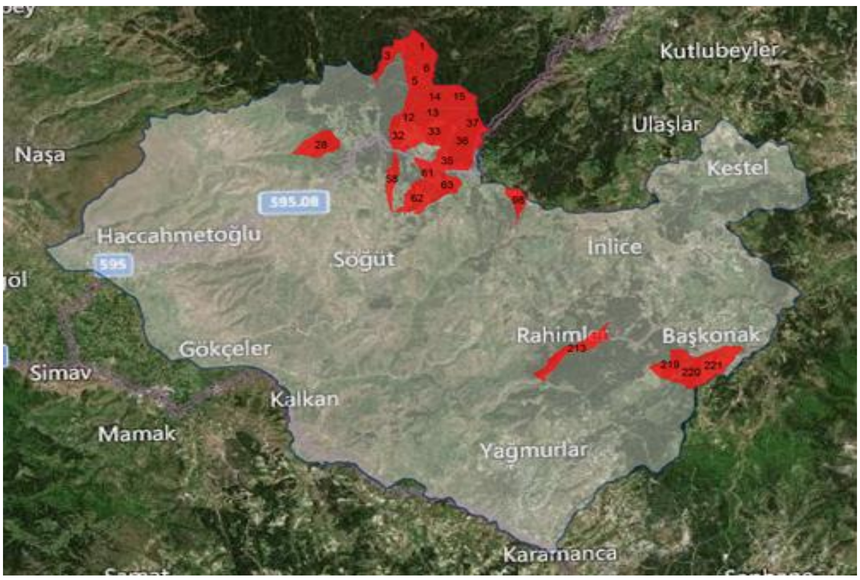

Figure 6. Share of Forest Fires within the Last 10 Years

Share of forest fire outbreaks within the last 10 years in the borders of Söğüt Forest Sub-District Directorate which is 1st degree fire-sensitive are shown above (Figure 6). According to this, it is understood that most of the fires causing 411.29 ha of area to be damaged in last 10 years were caused by negligence and were human-driven. Also, it also draws attention that there have been natural fires caused by lightning in 2008 and 2011 at the east-southeast borders of the directorate (Table 1).

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Table 1. Information of Forest Fires within Last 10 Years

	YEAR	Compartment No	Fire Start		AREA (ha)	TREE SPECIES	CAUSE	Responsible
			Date	Hour				
1	2005	219	12.09.2015	17:50	0.01	Black Pine	Power Transmission Line	Accident
2	2007	1,3,5,6,12,13,14, 15,33,35,36,37,61, 62,63	25.07.2007	2:15 PM	410.5	Black Pine	Unknown	Unknown
3	2008	220	04.09.2008	1:20 PM	0.1	Black Pine	Lightning	Lightning
4	2009	58	17.09.2009	2:45 PM	0.02	Black Pine	Unknown	Unknown
5	2011	221	21.09.2011	6:30 PM	0.5	Black Pine	Lightning	Lightning
6	2013	28	03.08.2013	5:00 PM	0.1	Black Pine	Negligence	Unknown
7	2014	98	30.08.2014	8:00 AM	0.03	Black Pine	Negligence	Unknown
8	2015	213	08.09.2015	2:25 PM	0.01	Black Pine	Negligence	Unknown
9	2015	32	01.11.2015	2:40 PM	0.02	Black Pine	Negligence	Unknown
TOTAL					411.29 ha			

It has been determined that there were fire-fighting vehicles deployed separately in 1st degree fire-sensitive areas within each sub-district directorate including Simav Forestry Directorate, and sprinkler truck, first responder vehicle and fire extinguisher tanks had been used actively on responding to fires at the sub-district directorate in question as well (Figure 7).

Figure 7. Sprinkler truck , First Responder Vehicle and Fire Extinguisher Tank

Sprinkler trucks are fire-fighting vehicles that have passenger capacity of 5-7 persons including the driver, have a function of switching between 4x4 and 4x2, can climb up to 60% slope at most and can move at the 30% slope at most. They are among the most efficient vehicles employed at responding and fighting forest fires due to their abilities of movement and climbing at rough land conditions. Sprinkler truck s have 3,000-6,000 liters of water tank attached via gimbal joints and 200 liters of chemical fire foam capacity at most (URL-3) In addition, pick-up type first responder vehicles (Ford Ranger), which are going to be employed during the first response of fire-fighting, provide more advantage with their agility in the field and swiftness in first responding at the beginning of the fire, as well as their capacity of 350 liters water and 20 liters fire foam. Along with that these vehicles, which have the ability to pump water and use fire foam via their pump on top, can respond the fire swiftly, they are also utilized within the scope of forest pest control with half-biological pesticides in off-fire-season. Besides this, with their water capacity of 2.5 tons and 100 meters of hose, multi-purpose water tankers, which are expected to be useful for fire not to grow and to be contained at the beginning until other squads arrive in order to be able to fight against possible fires in a more efficient way and which are usually delivered to the village reeve, can

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perform any tasks that a sprinkler truck can do. Apart from fire extinguishing, they can be utilized on watering gardens and crops, road watering and cleaning, and carrying drinking water as well.

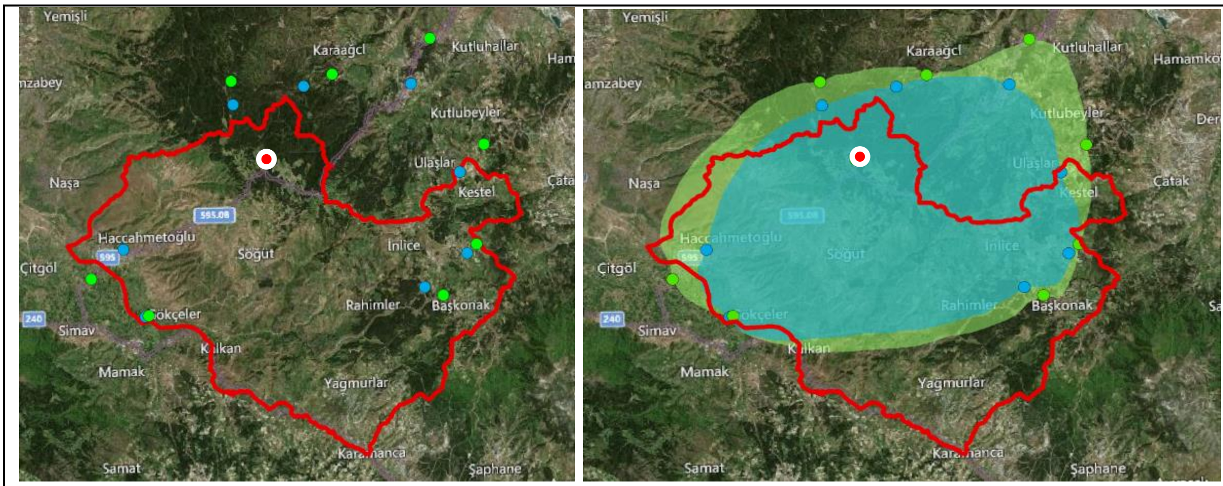
Gölcük First Fire-Responder Squad Building and Fire Departure Point based within the borders of Forest Sub-District Directorate are located at 5.1 km north of Söğüt and on 1326 m altitude. Gölcük First Responder Squad, of which geographical location is 39° 09' 57,2" north latitude and 29° 05' 11,8" east longitude, responds a possible fire within the shortest time with its 1 sprinkler truck, 1 first responder vehicle and 7 fire safety workers in total, 2 of which are seasonal workers.

Table 2. Distance Coverage (km) of Each Vehicle within the Critical Response Time

	IN 15 MIN. COVERED DISTANCE (KM)	
	SPRINKLER TRUCK	FIRST RESPONDER VEHICLE
Road No 1	13.5 km asphalt	16.2 km asphalt
Road No 2	13 km asphalt	15.7 km asphalt
Road No 3	9.5 km asphalt + 4.2 km stabilized	10 km asphalt + 5 km stabilized
Road No 4	9.4 km asphalt + 4.3 km stabilized	9.4 km asphalt + 5.4 km stabilized
Road No 5	4.5 km stabilized + 9.1 km asphalt	4.5 km stabilized + 8.9 km asphalt
Road No 6	5.5 km dirt road + 1.3 km stabilized	5.5 km dirt road + 2.5 km stabilized
Road No 7	1 km stabilized + 4.9 km dirt road	1 km stabilized + 6 km dirt road
Road No 8	12.2 km asphalt	14.7 km asphalt

*15 min = Critical Response Time for Fighting Against Forest Fires

Additionally, distance coverage of each vehicle within the critical response time has been introduced according to road type, road condition and vehicle speed for each vehicle employed at the field by the repetitive time measurement method, on the condition of moving them on each predetermined routes (Table 2). In addition, coordinates taken for each spots, at which each vehicle arrived within the critical response time, have been processed on GIS and efficient fire-fighting organization planning has been done by considering features of fire-fighting vehicles (Figure 8).



First Responder Squad Building
Spots That Can Be Reached Within the Critical Response Time by Sprinkler truck
Spots That Can Be reached Within the Critical Response Time by First Responder Vehicle

Figure 8. Borders That Can Be Responded in 15 min by Both of the Vehicles.

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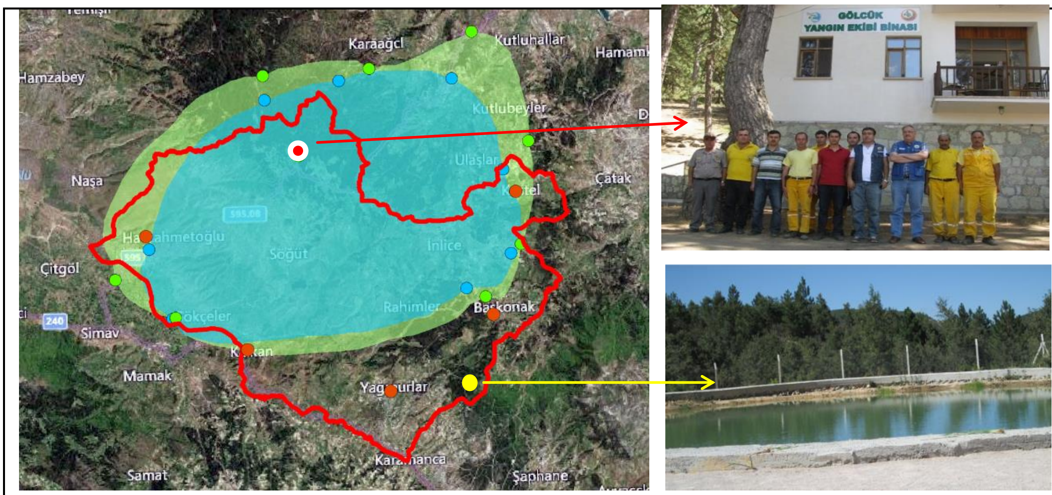
As a result of this study, by using all roads located on total 21455.00 ha area and at the directorate which has 1. degree fire-sensitive structure, it has been figured that sprinkler truck can respond to an area of approximately 13513.3 ha and first responder vehicle can respond to an area of approximately 15791.7 ha within the critical respond time (15 min). According to this, it has been determined that while 62,98% of the total area can be responded via sprinkler truck , 73,27% of the total area can be responded via first responder vehicle within the critical response time. On planning 26,73% of the area that cannot be responded within the critical response time, critical areas in terms of fire have been determined and average distance covered by fire extinguisher tank within the critical response time (4.1 km) have been introduced by repetitive time measurement method. Therefore, a planning has been done in the way that water tanks, which are usually utilized by assembling on tractors and which are considered useful for containing and controlling the fire at the beginning until other squads arrive, to be deployed in suitable the forest villages (Kalkan, Yağmurlar, Başkonak, Kestel, Karacaören) in order to fight against the possible fires of which planning had been done. It should not be forgotten that deploying water tankers, which can be distributed by the Forest Directorate and by Provincial Administration, especially in each forest village where cannot be responded within the critical response time would increase the success. As another alternative, if there are enough economic conditions and enough numbers of vehicles equipment pool, a new squad should be formed around water collection pond (geographical location is 39° 03’ 54” north latitude and 29° 11’ 16” east longitude) which had been established on 1345 m altitude in the forest by the directorate for the areas where cannot be responded in case of fire, or some of the fire-fighting vehicles should be deployed in these areas during the fire season (Figure 9). Thereby, a faster and more efficient response capability that would make possible to respond and eliminate the forest fires with lesser losses before they turn into a treetop fire covering the entire area have been provided. Besides, organization of the squad and equipments utilized in the most efficient way buy doing such an efficient planning.



First Responder Squad Building
Water Collection Pond
Spots (Residential Area) Determined For Deploying Water Tanks (Fire Extinguisher Tanks)

Figure 9. Planning the Areas Where Cannot Be Responded within the Critical Response Time.

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4. CONCLUSION AND SUGGESTIONS

When fires breaking out within the last 10 years are analyzed, it draws attention that there had been natural fires caused by lightning, fires caused by accidents (power transmission line), fires caused by unknown reasons and fires caused by man-included negligence. For them to be located at fire-sensitive areas and number of present fire operations base (squad building) being only one makes it obligatory to do this planning for fire-fighting vehicles to be able to respond to fires in the most efficient way.

Apart from the areas where can be responded by vehicles at the present equipment pool within the critical response time, to remote villages where responding is not possible within this time period by the squads should be responded early by providing distribution of water tanks to people in charge who are watching for fires for 24 hours of a day within the area of responsibility since they have authority to respond without waiting for a directive at the time of fire; in this way, the planning should be ensured to reach its goal. Also, because of the importance of watchtowers on locating possible fires at risky areas, camera surveillance systems with suitable sensitivity should be installed. Additionally, alternatives such as improvement of road networks of the area and increasing the average travel speed by improving road standards should definitely be evaluated to be able to provide on-time arrival at the areas where cannot be reached within the critical response time. It should be remembered that forest fires and fire losses can be reduced to minimum level by raising awareness among local community in terms of continuity of forest presence and sustainable forestry activities, considering that the main reason of forest fires is mostly the human factor, and by conducting coordinated and effective practices. Possibilities of changing forest areas with high fire risk into protected areas should be evaluated when it is necessary on fighting against forest fires. Within the plans to be prepared by Forestry Administration, number of ponds that are used on extinguishing fires and are located within the borders of the directorate should be increased. Furthermore, importance of planning location and number of fixed observation points well, equipping them with advanced communication tools and the forest being watched by mobile squads consistently on early response should not be forgotten.

Consequently, it should be emphasized that success of people working at forest management on fire-fighting should be appreciated, that, however, despite the developments in recent years, current situation was not enough in terms of equipments, trainings, precautions and management organization; and that first respond success should be increased by doing an efficient planning regarding to an efficient response to the fire within the frame of the opportunities provided by advancing technology on these aspects. This is extremely important on reducing the fire losses by decreasing the first respond time. Also, to be able to overcome forest fires with minimum losses, it would be beneficial for forestry and economy of our country to improve and spread this practice, at which an efficient planning had been done aiming at early responding, to other fire-sensitive regions as well.

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FOREST ROAD RETAINING TECHNOLOGIES ON DIFFICULT SLOPES IN JAPAN

Mika YOSHIDA[1*], Hirofumi TAKAHASHI[2], Hideo SAKAI[2]

[1]Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, 305-8577 Ibaraki, Japan. Tel: +81-3-5841-5205, E-mail: mika.science98@gmail.com
[2]Grad. Sch. of Agric. and Life Sci., The Univ. of Tokyo, 113-8657 Tokyo, Japan.

ABSTRACT

In Japan, soft and sandy soils and steep slopes were native problems and usually caused difficulties in forest road construction. In addition, there were many crushing zones in mountainous forested area, and underground water often sprung out from stones and rocks in these crushing zone. This underground water often caused road degradation and should be drained. Some forest road retaining technologies had been introduced recently for stabling spur roads. One was L-shaped steel retaining wall technology called L-shaped mesh wall. It was easy to construct and underground water could be drained easily. The other was reinforced soil wall using thinned logs and geotextile called TK wall. The bearing capacity and usage of these technologies were analyzed. L-shaped mesh wall was effective when applied to cross the short section of crushing zone. TK wall was easy to construct on steep slopes with narrow clearing width for roadway by its perpendicular filling slope, and provided environmental friendly landscape with recovered vegetation from the seed contained at surface as well as using thinned woods. Both technologies made easier to construct spur roads on slopes with soft soils but it was clarified that they needed appropriate drainage systems and their regular maintenance for economical use.

Key words: Crushing zone, forest road retaining, L-shaped steel retaining wall, reinforced soil wall

1. INTRODUCTION

In Japan, soft and sandy soils and steep slopes were native problems and usually caused troubles for forest road construction. In addition, there were so many crushing zones in mountainous forested area, and underground water sometimes sprung out from stones and rocks in these crushing zone. This underground water often caused road degradation.

Apart from main forest road which had the function as a public road in a region, spur roads constructed mainly for the purpose of forestry use were required to be cheaper and stout. Such spur roads in Japan must be constructed with low cost by harmonizing terrain, and also be endurable for the repetition of traffics (Japanese Forestry Agency 2010). Therefore, road structures were fundamentally made by only earthworks, and retaining structures could be used only for unavoidable reasons such as terrain, geology, and soil. Some forest road retaining technologies has been introduced recently. Two retaining technologies could be available for this research from actual forestry field. One was L-shaped steel retaining wall technology, whose product name was L-shaped mesh wall. It was easy to construct and underground water could be drained easily. The other was reinforced soil wall using thinned

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logs and geotextile, whose product name was TK wall. These technologies are discussed from the points of terrain, bearing capacity, future possibility, and the way of effective introducing to low volume road.

1.1. Merits of reinforced soil wall and retaining wall

Reinforced soil wall by laying structural reinforcement in the filling could compensate tension resistance force and shearing resistance force which lacked when constructing only by earthwork. It realized the force balance like retaining wall against soil pressure which worked on the wall standing nearly vertical (Osaka National Government Building 2005). In the conventional forest road construction, volume of earth work increased as steepening slopes. Reinforced soil wall could save the volume of earth work on steep slopes because it enabled narrow clearing width for roadway (Tatsuoka 2005), which would reduce land collapse caused by road construction. As slope gradient of reinforced soil was nearly perpendicular, the height of filling and cutting slopes could be lower by adjusting formation of the road. Reinforced soil wall also would reduce the construction cost by utilizing soil and rocks obtained at sites.

Retaining wall was also constructed nearly vertical, and would reduce earthwork by overhanging on valley side and by lowering the height of cutting, which enabled to construct narrow clearing width for road making. When crossing the crushing zone by simple structures, quilt basket or retaining wall were effective because the weight of stones and rocks in the structure pressed down the road foundation with high water permeability. These advantages would realize stable forest road construction (Figure 1).

Especially in Japan, trees in planted forest were getting matured and it was predicted that forestry vehicles would become larger and larger. Therefore, it was necessary to utilize road width efficiently especially at the outside of curves in front of valley by strengthening filled bank (Figure 2). These technologies were effective and furthermore provided environmental friendly landscape with recovered vegetation from the seed contained at surface.

Figure 1. Retaining wall (L-shaped steel retaining wall) crossing crushing zone

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Figure 2. Retaining wall (L-shaped steel retaining wall) utilizing road width efficiently

2. MATERIAL AND METHODS

2.1. L-shaped steel retaining wall

A L-shaped steel retaining wall technology, whose product name was L-shaped mesh wall developed by Nippon Steel & Sumikin Metal Products Co., Ltd. in 2010, was investigated (Figure 1) (Takahashi *et al.* 2015a). It was easy to construct and underground water could be drained easily (Nippon Steel & Sumikin Metal Products Co., Ltd. 2011). The structure was composed of L-shaped stiffening steel mesh and horizontal steel mesh which reinforced tensile strength and to prevent deformation of wall (Figure 3). It was not designed as reinforced soil wall, but it realized the effect of reinforced soil wall by increasing bearing capacity of filling. The weight of filled soil secured its stability as the cage filled with stone. The difference between the L-shaped mesh wall and the cage was, however, the latter deformed easily when using soil on site whereas the former could be pressed rolling without deformation. The former one was also easy to recover the vegetation on the surface by greening sheets which contained seeds. The permeability of the L-shaped mesh wall had been investigated, and confirmed the high permeability. When the height of wall high, it could save cutting volume by combining with cart frame (Nippon Steel & Sumikin Metal Products Co., Ltd. 2011).

The weight of 2 m^2 elements of the L-shaped mesh wall is 21.9 kg, and the 5.1 kg of horizontal mesh, so that it is easily constructed by only manual power using soil on site (Nippon Steel & Sumikin Metal Products Co., Ltd. 2011). Labor productivity per 10 m construction was said to be 0.05 men as a manager, 0.7 men for assembling, 0.4 men for back-filling. The productivity of machines were 1.1 hours for backhoe operation with bucket volume 0.28 m^3, and 0.09 days for ramming (Nippon Steel & Sumikin Metal Products Co., Ltd. 2011). The L-shaped mesh wall had been introduced in 36 forest roads at all over Japan till June 2012 from hearing investigation.

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Figure 3. Structure of L-shaped mesh wall

2.2. Reinforced soil wall

A reinforced soil wall using thinned logs and geotextile (Figure 4) was also investigated (Takahashi *et al*. 2015b). Its product name was TK wall which developed by KIC Co., Ltd, Maedakosen Co., Ltd., and Ishikawaken-mokusakupaneru-kyogikai (Ishikawa Prefecture Federation of Forest Owners' Associations 2011) in 2003. The structure of TK wall was the combination of L-shaped outer frame and the wall by diagonal brace frame which utilized thinned logs. Polyethylene geotextiles winded them as shown in Figure 4. The geotextile in the filling made the resist force of shearing strong, and would be integrated into the soil resulting in stabilization of road bed. The thinned logs in the soil would be rotten soon, but the durability of structure would be maintained by its self-strength and few tensile elongation of geotextile. The first merit of this system was to lead the increase of effective utilization of thinned logs.

Figure 4. TK wall before use

2.3. Bearing capacity

The bearing capacity of the road surface was investigated to confirm the strength of these new technologies using simple measuring instrument, CASPOL made by Marui Co. Ltd. (Osaka National Government Building 2005), and CBR（California Bearing Ratio） values were collected. Measured points were mountain side ruts, valley side ruts, center of both ruts, and shoulders on a line crossing the road (Takahashi *et al*. 2014). Measured roads included brand-new sections which had not been in service previously, so that the medium class logging trucks with the distance between tires in 200 cm were assumed. The number of samples was designed to be nearly same among straight sections, and beginning, center, and end of curves.

At each point, three to five times were measured, and the average value of them was used to analyze.

2.4. Investigated sites

2.4.1. L-shaped mesh wall

The L-shaped mesh wall was investigated in a section of 1,853 m of the forest road constructed in 2012 at Seki city, Gifu Prefecture. The road was used for thinning extraction and patrols after thinning. Road width was 4.4 m unpaved, and soil type was sandy gravel. There existed welling of water at 11 points and some of them were applied culverts. The L-shaped mesh walls were prescribed at 6 points which were considered crossing crushing zone (Figure 5). The crushing zones had both usual and temporal water flows. Total prescribed length was 83.0 m. The purpose of introducing L-shaped mesh wall was to secure stability of road bed by the weight of structure and to drain water by the high permeability (Figure 1). The contractor X constructed the beginning part of 1,040 m including four L-shaped mesh walls, and the contractor Y did the next 800 m including two L-shaped mesh walls.

Figure 5. An example of crushing zone and welling water where L-shaped mesh wall was prescribed

2.4.2. TK wall

The TK wall was investigated at a forest road located at Kaga city, Ishikawa Prefecture (Figure 6). It was constructed from 2010 to 2012 and the length was 557.4m including the section of TK wall in 192.2 m. Pavement was sat mingled with gravel. The section constructed in 2010 was already in service but the section constructed in 2011 and 2012 was not used previously. The road width was 5.3 m and soil type was gravely soil. The TK wall was applied where the height of filling exceeded 2 m.

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Figure 6. Investigated section where TK wall was prescribed

3. RESULTS AND DISCUSSION

3.1. L-shaped mesh wall (L-shaped steel retaining wall)

Between two contractors X and Y, the average mountain slope was 38.3 and 39.4 degrees where the L-shaped mesh walls prescribed, and 30.4 and 34.4 degrees where L-shaped mesh walls not prescribed, respectively. The sections of the L-shaped mesh wall were steeper. Although they were applied when crossing crushing zones, they were also introduced at the steep sections because of keeping the filling minimum effectively.

In the sections of L-shaped mesh wall, the CBR values of the contractor X on mountain side ruts and valley side ruts were about 15 to 25 %, and those of the contractor Y were 15 to 20 %. The CBR values of both mountain side and valley side ruts were the highest, and those of center of both ruts followed, and the median of those of shoulders was lower at 15 % and 8 % for the contractors X and Y, respectively.

In the sections of non L-shaped mesh wall, the CBR values for contractor X were 25 - 35 % at mountain side and valley side ruts, and those of contractor Y were 15 to 25 %. Contractor X usually realized higher values because they were a beginner and seemed to intend to pay attention. Those of shoulders were 13 to 14 %, which were lower than those of road inside. As the compaction was emphasized on the carriage way, the CBR values of shoulders were lower.

The CBR values except shoulders which showed lower values were shown in Figure 7. In the section of contractor X, the CBR values without L-shaped mesh were significantly higher than those with L-shaped mesh. On the other hand, there were no significant differences in the section of contractor Y, and the CBR values without L-shaped mesh were similar as those with L-shaped mesh in the section of contractor X. The depth of L-shaped mesh was 1 m and the height was 1 m, so that the area directly affected on the bearing ratio was 1 m from the filling surface (Figure 3). Thus, the CBR values with L-shaped mesh were not necessarily to be high, because filling slope and road bed was stable by the L-shaped mesh wall and the minimum bearing force was secured.

Contractor X took charge of the steep section located on a concave slope at the valley head where land slide would occur. Indeed, the L-shaped mesh walls were prescribed at the both ends of this section, but it was not prescribed at the middle of the section, where two cracks were found at the shoulder of filling. As soil was mainly poor cohesive sandy gravel, it seemed difficult to achieve sufficient compaction. It was pointed out that the concave slope at

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the valley head was dangerous area to construct roads (Oohashi 2011, 2012). The crack might be partly caused by rain water flow, and the maintenance was difficult and the road would collapse in the future in the worst case. It is difficult to construct L-shaped steel retaining wall, reinforced soil wall, and even concrete retaining wall if the base is thus unstable. Therefore, soil, geology, and terrain should be noted carefully prior to route location, and furthermore drainage was also the most important.

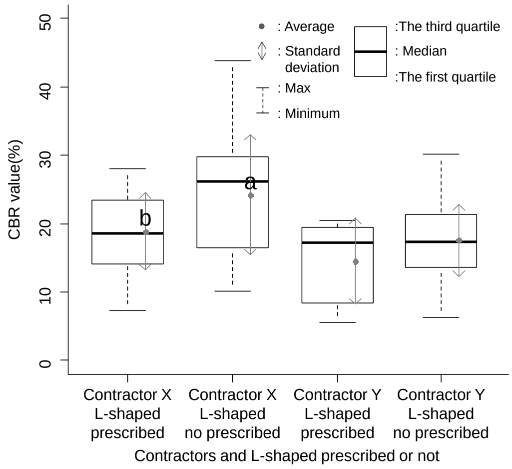

Figure 7. Relationships of CBR values between contractors where prescribed L-shaped mesh wall and not prescribed (Takahashi *et al.* 2015a) (Note: There is 5 % significant difference between "a" and "b")

3.2. TK wall (Reinforced soil wall)

The average slope of the TK wall was 38.2 and 35.0 degrees prescribed or not, respectively, and differed significantly. Thus, the TK wall was applied to the steeper slopes which would bring much volume of filling.

In case of both TK wall prescribed and not, there existed significantly different CBR values between the group of mountain side and valley side ruts and center of both ruts, and shoulders (Figures 8 and 9). The CBR values of carriage surface were even and higher than those of shoulders. The relationships between TK wall prescribed or not and the CBR values except shoulders were shown in Figure 10, and there was no significant difference. This meant that roads were constructed to realize enough bearing capacity in all sections.

Road surface erosion occurred at the investigated site regardless of the TK wall existed or not. The CBR values tended to be smaller by the road surface erosion at mountain and valley sides ruts (Figure 11), and there was a significant difference between with and without erosion. This reason was considered that the compacted surface was run off by the erosion and that water penetrated into road bed and weakened the bondage force among soils. Once a rut formed, water was concentrated, and the eroded weak part was easily damaged by erosion force. Even in the section with TK wall, it was recognized that the drainage facilities to prevent surface erosion and early restore were fundamentally important.

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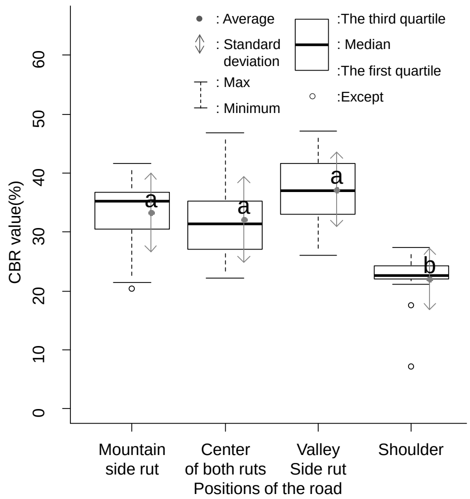

Figure 8. Relationships between positions of the road and CBR values where prescribed TK wall (Takahashi *et al.* 2015b) (Note: There is 5 % significant difference between "a" and "b")

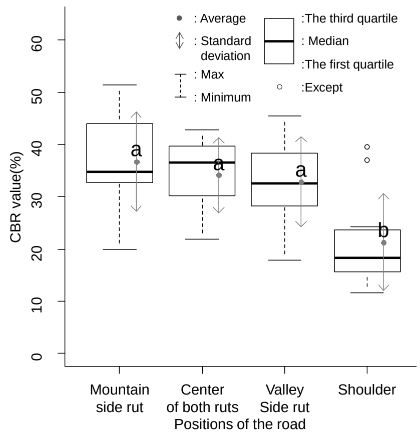

Figure 9. Relationships between positions of the road and CBR values where did not prescribed TK wall (Takahashi *et al.* 2015b)(Note: There is 5 % significant difference between "a" and "b")

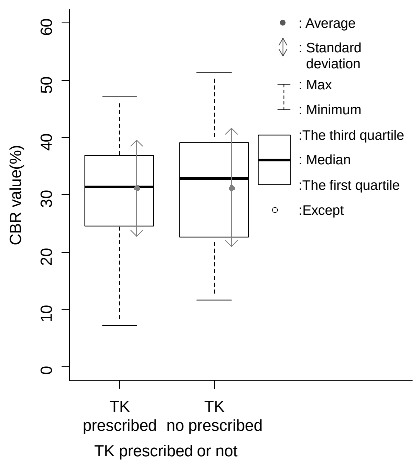

Figure 10. Relationships of CBR values between TK wall prescribed and not (Takahashi *et al.* 2015b).

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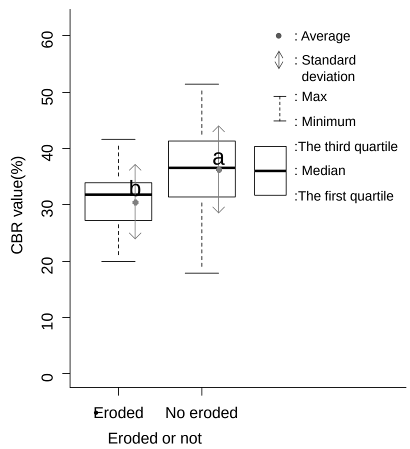

Figure 11. Relationships of CBR values between eroded and not eroded (Takahashi *et al.* 2015b) (Note: There is 5 % significant difference between "a" and "b")

4. CONCLUSION AND SUGGESTION

From the results, the L-shaped mesh wall had stable bearing capacity and permeability, and it was effective with its weight to cross small sized crushing zone which sometimes caused land slide. Reinforced soil wall could also save earth work on steep slopes and increase flexibility of route location. It was, however, necessary for securing sustainable bearing capacity to locate enough drainage facilities. Actual forest roads tended to suffer unexpected situations such as heavy rain and spring water, and sometimes erosion after finalized. Therefore, road maintenance especially on drainage systems was important to keep these structure effective. By using forest road repeatedly for long time, the construction cost would be negligible as well as by adopting the most appropriate roading method according to soil, geology and terrain conditions.

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* In Japanese and titles were tentative translation by the authors.

** In Japanese with English summary.

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COMPARISON BETWEEN ICONA AND CORINE METHODS IN DETERMINATION EROSION RISK POTENTIAL

Mahmut REIS*[1] Nursen BOLAT[1] Hurem DUTAL[1] Gamze SAVACI[2]

[1]Kahramanmaras Sutcu Imam University, Faculty of Forestry, Department of Forestry Engineering, 46060 Kahramanmaras, Turkey. Tel: +90 344 2801738 Fax: +90 344 2801961
E-mail: mreis@ksu.edu.tr*
[2]Kastamonu University, Faculty of Forestry, Department of Forestry Engineering, 37000 Kastamonu, Turkey.

ABSTRACT

Turkey is among the countries influenced by erosion due to its topography, climate and soil properties. Erosion susceptibility must be determined for avoiding erosion and reducing direct and indirect problems arising from erosion. Various erosion risk analysis method was developed by using remote sensing (RS) and geographic information systems (GIS). Parameters used in these methods are more or less different from each other. In this study, erosion risk of Haman Stream Watershed located in Kahramanmaras city was evaluated by using CORINE (CooRdination of Information on the Environment) and ICONA (Institute for the COnservation of the NAture) models and then compared with each other. According to results, 23,22% and 76,78% of the area was subject to medium and high erosion risk respectively in CORINE model, while 91,77% was subject to high erosion risk in ICONA model. Differences in erosion risk ratio of the models result from parameters used in each model. Results obtained from models share similarity that the better part of watershed has high erosion risk. Soil protective measures should be taken in the watershed especially in agricultural area with high slope and rangeland which have high erosion sensitivity.

Key words: ICONA, CORINE, soil erosion, GIS

1. INTRODUCTİON

Soil erosion is weathering and transportation of soil, and then deposition of it elsewhere with the effect of one or more factors (precipitation, runoff, wind, incorrect land use techniques, etc.) caused by natural or human (Boardman and Poesen, 2006). Sedimentation always exists in nature. But, incorrect land managements and practices in upstream increase severity of natural erosion. Forest area reduction, extreme and planless grazing, incorrect soil tillage systems and nonscientific agricultural practices are examples for practices accelerating soil erosion (Pimental, 1998).

Over the last 40 years, about 1/3 of the arable area in the world was lost by losing over 10 billion hectares for each year, due to soil erosion which is widespread and very important environmental threat for terrestrial ecosystems in the World (Pimental and ark., 1995). In the roughly 1/3 of OECD countries, over 20 % of agricultural lands are exposed to erosion ranging from medium to high severity (OECD, 2008). Degradation often occurs in the Mediterranean countries with the effects of climate, geomorphological changes and human activities, and it in especially high stress zones (arid and semi-arid) may result in desertification (Lo´pez-Berm´udez, 1993). Erosion, as experienced in some region of the World, is one of the most important ecological problems threatening natural resources in Turkey also. According to sediment measures performed in 26 large watersheds, sediment amount transported to sea and lakes is about 50 billion ton per year (Dogan et al., 2000). Sedimentation leads to great damages in particularly catchments. There is a strong relationship between economic life of a dam and soil erosion. Therefore, erosion is one of the natural factors which plays important role in planning phase of any dam project. Vegetation, fauna, sedimentation and dam life are also influenced by erosion. So, erosion must be considered in analyzing valuable area (Sahin and Kurum, 2002). For these reasons, areas that are exposed to erosion must be determined, and proper protection measures must be taken (Mitra et al., 1998). However, researchers experience immense difficulties in calculating relationship between erosion and factors affecting erosion, because erosion is a complex phenomenon involving effects of wide range of factor. Soil erosion risk and prognosis maps are often used in action plan with regard to soil protection. Especially in Europe, demand for these maps quickly increase in concept of water frame directive. Soil erosion risk and prognosis map are generally produced by using models (Prasuhn et al., 2013). Various models including USLE (Universal Soil Loss Equation) (Wischmeier and Smith, 1978), RUSLE (Revised Universal Soil Loss Equation) (Renard et al., 1997), EPİC (Erosion Productivity Impact Calculator) (Williams, 1985) and WEPP (Water Erosion Prediction Project) (Flanagan and Laflen, 1997) have been developed to evaluate soil erosion (Sun et al., 2014). In order to predict soil loss, USLE' (MAPA/ICONA, 1983; MOPU, 1985) is commonly used model which was developed in USA for predicting soil loss resulting from agricultural activities. Generally, models evaluating soil erosion are divided into 2 groups: quantitative (USLE, MUSLE etc.) and qualitative models (ICONA, CORINE etc.). Quantitative models generally include measurements and calculations relating to various components. On the other hand, qualitative models are based on certain provisions and analytical analysis. But it is important that these provisions and analysis must comprise systematic and universal approaches (NRA, 1993). Each model has typical parameters. İn countries where erosion is one of the great problems and necessary data used in some erosion models are insufficient, obtaining data needed is a both costly and time-consuming process. So, data preparation for any models is significant. In this study, erosion risk maps were generated by using CORINE and ICONA models for Haman Stream Watershed located in Kahramanmaras city, and model results were compared each other.

2. MATERIAL AND METHODS

2.1. Study area and GIS data

Haman stream watershed whose area is 1216.34 ha falls within 36° 53' 56" -36° 56' 46" East longitude and 37° 40' 50" - 37° 39' 15" North latitude, and 40 km away from Kahramanmaras city (Figure 1). Elevation ranges from 600 m to 1870m, while slope ranges from 0 % to % 34 in the study area. Annual average precipitation and temperature values are slightly over 700 mm and 16.7 °C, respectively. Maximum temperature is 45.2 °C (July), while minimum temperature is –9.6 °C (February) in study area (GDMS, 2010). Study area is dominated by forest ecosystem, bare areas, shrubs areas, grasslands and agricultural systems (fallowing and plantation). Study areas has ($C_2B_3{}^{'}s_2a^{'}$) sub-humid, mesothermal and large water deficiency in summer climate type according to thornthwaite climate classification. Study area is located

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in Mediterranean floristic zone which is one of the 3 major floristic zones in Turkey (Ansin,

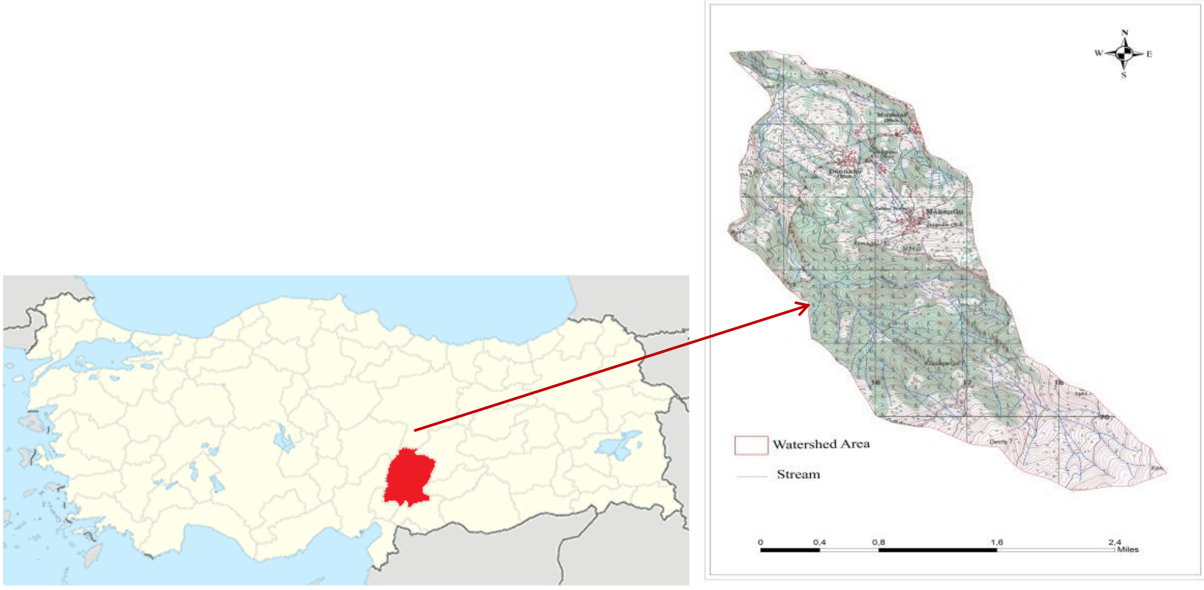

Figure 1. Study area Location in Topographic map and satellite image.

1983). In study area, woody, herbaceous and shrub vegetation exist. Dominant forest tree species are taurus cedar (*Cedrus libani*), oak (*Quercus brantii),* calabrian pine (*Pinus brutia*) and juniper (*Juniperus sp.)* in study area. Especially, juniper (*Juniperus sp.)* stands have been under intensive destruction.

In this study, 1/25000 scale topographic map falling within GM37c2 plot was used as base map and was digitized. In order to determine geological properties of study area, 1/25000 scale digitized geology map produced by General Directorate of Mineral Research Exploration was used. Landsat 5 TM satellite image dated 20 August 2011 was used for determining vegetation coverage properties (Normalized Difference Vegetation Index, NDVI). Land use map was generated by using supervised classification method in Erdas Imagine 9.1. Soil depth and stoniness values were obtained from 1/25000 scale soil maps.

2.2. Method

2.2.1. ICONA model

Generating erosion risk map by using ICONE model consists of 7 phases (Figure 2). In the first phase, slope map is produced by using DEM in ArcGIS 10 environment, and then it was classified as Flat and gentle (0-3%), Moderate (3-12%), Steep (12-20), Very steep (20-35%) and Extreme (>35%). In the second phase, in order to generate lithosphere map, geology map was used. Then lithosphere map was classified in 3 groups by taking geological formation into consideration. İn the third phase, slope map was overlaid with lithosphere map to obtain soil erodibility map. In the fourth phase, Normalized Difference Vegetation Index (NDVI) whom topographic and atmospheric corrections were made was used for determining vegetation condition. NDVI was produced by using Band 4 and Band 3 of Landsat TM 5, and it is calculated by formula:

$$NDVI= (Band\ 4- Band\ 3)\backslash (Band\ 4+ Band\ 3) \quad (1)$$

where; Band 4: near infrared (NIR), Band 3: red (R)

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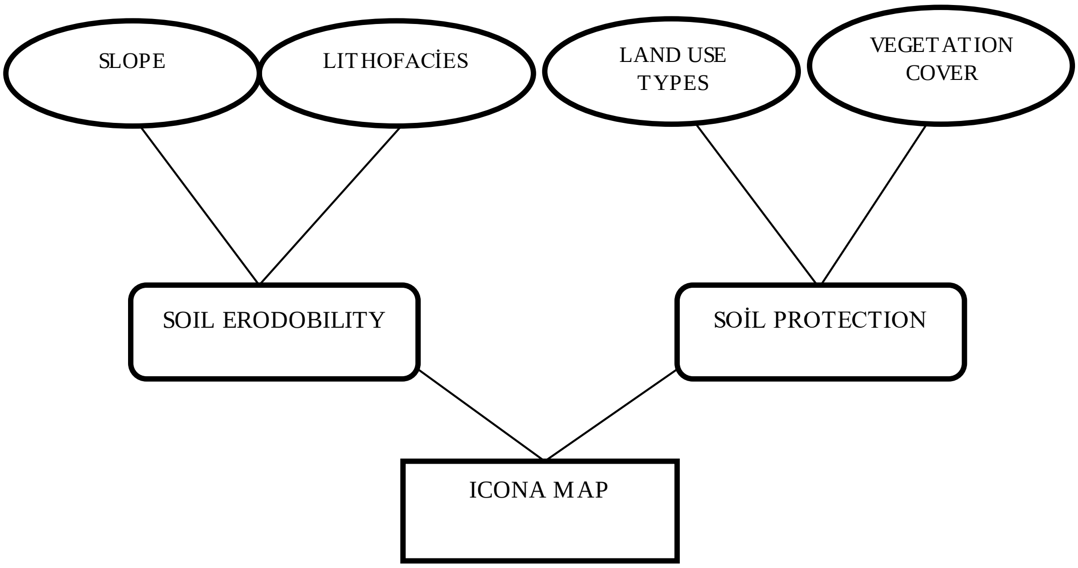

Figure 2. ICONA model phase (ICONA, 1997)

In determining land use that is fifth phase of the model was performed by using Supervised Classification in ERDAS IMAGINE 9.1(ERDAS, 2001) software. In the sixth phase, soil protection map was produced by overlapping vegetation map (NDVI) with land use map in ArcGIS 10. In the last phase of model, ICONA erosion risk map was generated by overlapping soil erodibility map with soil protection map.

2.2.2. CORINE model

In the CORINE methodology, soil texture was classified into three classes including slightly erodible (1), moderately erodible (2), and highly erodible (3) (Figure 3). Soil maps were used in order to classify soil stoniness and soil depth, which are important indicators of erosion. The stoniness was classified as fully protected (1) and not fully protected (2) soils, by considering the percentage surface cover of stones. The soil depth, which is the depth from the soil surface to the base of the soil profile, was classified as slightly erodible (1), moderately erodible (2), and highly erodible (3) soils. Finally, the soil erodibility index was calculated by multiplying these three soil factors (CORINE, 1992; Bayramin *et al.,* 2003; Aydın and Tecimen, 2010) and reclassified into classes of low (1), moderate (2), and high (3).

Erosivity factor can be defined as detachment and transportation of soil due to raindrop impact and runoff (Lal, 1994). The erosivity was calculated based on two climatic indices; the Fournier index and Bagnouls-Gaussen aridity index (BGI). Fournier index was used to measure erosivity at a regional scale (Fournier, 1960). The Fournier index (MFI) was then modified by Arnolds (1980) considering total precipitation in a month (P_i) and total mean annual precipitation (P_a) (Arnolds, 1980; Sadeghi and Tavangar, 2015):

$$MFI = \sum_{i=1}^{12} \frac{P_i^2}{P_a} \quad (2)$$

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The MFI was classified into five classes including very low (1), low (2), moderate (3), high (4), and very high (5). Since the MFI could not consider the moisture stress, the BGI was used as the second climatic index to consider moisture stress, which may increase the soil erosion due to reduction of vegetation cover. The BGI is computed as a function of the temperature and precipitation (Arnolds, 1980):

$$BGI = \sum_{i=1}^{12} (2T_i - P_i)k_i \quad (3)$$

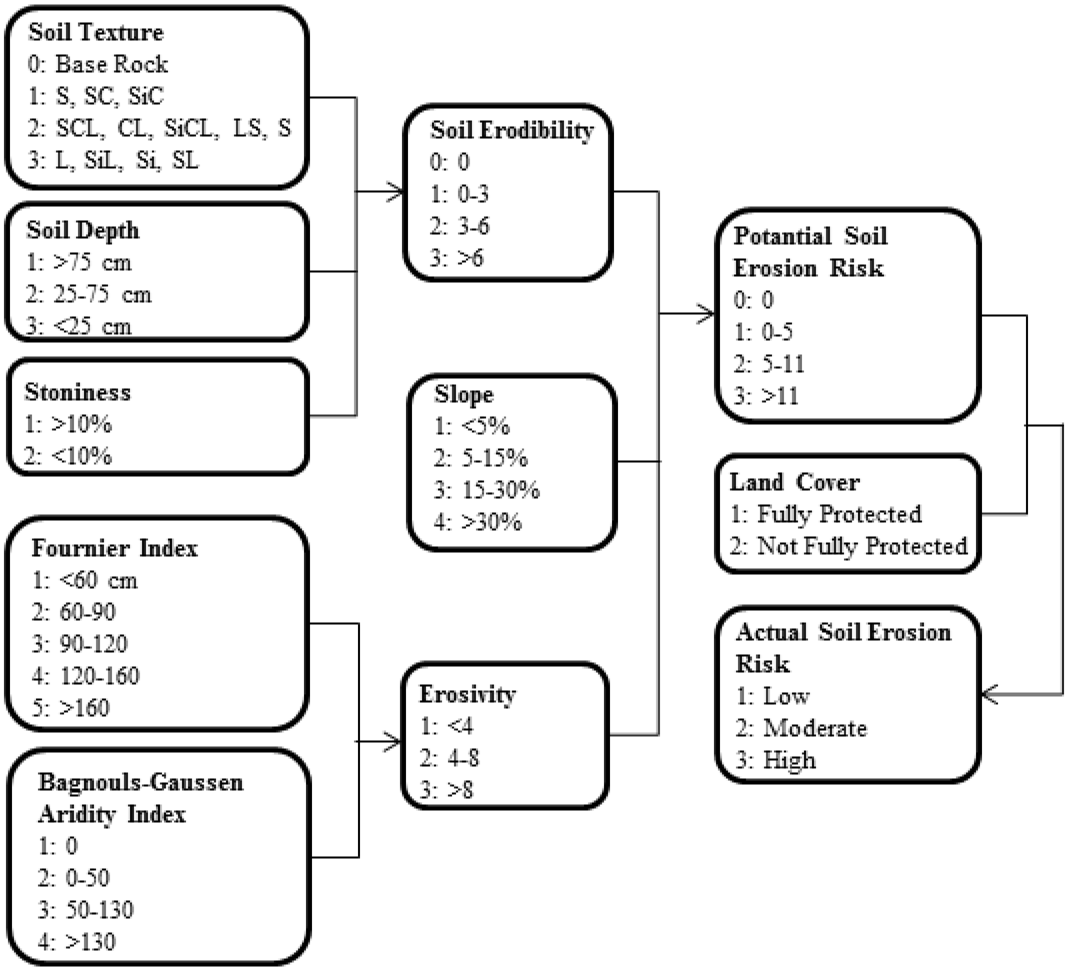

Figure 3. Flow diagram of the CORINE methodology (C: Clay, S: Sandy, Si: Silt, L: Loam)

Where T_i is the mean temperature for the month, P_i is the total precipitation for month, and k_i is the proportion of the month during which $2T_i$-P_i> 0. The BGI was classified into humid (1), moist (2), dry (3), and very dry (4). Finally, erosivity index was determined by multiplying Fournier and Bagnouls-Gaussen aridity indices. The input data of precipitation and temperature were obtained from the nearest weather station in Kahramanmaras for the period of 1985-2010. Finally, erosivity index was reclassified into low (1), moderate (2), and high (3) (Figure 3).

In CORINE methodology, the topographic factor (slope) is one of the key factors in estimating erosion. The topographic factor was defined as the average regional slope, which

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was mapped in ArcGIS 10 based on topographic maps derived DEM. Then, the slope data layer was classified into four classes according to the CORINE methodology: very gentle to flat (1), gentle (2), steep (3), and very steep (4).

In this study, a land cover map was generated using a Supervised Classification method of ERDAS Imagine 8.3 based on LANDSAT TM imagery acquired in August 2009. In classification process, the parallelepiped non-parametric and minimum distance parametric rule was used, and the image was classified into available land cover types in the study area. The accuracy of the classification was evaluated based on stratified random sampling method where 256 points were automatically selected from referenced topographic map and air photos. Finally, the classified land cover image was recoded into two classes; fully protected (1) and not fully protected (2) as suggested by the CORINE methodology.

After computing four main parameters including soil erodibility, erosivity, topography (slope), and land cover, potential soil erosion risk of the study area was determined by multiplying soil erodibility, erosivity, and slope indices and then mapped in ArcGIS 9.2 software. The potential soil erosion risk was classified into four classes: no erosion (1), low (2), moderate (3), and high (4).Then, the land cover factor was integrated with the potential soil erosion risk to find actual soil erosion risk. Finally, actual soil erosion risk map was generated and classified into three classes: low (1), moderate (2), and high (3).

3. RESULTS AND DISCUSSION

3.1. ICONA model

It was determined that 96.34 % of study area was included in steep and very steep classes, according to slope map (Table 1).

Table 1. Distribution of slope classes in the study area

Slope Classes		Area	Percent (%)
Flat and gentle	0-3 %	15.00	1.23
Moderate	3-12 %	29.56	2.43
Steep	12- 20%	99.34	8.17
Very Steep	20-35 %	478.86	39.36
Extreme	> 35 %	593.58	48.81
TOTAL		**1216.34**	**100**

Lithofacies map of the study area was produced using geology map as database. More than half of study area comprised of loose, non-cohesive sediments and detritic materials (Table 2). Soil erodibility map was produced by overlapping slope map with lithofacies map. When obtained map was evaluated, areas where soil erodibility was very low and low were located in streambed and relatively low slope area. Soil erodibility risk was very low, low and medium in 17.89% of study area, while it was high and very high in 82.11% of study area (Table 3). Study area was susceptible to erosion, as great part of study area comprises loose sedimentary rocks. Land use map was classified as Dry Farming, Ligneous Crops, Forest, Range, sparse shrub by performing supervised classification (Table 4).

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Tablo 2. Lithofacies classes of study area

Lithofacies Classes	Area (ha)	Percent (%)
(a) Non weathered compact rock, strongly cemented conglomerates or soil, crusts, hard pans outcrops (massive limestone, highly stony soils, igneous or eruptive rocks, locally crusted soils).	421.43	34.64
(d) Soft/low resistant or strongly/deeply weathered rocks (marls, gypsum, clayey slates, etc.) and/or soils.	162.38	13.36
(e) Loose, non cohesive sediments/soils and detritic materials	632.53	52.00
TOTAL	**1216,34**	**100**

Table 3. Soil erodibility classes of study area

Soil Erodobility Classes	Area (ha)	Percent (%)
Low (EN)	12.35	1.01
Moderate (EB)	36.33	2.99
Medium (EM)	168.97	13.89
High (EA)	304.84	25.07
Extreme (EX)	693.85	57.04
TOTAL	**1216,34**	**100**

Table 4. Land use type in study area

Land Use Classes	Area (ha)	Percent (%)
Dry Farming	380	31.24
Ligneous Crops (olive, almonds,fruit,trees,vineyards)	30	2.47
Forest	576.24	47.37
Range, sparse shrub	230.1	18.92
TOTAL	**1216.34**	**100**

NDVI map was classified in 2 groups as vegetation cover <25% and >25-50%. When examined the Table 5, a major part of study area was involved in initial group.

Table 5. Distribution of NDVI value in study area

Vegatation Cover Coverage	Area (ha)	Percent (%)
Less than 25 %	621.72	51.11
25-50 %	594.62	48.89
TOTAL	**1216.34**	**100**

Soil protection map was produced by overlapping land use map with NDVI map. According to soil protection map, 68.57% of study area has very low and low soil protection value, while 31.43% of it has medium value (Table 6). Although 47.37% of study area was forest; vegetation coverage in the forest was very low. Vegetation coverage is the main factor forming relationships among precipitation, infiltration and flow, and playing role in effect of raindrop on surface (Cürebal and Ekinci 2006).

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Table 6. Soil protection status of study area

Soil Protection Classes	**Area (ha)**	**Percent (%)**
Medium (M)	382.32	31.43
Low (B)	215.55	17.72
Very Low (MB)	618.47	50.85
TOTAL	**1216.34**	**100**

Briefly, role of land use and vegetation coverage was very important. Vegetation decrease erosivity tendency of soil by decreasing raindrop effect on soil. Erodibility increases in areas where vegetation coverage or litter is nonexistence or very low (Wall, 2003). A great part of study area has vegetation coverage less than 25% and so this condition increases erosion risk in study area. Actual ICONA risk map was generated by overlapping soil erodibility map with soil protection map (Figure 4). According to results, 1.29% of study area was subject to low and very low erosion risk, while 91.77% of it was subject to very high erosion risk (Table 7).

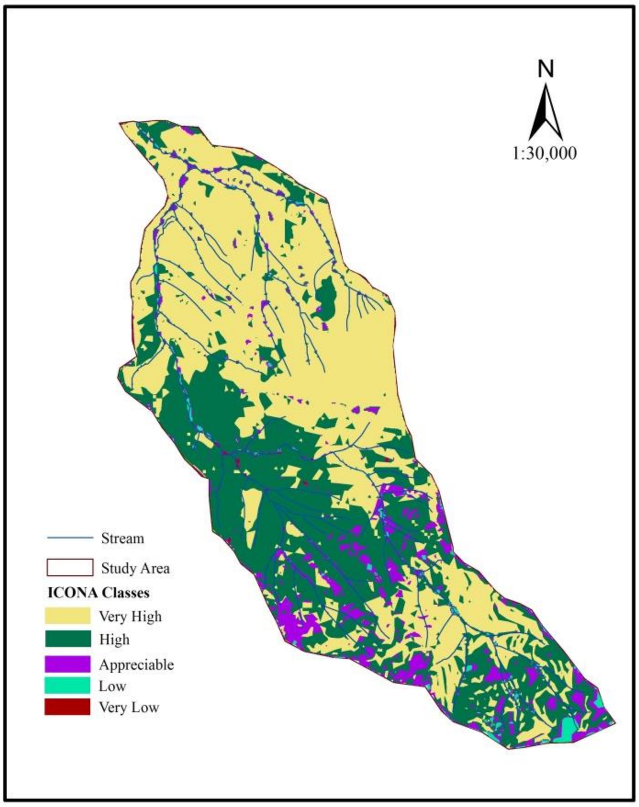

Figure 4. ICONA risk map of study area

Table 7. Erosion risk status of study area

Erosion risk classes	**Area (ha)**	**Percent (%)**
Very High	652.84	53.67
High	463.36	38.1
Appreciable	84.46	6.94
Low	14.24	1.17
Very Low	1.44	0.12
TOTAL	**1216.34**	**100**

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3.2. CORİNE model

According to soil texture results, it was determined that total area covered by high erodible sandy and loamy sand soil was 69.37% of the study area (Table 8). Areas having less than 25 cm soil depths have high erodibility and constitute 61.35% of total area (Table 9). Areas where soil stoniness is less than 10% have high erodibility and constitute 56.85% of study area (Table 10).

Table 8. Texture classes, areas and ratio of soil in study area

Class	Area	(%) Ratio
0 bare rocky	15.30	1.27
1 C, CS, SiC	71.24	5.86
2 SCL, CL, SiCL, LS, S	285.5	23.5
3 L, SiL , Si, SL	844.3	69.37
Total	1216.34	100

Table 9.Deptness classes, areas and ratio of study area soil

Class	Area	(%) Ratio
1 >75 cm (Low)	-	-
2 25-75 cm (Medium)	470.16	38.65
3 < 25 cm (High)	746.18	61.35
Total	1216.34	100

Table 10. Soil stoniness classes, areas and ratios in study area

Class	Area	(%) Ratio
1 >%10 (Low)	524.88	43.15
2 <%10 (High)	691.46	56.85
Total	1216.34	100

Fournier index, in other words rainfall erosivity index was determined as 136.06 for the study area. Because Bagnouls-Gaussen drought index value was calculated as below zero, it was not taken into consideration. In the study area, areas within 0-3% contained %53.32 of total area in terms of erodibility, while those within >6% and within 3-6% contained 35.92% and 10.76% of total area, respectively (Table 11).

Table 11. Erodobilty classes, areas and rations in study area

Class	Area	(%) Ratio
1 Low (0-3)	648.74	53.32
2 Medium(3-6)	130.78	10.76
3. High (>6)	436.82	35.92
Total	1216.34	100

Potential risk map was produced by overlapping soil erodibility, erosivity and slope maps (Figure 5). According to potential risk map, areas whose value are 0-5 % (low risk) constitute 70.83% of total area, while areas whose value are more than 11 % (high risk) cover 29.17 % of total area.

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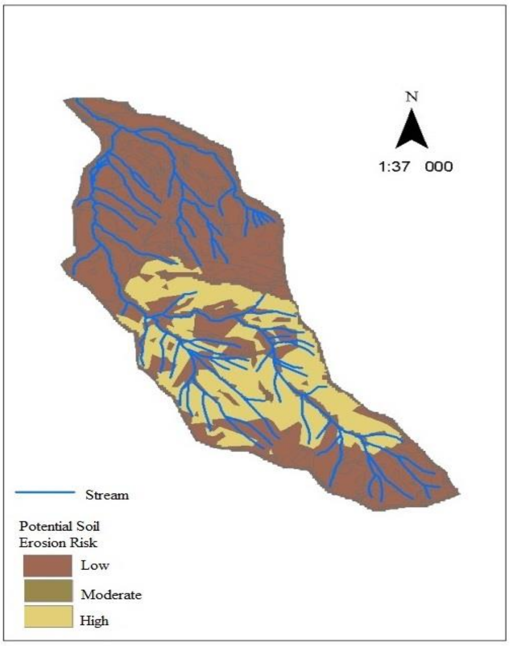

Figure 5. Potential erosion risk map of study area

Actual erosion risk map seen Figure 6 was generated by overlapping potential erosion map, NDVI and land use map produced by using remote sensing technique. According to actual erosion risk map, 23.22 % of study area was subject to medium erosion risk, while76.78 % of it was subject to high erosion risk (Table 12). Bayramin et al. (2005) determined actual erosion risk using same model in Beypazarı-Ankara, and reported that 60 % of the area was subject to very high erosion risk, while only 20 % of the area was subject to low and very low erosion risk.

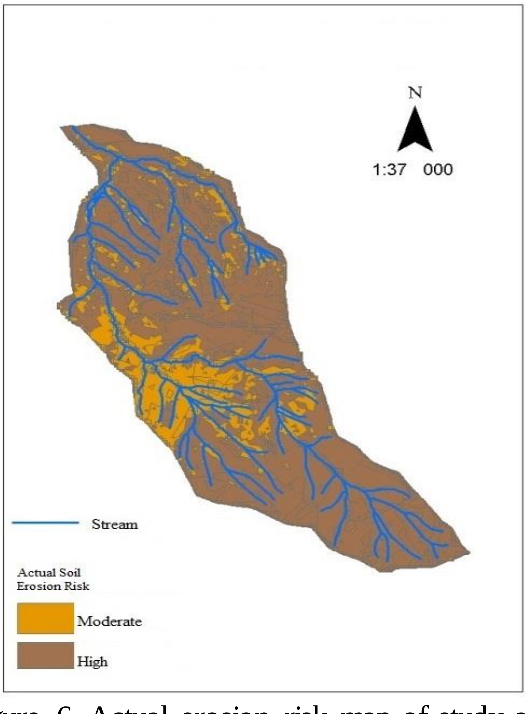

Figure 6. Actual erosion risk map of study area

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Table 12. Potential and actual erosion risk value of study area

	Potential erosion risk		**Actual erosion risk**	
Index values	**Area**	**Percent**	**Area**	**Percent**
1 low	864.07	70.83	-	-
2 medium	-	-	282.42	23.22
3 high	352.27	29.17	933.92	76.78
Total	1216.34	100	1216.34	100

4. CONCLUSIONS

In this study, erosion risk maps was produced by using two erosion risk model namely ICONA and CORINE for Haman stream watershed located in Kahramanmaras city of Turkey, and results obtained were compared each other. According to results obtained from both models, study area was subject to high erosion risk. Areas with high erosion risk generally were located in steep slope and mountainous terrain, rangelands and bare areas. Erosion risk is quite low in streambed and areas with high vegetation. Vegetation, land use, parent material, topographic and climatic properties have considerable influence on erosion.

A major part of study area was subject to high erosion risk in both models. But there are differences between the models resulting from parameters used by the models. For example, erodibility value is determined using slope and lithosphere map in ICONA model, while it is determined using soil texture, soil depth and stoniness values in CORINE.

ICONA erosion risk model is quite useful to evaluate erosion risk in large area. Though ICONA model presents a general erosion risk condition, it is weak point that ICONA don’t use meteorological data (Bayramin et al., 2003). On the other hand, CORİNE model use Fornier index taking average precipitation value of long period in certain area into account. But it is known that total precipitation and monthly or daily maximum precipitation have quite effect on soil transportation.

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ORAL PRESENTATION

SLOPE STABILITY PLANTING MEASURES IN FOREST ROADS AND EXEMPLARY SLOPE PLANTING MODEL

Salih PARLAK

Bursa Technical University, Faculty of Forestry, Yıldırım, Bursa, Turkey.
Tel: +90 224 3003422 Fax: +90 224 3003429 E-mail: salih.parlak@btu.edu.tr

ABSRACT

Just after forest road building, slopes left without any plantation assuming slopes will become covered with natural vegetation. Especially following road building with steep slopes in case insufficient seed or unsuitable seed cast time expected precursor plant succession does not occur or happen late and as a result, slopes exposed to serious soil erosion and soil lost. In later times conditions might be unsuitable for late plantings following the soil lost. If seed cast time and soil conditions are favorable, sometimes natural plant cover can develop and prevent negativities caused by erosion to some degree. Especially in first years after building road slope stability is not secured yet. Things fell or toppled into roads might cause accidents or sometimes shut the road to transportations. Roads with high vehicle traffic or tourism potential is at the earliest should be planted with suitable methods. In this study, for planting principals and prevent likely hazards an exemplary planting model is suggested for lower and upper slopes of roads which must kept always open for transportation like Uludağ Mountain.

Key words: Forest road slopes, Planting model

1. INTRODUCTION

Forest roads are activities that interrupt ecological integrity of field and forest. But a certain amount of road network is needed to carry out forestry activities. During road network planning it must be considered that route may minimal effect of natural vegetation as soon as possible. Principally during excavation, it is should be noticed that keeping cut and fill slopes at minimum is not only economically but also ecologically important. Especially excavation on roads with a steep slope grade, fill and cut slopes cause much more damage on forest vegetation. In addition to this damage, drift of filling material may fill streams and become a damaging element for plant populations on slopes (Figure 1). According to Öztürk, (2010) natural reclamation of these damages may take many decades.

The natural succession may take much more times on fields with inefficient seed source and unsuitable germination conditions. Afterwards attempt for planting may fail due to soil erosion (Figure 1). Snow fighting on forest roads are carried out with graders or snow sweepers. Graders shovels snow to road side, sweeping machines cast away snow to either under side or upper side. During these measurements plants existing on slopes sometimes completely are scratched away by graders or broken by excessive snow accumulation and loss their functions. Locations with busy winter tourism especially need properly and sufficiently planted for preventing soil erosion and keeping visual quality. Öztürk (2010) reports that live material is much more effective than dead material in terms of beauty, efficacy and continuity, and plants on both side slopes of road decrease bump impact.

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Figure 1. Damage caused by forest road construction on steep slope grades

Selection of tree and bush species with a constant height snow shelterbelt (TCK 1998) and in common establishment of snow shelterbelts 20 -25 m. away from road sides (Akdoğan 1972) are convenient in order prevent snow accumulation. Shelterbelts to prevent snow accumulation which may cause traffic accidents should be established by properly planting bush and trees on both sides of road (Öztürk, 2010).

It should be avoided from using a single species in planting, and such species that starts ramifying from above ground, ever green and with a height not taller than 2-3 m resistant to exhaust gases, salt, extreme heat and pruning should be chosen (Koç and Şahin 1999).

Plants to be selected for slope stability should have a sturdy root systems, grow fast and cover soil surface. In order to prevent landslides, it advised in general building support walls made of cement or stones. When these support walls become incapable it is advised planting plants with a deep root system and bushes with extensive branches against stone falling (Altan, 1992).

2. MATERIAL AND METHODS

As a method in the study, road tree plantings have been studied, photographed and discussed. Related articles, periodic and other issued resources have been scanned. Field observations have been carried out, current applications documented and a model has been suggested especially for plantations in newly made slopes.

2.1. Plantation model suggestion

In case heavy snow precipitation and risk of snow mass slide, it is needed a system for preventing motion of snow mass in cut slopes. Where there is risk of snow mass slide, it can be used local natural species for building live barrier. This live barrier could be made of either dwarf and splay species (dwarf and creeping junipers) or local trees planted by interleaving, cut from certain height, thick and highly stable. Live barriers with these features by carrying out the mission of a stake, will stop motion of snow mass, and not easily toppled down thanks to body stability. Plants with thick structure (such as dwarf and creeping junipers, Spanish

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broom and vetiver grass) in order to stop water and mud from filling the road, might be placed on cut slopes (Figure 2).

Figure 2. Model for building a live barrier by cutting top of always green trees

If trees on slopes especially on cut slopes is not cut from certain height and grow a normal tree and loss stability and toppled down towards road due to insufficient soil depth and snow load. Toppled trees will become an obstacle for traffic.

For elimination of danger created by toppled trees on slopes, stability of trees should be maintained. For this purpose, if coniferous species especially trees trunk with monopodial ramification is cut from a certain height vertical growth will stop and increase horizontal growth. In this way, stability will be increased by maintaining root and trunk development and without height increment (Figure 2). Snow height might be a criterion for determining of cut height of live barriers. To continue respiration, cutting height of evergreen trees should be at least two times of maximum snow height in winter. And to keep tree stability tree height should not exceed five times of maximum snow height. At localities with a lesser snow precipitation cutting height should not exceed 5 m.

In cut slopes mix of dwarf junipers species, Spanish broom and creeping bush and tree species like vetiver grass might be used. At localities where there is no snow precipitation but there is risk of mud and rock fall. Planting these species interleaved running water and mud will be stopped and filtered. Dwarf species maintain a natural gradient to forest, prevent direct fall of rain drops onto soil surface. They will cover soil surface and make surface flow of precipitation slower. Precipitation amount, soil type and depth should always be noted in slope plantations. The species adapted to arid localities and successful such as rosemary, Spanish broom, various cactus species, some dwarf and creeping juniper species might be used. According to Cindik and Demirel (2013) Cover ground with plants reduces the kinetic energy of rain drops, reduces surface runoff and wind erosion. Vetiver grass can be used to prevent soil losses on highway slopes and to stabilize slopes since its strong roots and large crown development can reduce soil loss. In order to stabilize slopes on long terms grass and ground covering plants must be used and then this cover should be supported with trees and shrub species. On roads busy in winter and needed to keep open (For example Uludağ Road) salt is spread in order to ease melting of snow. During remove of snow and melting, this salt

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accumulates road sides or in the middle, and affect negatively plant health. Xiea and Jina (2013) report that this spread salt cause pollution and harms plants.

These kind of practices used on road slopes are not only measures against future danger but also forms a defense line against wild fires by decreasing combustible mass. Species chosen to plant on slopes should be selected from species not easily flammable and not containing etheric oils and with a high ignition temperature. Plants containing etheric oils might be preferred if there is low wild fire risk. Due to its resistance against fires and evergreen nature cypresses species are suitable for both localities arid and with snow precipitation.

On road slopes species bearing fruits and hazardous when fell onto road should not be preferred. In particular in case use of species slippery when smashed traffic safety is in danger. In case use of species bearing fruits consumed by wild animals, fox, bear, rabbit and wild hog etc. are threat for road traffic safety and can cause accidents. For this purpose, species bearing fruits might be planted farther from road sides and must be left passages for wild animals. Mol (1986) emphasizes that natural species must be used for road side plantings and these places are important for wild life. At plantation works with trees and bushes having high root potential, loosening rocks and dislodging by plant roots might be dangerous. Therefore, species like plane tree, poplar, eucalyptus should be avoided for plantation at places where there is rock fall risk.

3. RESULTS AND DISCUSSION

On forest roads, the trees with bad stability on upper cut slopes create danger by toppling down toward road. Due to less soil depth, cut slopes water economy is less and growing plants is harder than fill slopes. On fill slopes land slide is main danger but in cut slopes land slide, rock fall, snow drift, toppled trees and mud flow considered in selection of different plantation technique. Especially in winter during removing snow on snow covered roads, throwing snow mass in to the cut slopes increases danger. Therefore, it is needed that cut slopes should be planted in such way that above mentioned risks eliminated. In cut slopes with long lines, in order prevent road to be closed by sliding of snow mass, it should be considered to build a live barrier that is made of dwarf trees but developing dense root, can withstand against pressure of existing snow mass (Figure 3).

Figure 3. During snow fighting, degradation of road slope and landslides on new formed slopes.

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On newly build forest roads, stability of the slopes is not maintained yet and solidarity between trees is broken on stand sides, and stand stability is weaken at this sections. For that, on newly build roads, the trees on cut slope side are toppled down much more easily. In order stop tree toppling, it should be paid special attention that tree roots at the end of cut slope should be kept completely inside soil. If roots are exposed even tree is healthy should be cut and removed for preventing toppling risk (Figure 4).

Figure 4. Material fall and trees with broken stability on newly build roads

Live barrier establishment against materials coming from cut slope and endanger road safety can minimize existing dangers. In this regard live barrier establishment should have following features:

-Starting ramification from ground level and grow dense green structure, not quick fragile and less flexible stems and resistant against extreme conditions, not be affected from gas and dust (Akdoğan, 1967; Küçük, 2010).

Besides;

-It should look like continue of natural cover,
-Salt resistance where snow fighting happens,
-Formation of thick structure and evergreen,
-High visual quality,
-Strong root, thick and sturdy stem,
-Not invasive species,
-Not disturbing visual quality and having dwarf body not preventing view,
-Not having allergic for human body.

4. CONCLUSION AND SUGGESTIONS

On newly built roads, road slope stability should be as soon as possible maintained with a suitable planting. In particular at places with high altitude and longtime become covered with snow and also important for winter tourism it is necessary to keep visual quality as well as road safety. For this purpose, use of adaptable natural tree and bush species can maintain following benefits:

Maintain road safety,
Prevent rain erosion occurs in slopes,
Prevent landslides,
Prevent fall of dangerous large materials,

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Prevent mud flows from forest,
Prevent fall of snow mass
Prevent of toppling trees,
Prevent of endangering vehicle safety by wild animals,
Maintain continuity of natural cover.

It should be paid special attention to plantation made be with natural species can keep vitality even after cutting top at a certain height (Figure 5).

Figure 5. Planting model on slopes (planting on fill slope (left) and natural regeneration on cut slope (right)

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ORAL PRESENTATION

COMPARISON OF THE USE OF AERIAL PHOTOS TAKEN FROM MANNED AND UNMANNED AERIAL VEHICLES IN TERMS OF ESTIMATION OF STAND PARAMETERS: A CASE STUDY IN MUT FOREST ENTERPRISE

Volkan YILMAZ[1]*, Oğuz GÜNGÖR[1], Ali İhsan KADIOĞULLARI[2], Fevzi KARSLI[1], Turan SÖNMEZ[3]

[1]Karadeniz Technical University, Engineering Faculty, Trabzon, Turkey.
Tel: +90 462 3772763. E-mail: volkanyilmaz.jdz@gmail.com*
[2]Karadeniz Technical University, Faculty of Forestry, Trabzon, Turkey.
[3]Bursa Technical University, Faculty of Forestry, Bursa, Turkey.

ABSTRACT

Recently, forest resources are planned in the sense of based multiple use forest planning, in which the actual status of forests are needed to be identified accurately to present the products and services offered by forests, except for the wood products. In this regard, precise estimation of stand types and stand parameters affects the accuracy and applicability of forest management plans in a positive way. In this study, aerial photos taken from a manned aerial vehicle and used by General Directorate of Forestry to produce forest management plans, were compared with the aerial photos acquired from an unmanned aerial vehicle in terms of stand parameter estimation. Stand heights, closure maps and stand maps were determined by using the aerial photos taken from manned and unmanned aerial vehicles. Determined stand parameters were compared to each other and also be checked by means of the terrestrial measurements conducted in August 2015. The reason for choosing the Mut forest enterprise as study area is because this area is an important ecosystem, which is sensitive to fire and includes gene protection areas, in which different planning approaches (Gazipaşa Mut Model, Classical Planning, Ecosystem Based Functional Planning) are conducted. This enterprise also includes seed fields, wildlife development areas, old growth forests, natural parks, natural monuments and natural/cultural protected areas. PhotoScan Professional software was used to generate the point cloud from aerial photos. MATLAB programming language was also used to determine the position of each tree and generate the tree closure map. The spatial resolution of the orthophoto image generated from the aerial photos taken from the unmanned aerial vehicle was 10 cm.

Key words: Stand parameters, PhotoScan, Orthophoto, Stand type maps, Aerial vehicles, Tree height

1. INTRODUCTION

Since forests are live ecosystems, they should be managed in conjunction with technological developments. In this way, they constitute a natural resource utilized by people and other creatures (Özgün, 2014). Unsystematic management of the forests leads to decrease in biodiversity, erosions, environmental pollution, forest destructions and failure in achieving sustainability (Ün, 2006). Forest management plans are produced to protect the forests and maintain their sustainability. In Turkey, forest management plans are produced for 10 or 20 year periods. Inventory collection, which is the key step to produce a forest management plan,

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is made periodically to monitor the actual status of forest resources (Borucu, 2014). In Turkey, inventory data is generally collected by means of terrestrial measurements. Collecting the inventory data this way requires a huge amount of time and labour force. This, of course, is not practical especially for large-scaled areas. In recent years, forest resources have been monitored with remote sensing technologies, which facilitates to decrease the amount of the needed time and labour force. In the literature, there are various studies in which satellite imageries were used to collect inventory data. Using point clouds is another way of gathering detailed information relating to the surface of the earth. Since point clouds are very successful in representing the topography of the surface of the earth, they have been used in many forestry-related studies. LiDAR (Light Detection and Ranging) point clouds are very efficient to collect forest inventory thanks to the ability of LiDAR sensors to provide multiple returns. However, the acquisition and processing of LiDAR data is still a costly process, which constitutes an impediment to the use of LiDAR point clouds. Hence, the use of point clouds generated by using the aerial photos taken from manned or unmanned aerial vehicles (UAV) is a reasonable alternative for LiDAR point clouds. The aim of this study is to collect forest inventory by using point clouds extracted from the photos taken from a manned (MAV) and unmanned aerial vehicle (UAV). A MATLAB script was written to detect the tree tops in the study area. More information relating to the methodology followed in this study is given in Section 4.

2. MATERIAL AND METHODS

2.1. Study Area

The study area is in Mut, a province of the city of Mersin. The city, which is surrounded by the cities Antalya, Karaman, Konya, Niğde and Adana, lies on the south coast of Turkey. The study area can be seen in Figure 1.

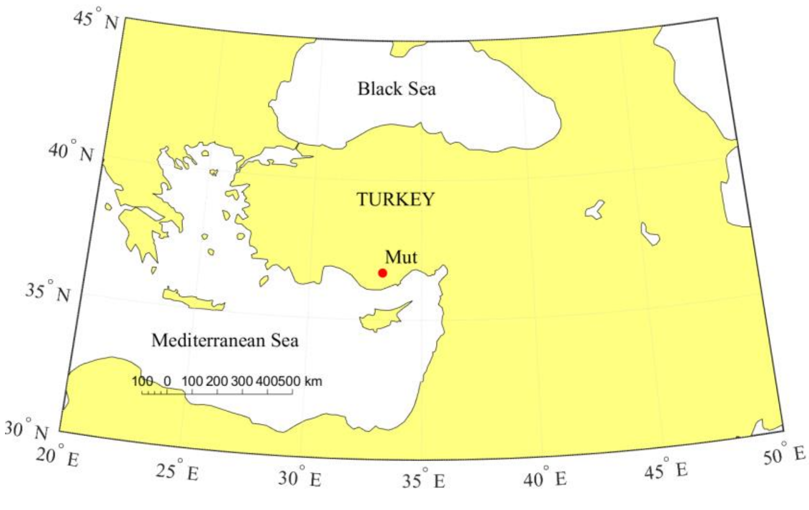

Figure 1. Study area

2.2. Material

Since this study aims at comparing the stand parameters extracted from the MAV-based and UAV-based point clouds, aerial photos taken from the MAV and UAV were used to generate point clouds. 6 aerial photos, taken by the flight conducted by the General Command of Mapping from an elevation of 5500 m, were used to generate the MAV-based point cloud. The MAV-based aerial photos were taken by the UltraCamEagle camera. The UAV-based aerial photos of the study area were acquired by the RICOH GR DIGITAL IV digital camera mounted on the GateWing X100 UAV. 294 aerial photos were taken from an elevation of 250 m.

2.3. Method

The very first step of the followed methodology is to generate the point clouds by using the MAV-based and UAV-based aerial photos. The Agisoft PhotoScan Professional software was used to process the aerial photos and generate the point clouds. As a result of the processes, MAV-based and UAV-based point clouds, which have densities of 2.5 point/m^2 and 13 point/m^2, were generated. Afterwards, 20 cm-resolution DSMs (Digital Surface Model) were generated with the interpolation of the MAV-based and UAV-based point clouds. Since the produced point clouds include the elevations of all objects on the ground, point clouds should be filtered to remove the points belong to the objects on the ground (i.e. trees, buildings, bridges etc.). This procedure is called ground filtering. Ground filtering was done by using the Agisoft PhotoScan Professional software. Once two point clouds were filtered, ground points were interpolated to generate the DTMs (Digital Terrain Model). The spatial resolution of the produced DTMs were as the same of the DSMs (20 cm). It should be noted that bilinear interpolation algorithm was used to generate the DSMs and DTMs. Besides, a 30 cm and 10 cm-resolution orthophotos were generated by using the MAV-based and UAV-based aerial photos, respectively. Subtraction of the DTM from DSM results in the Canopy Height Model (CHM) (Pitkänen et al., 2004; Hyyppä et al., 2004), which represents the normalized heights of the trees. Figure 2 shows the produced orthophotos and CHMs.

In the next step, two crown closure maps were produced by using the orthophotos generated with the MAV-based and UAV-based aerial photos. Both orthophotos were then classified with Support Vector Machines (SVM) classification algorithm. The reason for using the SVM classifier was because this algorithm has been used in numerous studies thanks to its ability to discern the classes. The MAV-based orthophoto was classified into three classes as ground, tree and shadow; whereas the UAV-based orthophoto was classified into two classes as ground and tree. Classified images were then used as inputs to generate the crown closure maps. A sliding window was employed on the classified images. A crown closure ratio was computed for each window position by calculating the ratio between the total number of the tree pixels and non-tree pixels in the window. As known, a closure ratio between 11% and 40% presents sparse density; whereas a closure ratio between 41% and 70% indicates normal density. A closure ratio greater than 71% presents high density. Crown closure map was generated in MATLAB environment. Figure 3 shows the generated classified images and crown closure maps.

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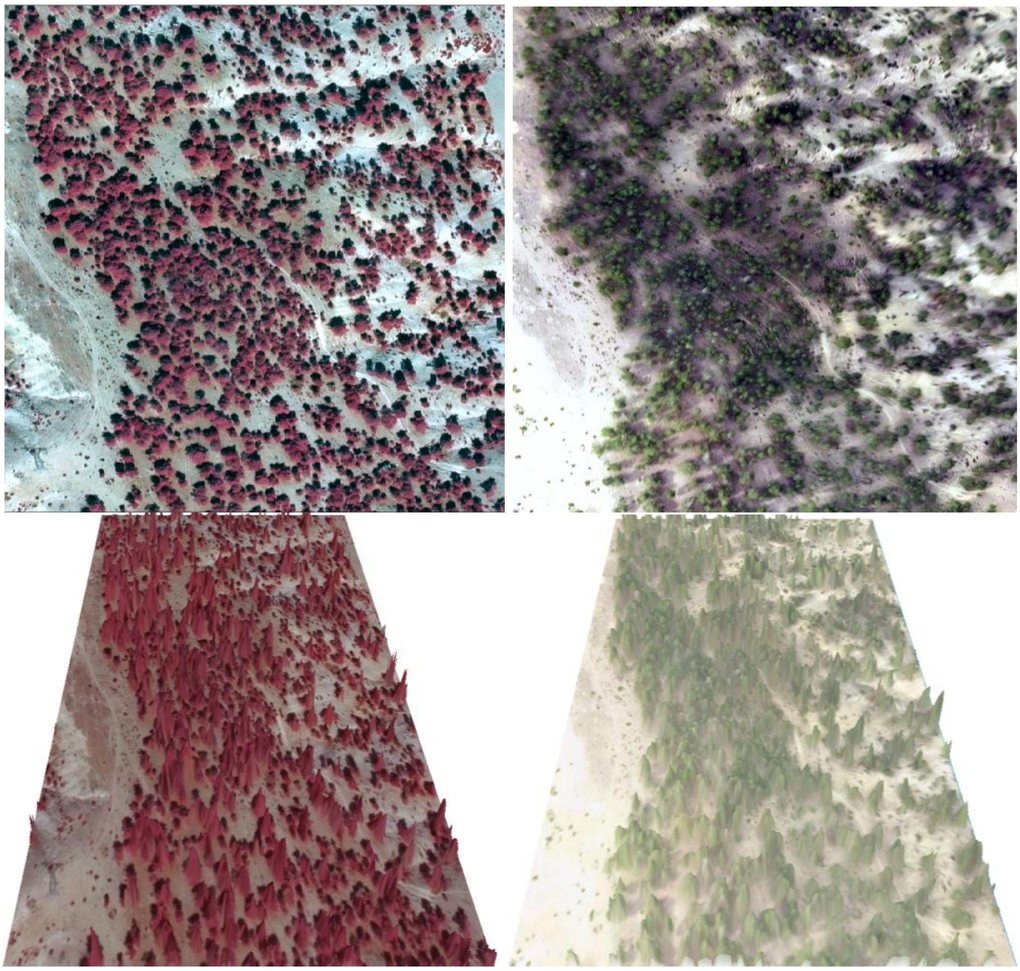

Figure 2. Orthophoto generated from the MAV-based aerial photos (top left), orthophoto generated from the UAV-based aerial photos (top right), CHM generated from the MAV-based aerial photos (bottom left), CHM generated from the UAV-based aerial photos (bottom right)

The procedure used to calculate the positions of tree tops benefits from the CHM. Except some abnormal situations, top of a tree is considered to be at the top centre of the tree crown. Elevation values decrease towards to the boundaries of the tree crown. In case where tree crowns are not interlocking, trees can spread their branches freely. However, if trees are interlocking, then their tops get closer to each other, which makes it more challenging to determine the position of tree tops.

The sizes of the orthophotos were resampled to the size of the CHMs. Afterwards, the elevation values lower than 3 m were set to 0 on the produced CHMs to eliminate the elevation errors, which may arise from the ground filtering process. Then, the local maximums were found by employing a sliding window on the CHMs. The size of this window was defined by the smallest crown diameter in study area. Hence, the crown diameter of the smallest tree was measured as 17 pixels. The pixels in the vicinity of each tree top were found by using a second threshold R. This threshold was calculated as the average of the crown diameters of the smallest and largest trees in study area. Since the crown diameter of the largest tree was measured as 39 pixels, R was calculated as 28 pixels. Afterwards, the

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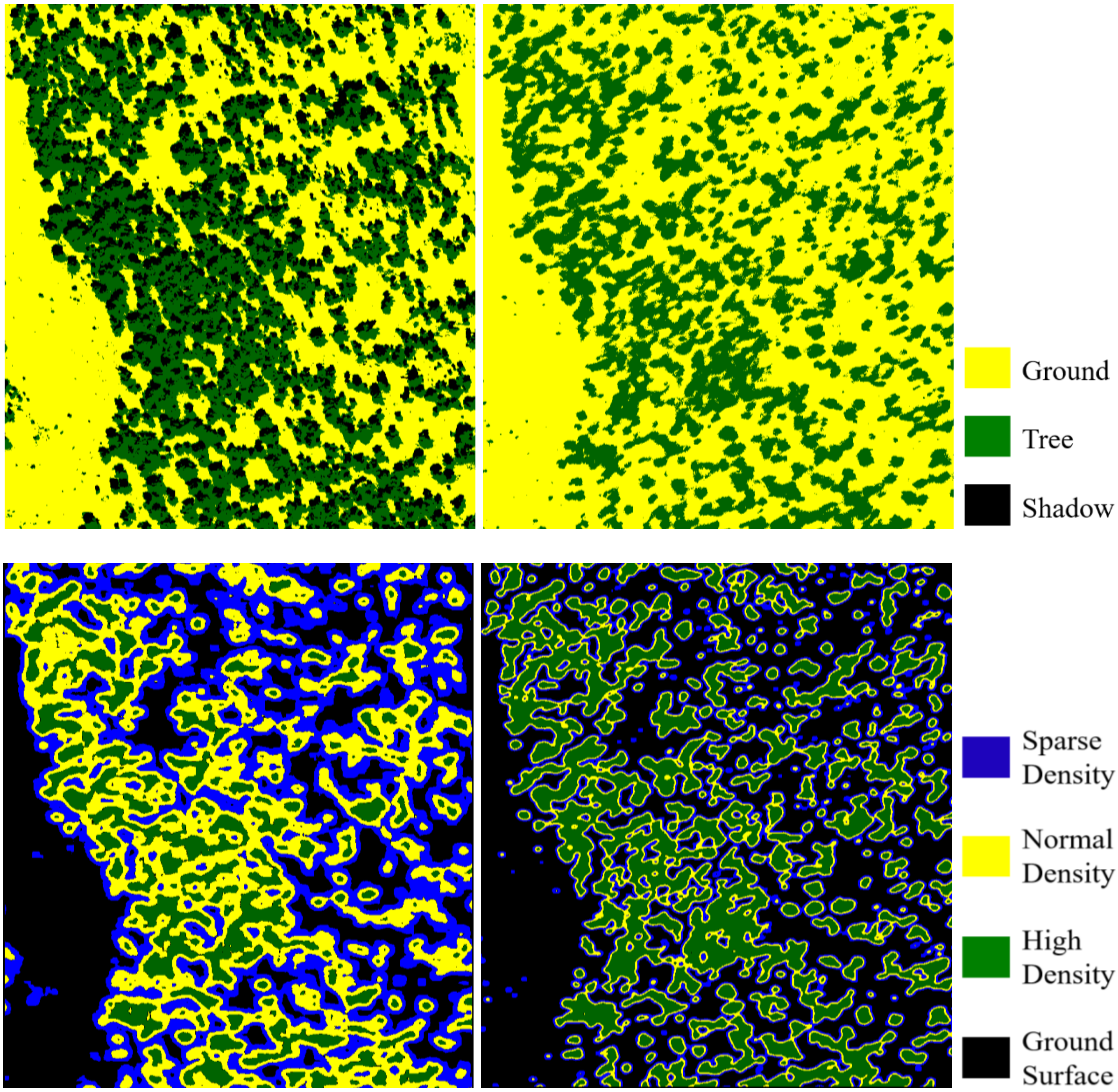

Figure 3. Classification of the MAV-based orthophoto (top left), classification of the UAV-based orthophoto (top right), crown closure map generated with the MAV-based orthophoto (bottom left), crown closure map generated with the UAV-based orthophoto (bottom right)

pixels whose distances to the tree tops were smaller than 28 were merged to form the objects. The areas of all objects were then computed. The objects whose areas were found to be smaller than a predefined threshold were removed. Finally, the centroid of each object was calculated to find the position of each object, i.e. tree top. All implementations were conducted in MATLAB environment. Detected tree tops can be seen in Figure 4. In the figure, tree tops detected with the MAV-based and UAV-based CHM were shown with green and red stars, respectively.

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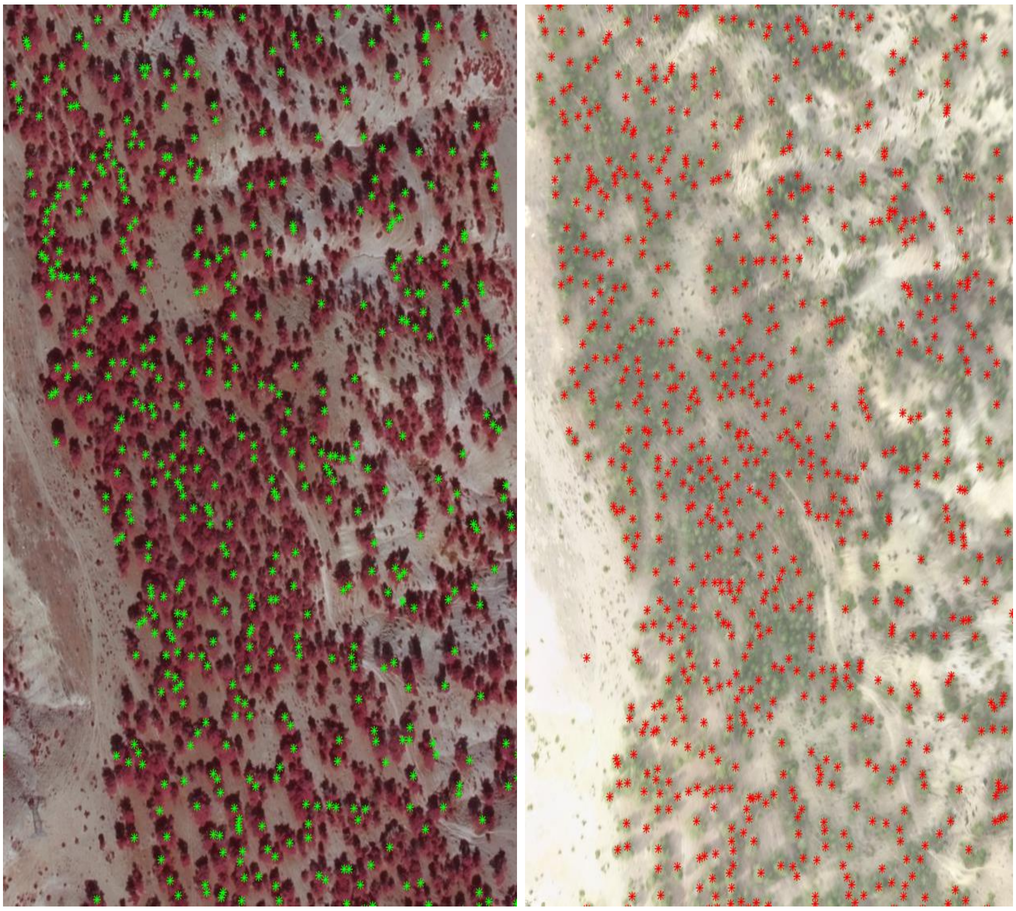

Figure 4. Tree tops detected by means of the MAV-based (left) and UAV-based CHM (right)

3. RESULTS AND DISCUSSION

The methodology followed in this study detected 489 tree tops in study area by using the MAV-based CHM; whereas 793 tree tops were detected by using the UAV-based CHM. As seen in Figure 4 (left), the written MATLAB script could not achieve to find lots of tree tops by means of the MAV-based CHM. The script detected the tree tops with a higher accuracy by using the UAV-based CHM. The reason for this is that the vertical accuracy of the MAV-based CHM is not as high as that of the UAV-based one, due to the errors arose from the ground filtering process. It can be inferred from these results that the methodology used in this study works well with the CHMs having higher vertical accuracies. In addition, the heights of the trees in study area were determined approximately 12-13 m.

The main conclusion drawn from this study is that the use of the MAV-based or UAV-based aerial photos facilitates to collect the forest inventory in a short span of time. This, of course, allows to update the forest management plans without spending too much time and labour force with terrestrial measurements. In this way, sustainable forest management will be possible. Future studies will focus on the determination of the diameters of the tree crowns in study area and investigation of the accuracy of the determined stand parameters with the help of terrestrial measurements.

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EFFECTS OF LOGGING METHODS ON SOIL PROPERTIES, ORGANIC HORIZON AND SOIL COMPACTION

Korhan ENEZ*, Temel SARIYILDIZ, Gamze SAVACI, Burak ARICAK

Kastamonu University, Faculty of Forestry, Department of Forest Engineering, 37200 Kastamonu, Turkey. Tel: +90 366 2801712 Fax: +90 366 2801038
E-mail: korhanenez@kastamonu.edu.tr*

ABSTRACT

Kastamonu presents 1.7% of Turkey's forest areas and its province is covered by 65% forestland. When the rate of utilization of forest areas is considered, 5.4% percent of nation-wide industrial wood productions is provided from Kastamonu's forests. In general, three methods are known for the logging activities; manpower, animal power and mechanical power. However, the most used logging methods in Kastamonu forest areas are widely farm tractors. In addition, the use of skidding through wire drawing is also often applied for the logging in the region. Main aim of this present study was to determine the effects of logging activities on soil properties, organic horizon and soil compaction after the silvicultural activities in Kastamonu region were carried out by farm tractors and the skidding through wire drawing at two different slope groups in the forest (30-60%, 60-100%). Soil sampling was taken from four different microecological sites that occured during the production activities, namely (1) skid road, (2) production wastes subbase, (3) mineral soil without topsoil and (4) control sites. At each site, mineral soil samples were taken from four soil depths (0-5, 5-10, 10-15, and 15-20 cm) and analyzed for soil pH, permeability, water holding capacity, organic matter, soil texture, bulk density, rock fragments or skeleton (>2 mm), soil compaction and dispersion ratio.

Key words: Logging methods, Soil properties, Slope angle, Scots pine, Kastamonu

1. INTRODUCTION

Forest management practices, such as logging, harvesting and mechanical site preparation have been reported to be the most significant soil and site disturbance activities, particularly affecting soil compaction, soil porosity and organic matter removal from forest surface and mineral soil (Jurgensen et al., 1997; Kozlowski, 1999; Tan et al., 2005; Powers et al., 2005). Expressed as decrease or completely loss of pores in the soil, soil compaction prevents plant roots from reaching lower parts of the soil and benefiting from water and nutrients (Günal and Özgöz, 2015). Soil compaction is a factor that affects and changes many characteristics of the soil, and causes deterioration of structure of soil particles under a significant load or pressure, decrease in soil porosity, infiltration and void ratio and increase in soil volume weight. Many factors play a significant role in soil compaction. The most influential factor is human factor (Savacı and Sariyildiz, 2015). Forest management practices such as production activities in forestry and mechanical site preparation (Tan et al., 2005; Turgut, 2012) and use of recreational area mainly cause soil compaction (Turgut, 2012).

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Proportional distribution of soil's sand, clay and dust content affects its volume weight as well. Values of 1,40gr/cm^3 and higher indicate compaction in a clay textured soil, while this value is considered as 1,70 gr/cm^3 and higher in dust textured soils (Foth, 1990) Penetration resistance measurement, which is the representative of penetration of roots into soil, is a method that is commonly used in determination of soil compaction. Penetrometer values higher than 2 MPa indicate that the soil has compaction (Günal and Özgöz, 2015).

Impact of soil compaction and organic matter removal on soil physical and chemical properties and tree growth have been widely studied by many researchers (Conlin and van den Driessche, 1996; Huang et al., 1996; Gomez et al., 2002). In general, they have shown that soil compaction reduces soil porosity and can affect soil physical and chemical properties such as aeration, water storage, temperature, infiltration and flow, susceptibility to erosion, and heat transfer (Tan et al., 2005; Gomez et al., 2002; Childs et al., 1989). It has been also shown that the soil physical environment, soil nutrient availability, and biological properties such as mycorrhizal inoculum can be affected by removal of forest biomass or forest floors (Jurgensen et al., 1997; Henderson, 1995). However, effects of soil compaction and organic matter removal on biological processes in forest soils have been received less attention (Piatek and Allen, 1999; Li et al., 2003; Li et al., 2004; Li et al., 2007). Although a number of researchers have studied the influence of forest stands and site organic matter on litter decomposition for alternative harvesting regimes (Yin and Perry, 1989; Prescott, 1997), for whole-tree logging (Bird and Chatarpaul, 1988) and for broadcast burning (Bisset and Parkinson, 1980) only a number of field studies have yet examined the combined effects of site disturbance from forest harvesting (losses in soil porosity and site organic matter) on litter decomposition (Kranabetter and Chapman, 1999).

Slope of any given forest site can be also an important factor influencing the soil properties and soil compaction rates during logging activities. Slope is one of the important factors of universal soil loss equation. Its geometry, such as slope angle, length and curvature influence runoff, drainage, and soil erosion (Aandahl, 1948) causing a significant difference in soil physico-chemical properties (Brubaker et al., 1993). Erosion would normally be expected to increase with increase in slope length and slope steepness, as a result of respective increase in velocity and volume of surface runoff. This study, which is a part of research project, aims to establish differences in certain soil characteristics and soil compaction values in microecological sites (skid road, production wastes subbase, mineral soil without topsoil and control sites) that occurred as a result of wood extraction activities with agricultural tractor in high slope group (30-100%) of *Pinus sylvestris* stands subjected to production in Kastamonu region.

2. Material and Methods

2.1. Study Area

This study was conducted in Sarıçam Sub-District Directorate within the borders of Daday district of Kastamonu province. Study area is between 41º33.715' north latitudes, 33º23.107' east longitudes, altitudes of 1458-1467 m, with Southwest exposure and average incline of slope between 60-100% (Figure 1). Bedrock of the study area consists of schists from the Trias-Sub-Jura geological era. Landuse capability is in class VI. It has a typical continental climate, usually hot and arid in summer and cold and snowy in winter.

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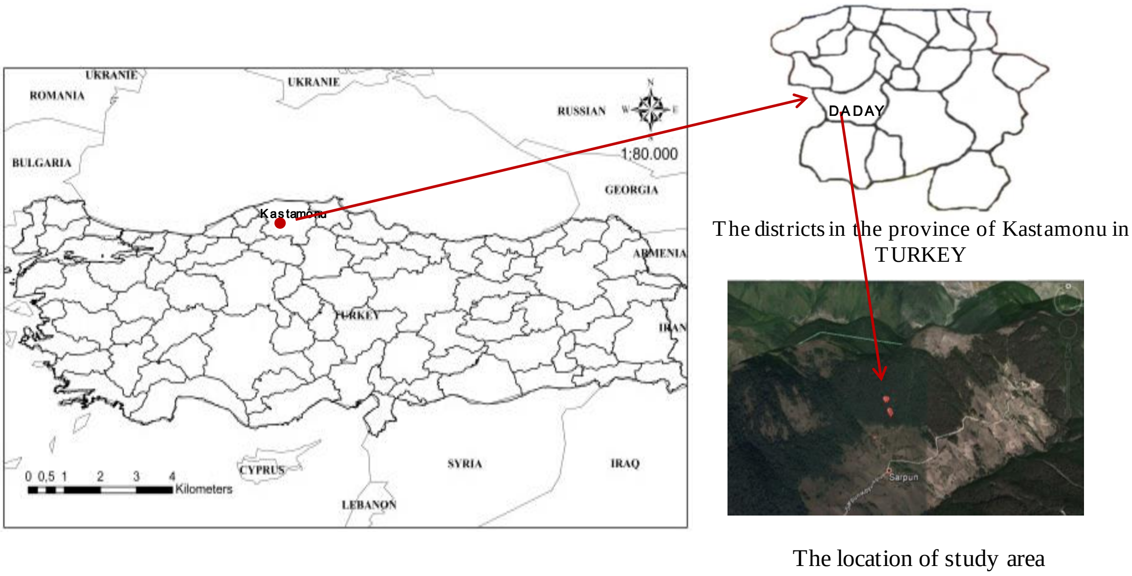

Figure 1. The location of study area

2. 2. Soil sampling, soil compaction measurement and soil analysis

The soil samples were taken randomly from 0-5cm, 5-10 cm, 10-15 cm and 15-20 cm soil depths by digging soil pits at micro-ecologic site. The samples were air-dried, ground and pass through 2 mm mesh-sized sieve. Two core samples from each soil pit were also taken and averaged to obtain representative bulk density. Soil compaction measurements were performed in the field using a 30^0 angled penetrometer over a 10 cm profile in 5 cm increments.

Soil samples collected from the field were sieved (<2mm) and the remaining larger structural aggregates (> 2mm) were calculated. Soil pH was measured in a 1:2.5 mixture of deionized water and soil using a glass calomel electrode (Origon 420 digital pH meter), after equilibration for 1h. Soil texture analyses were done on soil samples from the 0–20 cm layer. Soil pH was determined for soil samples from the 0–20 cm layer. The moisture content of soils was calculated by weight loss after drying aliquots of ca. 10 g of soil for 24 h at 105 ^oC.

Soil texture was determined using a Bouyoucos hydrometer in a soil suspension of 100 g of soil in 1 L of H_2O (Gülçur, 1974; Bouyoucos, 1962). Bulk density was determined by weight loss after drying the undisturbed soil core samples for 2 days at 105^{o}C (Blake and Hartge, 1986) Determination of weight percent organic matter in soils have been found with an ash furnace method. Firstly, oven-drying of the sediment to constant weight (usually 24 h at ca. 105 °C) organic matter is combusted in a first step to ash and carbon dioxide at a temperature between 700 or 800 °C. The loss on ignition is then calculated using the following equation: Loss on ignition (LOI) = ((105°C –700)/ 105)*100 (Gülçur, 1974). Petri and Wagner (1978) reference as reported by Trash (1988), amount of inorganic components such as blocks of stone, gravel that has above equivalent diameter of 2 mm the in each horizon is estimated as a percentage of a certain soil unit such as volume or weight Permeability of the soil samples was calculated according to Darcy's law (Öztan, 1980a).

P= (Q/A)X(Hs/ Hs+Hw) cm/saat (Özhan, 1977) (1)

where, P is permeability (cm/hour), Q is the amount of water flowing at a given time (cm/hour), A is cross-sectional area of soil sample (cm^2), Hs is height of soil sample (cm), and Hw is water column height with hydrostatic pressure (cm) (Öztan, 1980b).

For soil samples, the Dispersion Ratio (Middleton, 1930), computed as

DR= (percent silt+clay in water dispersed samples/percent silt+clay in calgon dispersed samples) x 100

was used as an indirect test of water stability (Piccolo and Mbagwu, 1990).

2.3. Data analysis

One-way ANOVA (analyses of variance) was applied for analyzing the effects of soil disturbances from forest harvesting on the forest and soil properties such as soil pH, forest floor water content, and soil water content for Scots pine using the SPSS program (Version 20.0 for Windows). Following the results of ANOVAs, the Tukey's Honestly Significant Difference (HSD) test (α = 0.05) was used for significance.

3. RESULTS

As is known, data must fulfil two assumptions in order to apply the analysis of variance. Firstly, data must have minimum interval scale. Secondly, data must show a normal distribution. That the data collected is quantitative data fulfils the first assumption. For the second assumption, fitness of data to normal distribution was checked through the Kolmogorov-Smirnov (K-S) one sample test. It was found that the data collected showed normal distribution (P>0.05) (Table 1).

Table 1. Kolmogorov-Simirnov data normality control test

Soil Properties	N	Arith. Mean ± Std. Dev.	P*
Bulk density	16	1.08 ± 0.14	0.987
Water Holding Capacity	16	17.26 ± 5.96	0.418
Skeleton Volume	16	58.74 ± 8.64	0.534
Permeability	16	448.43 ± 212.99	0.892
pH	16	5.12 ± 0.32	0.634
Sand	16	65.32 ± 5.22	0.591
Clay	16	22.08 ± 3.33	0.304
Silt	16	12.60 ± 5.34	0.022
Soil compaction	16	2.48 ± 1.01	0.174
Organic Matter	16	8.06±1.76	0.084

*P>0.05

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Constituting the most important part of production activities, the wood extraction is performed with agricultural tractors in Turkey in line with the current developments. Accordingly, when the analysis of variance was used to see whether there was any difference in certain soil characteristics based on the soil depth in the stand that remain after the wood extraction, it was found that there was no statistical difference in volume weight, water holding capacity, skeleton volume, permeability, pH, sand, clay, dust and compaction values based on different soil depths ($P<0.05$) (Table 2).

Table 2. Certain soil properties based on depth levels of forest soil

Soil Properties	Depth level				F	P*
	0-5	5-10	10-15	15-20		
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE		
Bulk density	1.0 ± 0.05	1.13±0.06	1.02±0.06	1.20±0.07	2.345	0.124
Water Holding Capacity	19.14±3.26	18.97±4.17	14.5±2.96	16.44±1.66	0.497	0.691
Skeleton Volume	60.43±1.82	61.24±4.43	54.43±5.34	58.86±5.71	0.440	0.729
Permeability	620.9±127.69	387.15±68.24	443.35±20.34	342.30±142.83	1.429	0.283
pH	5.08±0.17	5.08±0.27	5.08±0.06	5.24±0.13	0.210	0.888
Sand	65.32±2.92	65.32±2.92	65.32±2.92	65.32±2.92	0.000	1.000
Clay	22.08±1.86	22.08±1.86	22.08±1.86	22.08±1.86	0.000	1.000
Silt	12.60±2.99	12.60±2.99	12.60±2.99	12.60±2.99	0.000	1.000
Soil compaction	2.43±0.28	2.45±0.53	2.38±0.63	2.65±0.70	0.047	0.986
Organic Matter	8.89±2.02	8.43±1.01	7.79±2.93	7.13±2.09	0.713	0.563

* $P<0.05$

It was found that there were statistically important differences ($P<0.05$) in skeleton volumes, texture (sand, clay, dust) and soil compaction values among the microecological sites (production wastes subbase, skid roads, mineral soil without topsoil and control sites) that occured as a result of production activities (Table 3). No statistical difference was found among the volume weight, water holding capacity, permeability and pH values ($P>0.05$). When the microecological sites where different soil characteristics emerged were examined in Table 3, it was observed that skeleton volume in mineral soil without topsoil was different from other microecological sites and others were the same ($P<0.05$). In addition, amounts of sand, clay and dust in microecological sites were statistically different from each other. When soil compaction values were examined, the level of compaction in soils under production was different from other microecological sites, while others were statistically same with each other. In terms of organic matters, production wastes and skid roads were statistically different from each other and others and amounts of organic matters in mineral topsoil and control sites showed similarity ($P<0.05$).

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Table 3. Certain soil propertiesand differences and F and P values by microecological sites

Soil Properties	Microecological sites: Production wastes subbase	Skid road	Mineral top soil	Control	F	P*
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE		
Bulk density	1.10±0.06	1.08±0.08	1.01±0.07	1.14±0.07	0.592	0.632
Water Holding Capacity	14.24±1.35	19.63±3.94	21.56±2.25	13.62±2.56	2.142	0.148
Skeleton Volume	62.85±2.27^{b}	62.19±2.30^{b}	46.77±3.77^{a}	63.14±2.19^{b}	8.655	0.002*
Permeability	556.98±63.28	590.53±116.34	275.45±97.01	370.75±84.35	2.659	0.096
pH	5.16±0.17	4.87±0.23	5.17±0.09	5.28±0.09	1.306	0.318
Sand	67.95±0.0^{a}	71.96±0.0^{b}	58.67±0.0^{c}	62.70±0.0^{d}	2426x10^{28}	0.000*
Clay	17.76±0.0^{a}	24.25±0.0^{b}	25.98±0.0^{c}	20.34±0.0^{d}	2107x10^{28}	0.000*
Silt	14.29±0.0^{a}	3.79±0.0^{b}	15.35±0.0^{c}	16.95±0.0^{d}	1238x10^{28}	0.000*
Soil compaction	0.98±0.32^{a}	2.93±0.34^{b}	3.15±0.16^{b}	2.85±0.06^{b}	16.508	0.000*
Organic Matter	6.66±1.04^{a}	9.60±2.06^{b}	6.97±0.69^{c}	9.01±1.09^{c}	4.903	0.019*

*P<0.05

Although the microecological sites emerged after production activities, the data collected showed that two different soil types were observed in these sites: sandy-clay-loam and sandy-clay. Independent t-test was made in order to determine the differences among soil characteristics after wood extraction activities on these different soil types. Accordingly, the difference among skeleton volume, sand, clay, compaction values and organic matter amount was observed as statistically significant (P<0.05)(Table 4).

Table 4. Independent t-test was made since two types of soil were observed.

Soil Characteristics	Soil Type: Sandy-Clay-Loam	Sandy-Clay	F	T	P*
	Mean ± SE	Mean ± SE			
Bulk density	1,11±0,04	1,01±0,07	0,026	1,247	0,233
Water Holding Capacity	15,83±1,68	21,56±2,25	0,057	-1,782	0,096
Skeleton Volume	62,73±1,18	46,77±3,78	3,550	5,482	0,000*
Permeability	506,08±55,56	275,45±97,001	0,014	2,071	0,57
pH	5,10±0,10	5,17±0,09	2,628	-0,364	0,721
Sand	67,54±1,14	58,67±0,0	9,144	7,756	0,000*
Clay	20,78±0,80	25,98±	10,520	-6,460	0,000*
Silt	11,68±1,71	15,35	20,876	-2,144	0,055
Soil compaction	2,25±0,31	3,15±0,16	5,904	-2,616	0,020*
Organic Matter	8,42±1,88	6,97±0,69	5,617	2,253	0,041*

*P<0,05

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4. DISCUSSION AND CONCLUSION

The findings that were obtained as a result of this study show that differences in soil characteristics at different soil depths are not statistically significant but soil compaction has a decrease first depending on soil depth and then shows an increase (Table 2). The highest soil compaction was found at the lowest part of soil. This finding is similar to those of Menemencioğlu et al. (2013), Makineci et al. (2007), Demir (2007) and Savacı and Sarıyıldız (2015). According to the findings, organic matter accumulation on soil surface decreases with depth, while volume weight increases with depth.

It can be suggested that that the dispersion result is <15 (65.3%), increase in erosion risk due to high land slope and low permeability values play a role in occurrence of soil compaction. Besides, macropores and infiltration of soil decreases because of situations such as use of very heavily loaded equipments, frequency of vehicle passing times and condition of soil surface (wet or dry) during the production activities that are performed using tractor. Consequently, it is possible to observe surface runoff and associated erosion in the site (Balcı, 1996).

It was found that there are differences in soil characteristics of the microecological sites that emerged as a result of production activities and soil characteristics of different soil types (Table 3 and Table 4), while it was revealed that such activities caused soil compaction. In their study, Young and Ritz (2000) stated that such difference in soil characteristics affects increase of volume weight when tractors pass during skidding, characteristics, which affected microbial community structure, such as water permeability and aeration.

Among the microecological sites, compaction values are high in samples collected from skid road in high slope group (30-60%) and mineral topsoil (2.93±0.34 and 3.15±0.16, respectively); the highest sand rate was found in skid roads (71.96%); and the lowest sand rate was found in mineral topsoils (25.98%). It is believed that this is because high compaction values in association with increase in amount of clay soils with poor drainage in the site. In addition, it was found in this study that permeability value (mineral topsoils) decreases with the increase in clay and dust rates.

Studies show that compaction occurs with the first impact of machines on the land. For this reason, the road used on a land must always be the same. Compaction will be deeper in areas that are frequently passed, but a deep compaction on a single line should be preferred rather than a compaction on the entire land (Günal and Özgöz, 2015). This situation requires determination and inspection of production activities in forestry, in other words forestry operations, operation plans and particularly skidding routes.

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USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS) FOR PRECISE DETERMINATION OF STAND/SUBCOMPARTMENT SLOPE VALUES IN PLANNING AND PRODUCTION WORK: A CASE STUDY OF THE MUT-ALAHAN AND MİHALIÇÇIK-KIZILTEPE FOREST PLANNING UNITS (TURKEY)

Turan SÖNMEZ*[1], Ali İhsan KADIOĞULLARI[2]
Habip EROĞLU[2], Uzay KARAHALİL[2]

[1]Bursa Technical University, Faculty of Forestry, Department of Forest Engineering, 16300 Bursa, Turkey. Tel: +90 224 3003435 Fax: +90 224 3003429
E-mail: turan.sonmez@btu.edu.tr
[2]Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon, Turkey

ABSTRACT

The utilization of and expectations from forest services and forest products have diversified and undergone change over recent years. In the plans, these expectations are generally reflected in the form of conflicting purposes for the same forest subcompartment, with forest functions being determined according to set rules. Along with geographical information systems (GIS), accurate slope calculation has gained recognition as an important factor in the choice of techniques used in production activities. The calculations of the arithmetic mean method used under the present system provide very different slope values compared to calculations using the area weighted method. A forest subcompartment can be evaluated for the soil preservation function based on the slope values calculated by arithmetic mean, and can additionally be evaluated for forest production according to the area weighted slope values. Likewise, completely reverse situations can also occur, while the selection of a production technique can be indicated by the difference. This study analyzed the differences created by using these two methods in calculating slope values for a subcompartment and the manner in which they affected the wood extraction techniques and ground skidding expenses for two planning units having different forest ecosystems.

Key words: Slope, area weighted method, GIS, arithmetic mean method, protected areas

1. INTRODUCTION

Today, with the construction of ecosystem-based functional forest management plans prepared in order to meet the rapidly changing demands on the forest, slope is an important parameter in determining the expansion of forest functions. At the same time, the slope is one of the most important parameters in many areas, including the selection of techniques for extraction (harvesting) from the compartment (Swanston, 1974), the preparation of afforestation and rehabilitation projects, the identification of priority areas and the production of fire risk and danger potential maps (Sağlam et al., 2008) In this context, the accurate identification of the slope of a forest subcompartment can help to correctly determine forest functions and other forestry activities. Under the present system, slope values (percent of rise) are calculated using the arithmetic mean method which sometimes gives very high or very low values. However, slope value calculation using the area weighted method provides very

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accurate results. Within this scope, when the slope value of a forest subcompartment is taken into account, it can be evaluated for the soil preservation function based on the arithmetic mean value, and it can also be evaluated for forest production according to the area weighted value. Likewise, completely reverse situations can also occur, and the selection of a production technique can be indicated by the difference.

This paper examined the accurate calculation of slope for two ecologically different forest planning units (FPUs) in Turkey. Along with the usage of geographical information systems (GIS), the factor of slope has been gaining importance in the selection of forest function and logging techniques used in production as well as in other forest activities

2. MATERIAL AND METHODS

2.1. Study area

For this study, two planning units with different forest ecosystems were selected. The first study area, Mut-Alahan FPU (Figure 1), is an ecosystem susceptible to fires, but which hosts gene-protection forests, seed gardens, wildlife development and protected areas, natural old-growth forests, forests with aesthetic functions and historical and cultural protected areas. These characteristics of the study area require a more sensitive attitude during planning. Alahan FPU is located in a typical mountain watershed covering an area of 41,570.6 ha in the southern part of Turkey, according to the boundaries of the 2016 stand-type maps (GDF, 2016). The altitude varies between 135 and 2000 m with an average slope of 23%.

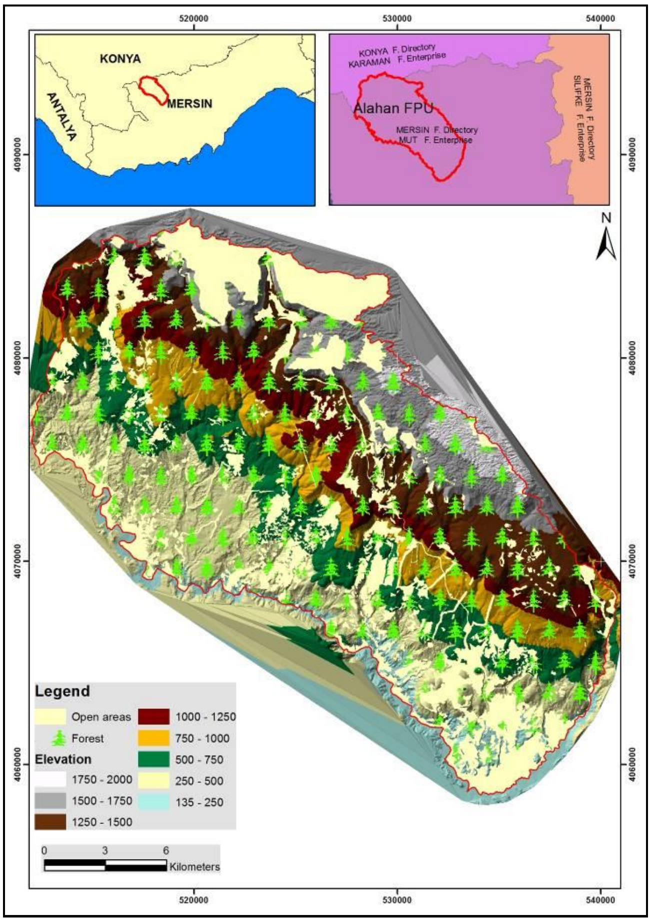

Figure 1. The geographic location of the Alahan FPU shown within the red lines

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Most of the second study area, Mihalıççık-Kızıltepe FPU, is a delicate transition ecosystem located in a dam basin with soil protection, wildlife development and protected areas and natural protected areas. Kızıltepe FPU (Figure 2) is located in a typical mountain watershed covering an area of 18,415.1 ha along the southern part of Turkey, according to the boundaries of the 2015 stand-type maps (GDF, 2015a). The altitude varies between 270 and 2000 m with an average slope of 36%.

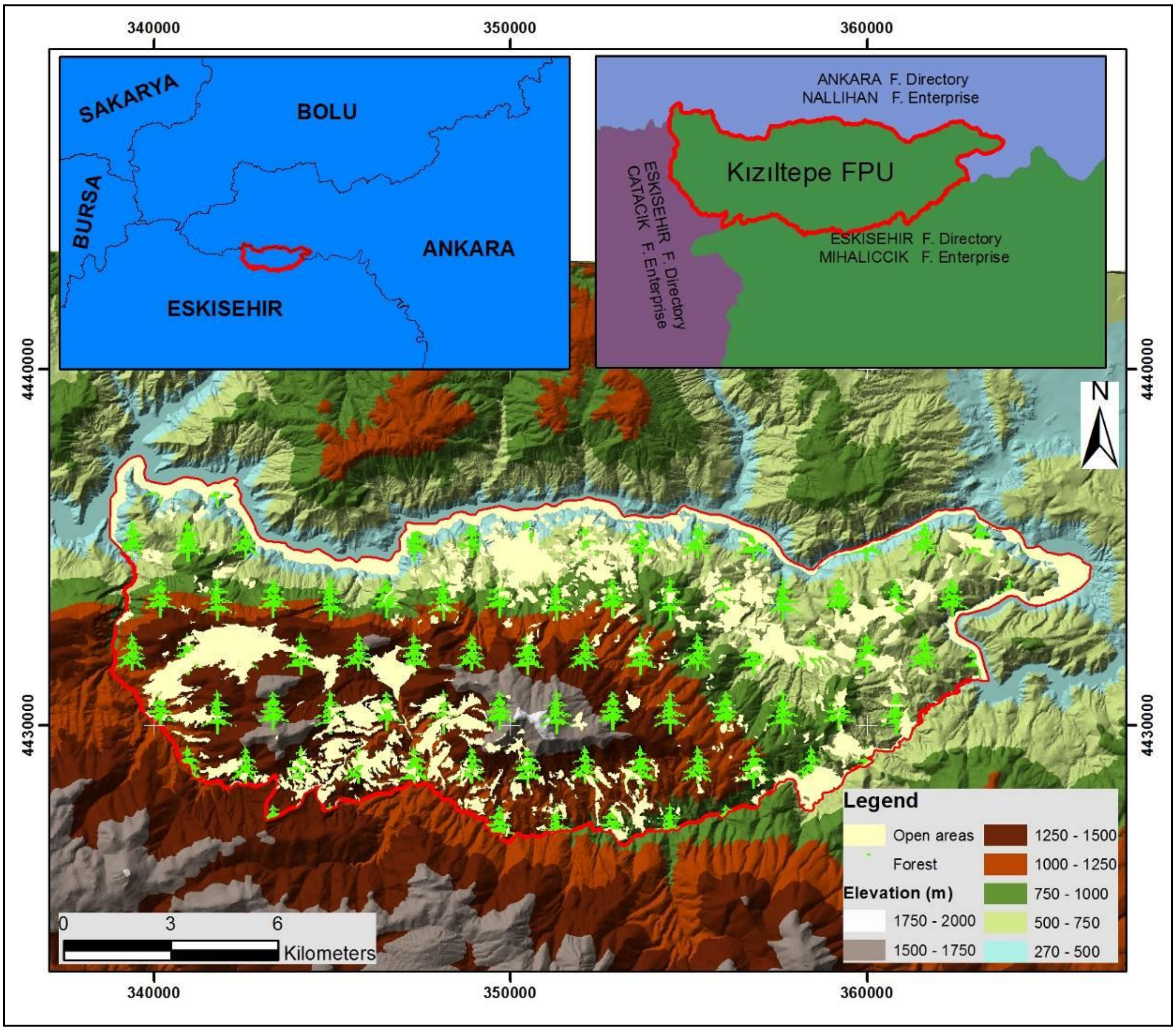

Figure 2. The geographic location of the Kızıltepe FPU shown within the red lines

2.2. Methods

In this study, forest-stand maps were obtained from plans produced by the Alahan and Kızıltepe forest managements (GDF, 2015a; 2016). The forest-stand-type maps were created with digital colored infrared aerial photos and controlled field survey data. These plan maps were saved as a single database and analyzed with other datasets by using ArcInfo 10.1™.

In order to calculate slope values, first, elevation maps were created for the two study areas by using a digital elevation model (DEM) produced from contour curves (10-m height accuracy) (Burrough and McDonell, 1998; ESRI, 2012; Kadıoğulları and Turna, 2015). Slope values were then produced from these DEM maps and classified into percent rise by intervals of 10% for the two study areas. These slope maps were saved in vector format and overlaid with the stand maps of Alahan and Kızıltepe FPUs. The slope values of all subcompartments were calculated via the arithmetic method and the area weighted method (Fig. 3). Lastly, these two slope values were analyzed for all subcompartments and presented by ArcGIS. The differences in these two methods were seen after the slope maps were overlaid with the subcompartment maps. The arithmetic method only divides the total number of component parts to calculate the value of the falling slope of each plot. In the area weighted method, the slope value for each section is multiplied by the area of the section and these are added together. The total value is then divided by the total area of the subcompartment to calculate the slope value. In this way, the effective size of the proportional contribution of each part of the slope is used to find the value closest to the actual slope value (Figure 3). In Alahan FPU, all subcompartments were classified into seven classes (-11 and -13, -5 and -10, 0 or -5, +5, 5 and 10, 10 and 20, 20 and 30 and >30) based on slope deviation. In Kızıltepe FPU, all subcompartments were classified into six classes (-11 and -15, -5 and -10, 0 or -5, +5, 5 and 10, 10 and 20 and 20 and 28) based on slope deviation.

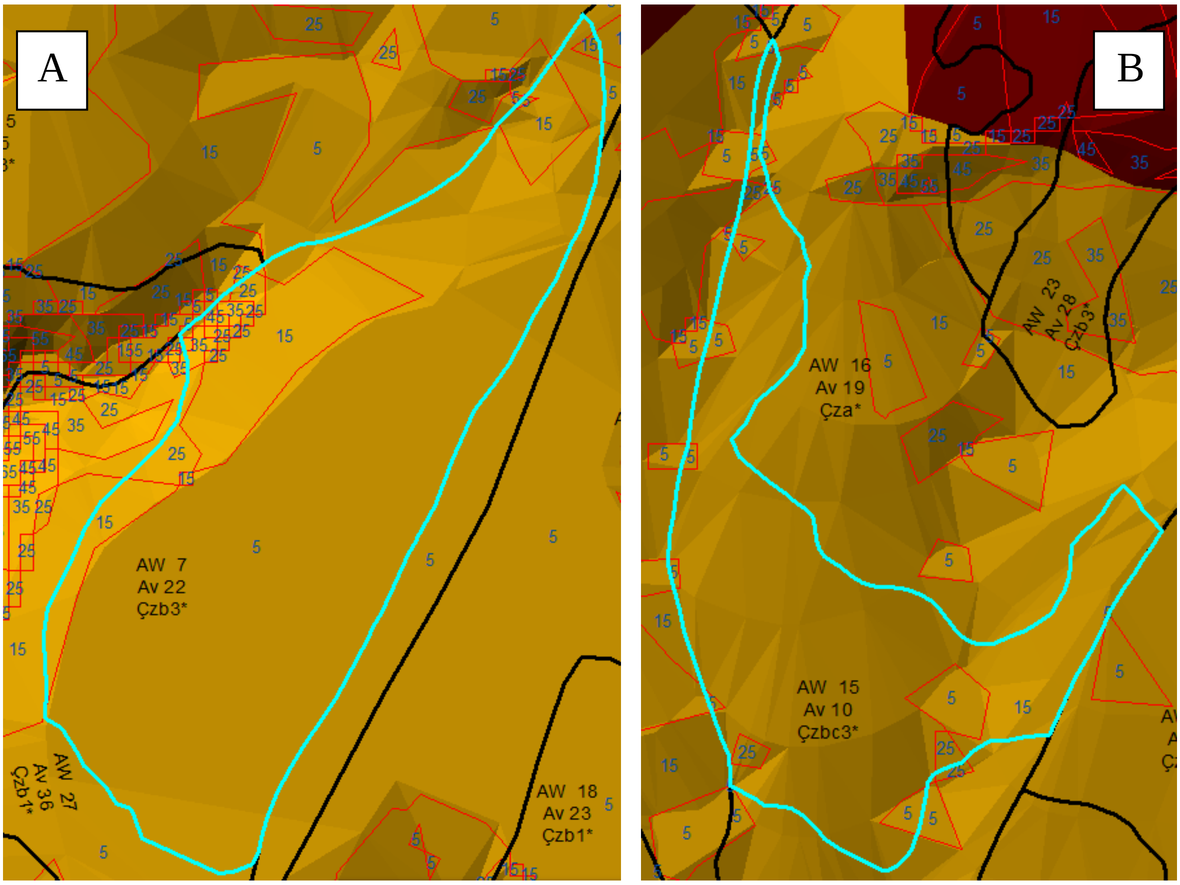

Figure 3. a) Example of an area weighted slope value lower than the arithmetic slope value; b) Example of an area weighted slope value higher than the arithmetic slope value (*Blue numbers show slope values for each section area; red lines show boundaries of section areas; black lines show boundaries of subcompartments.*)

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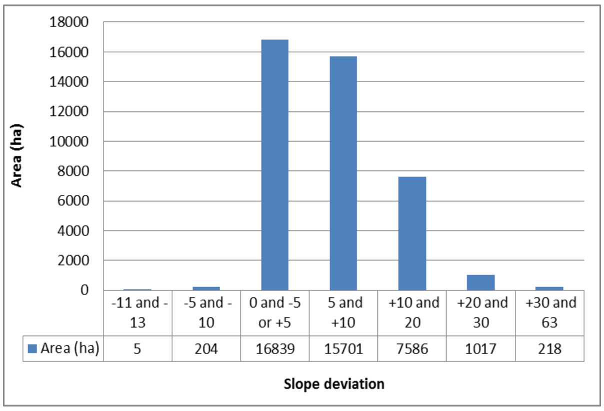
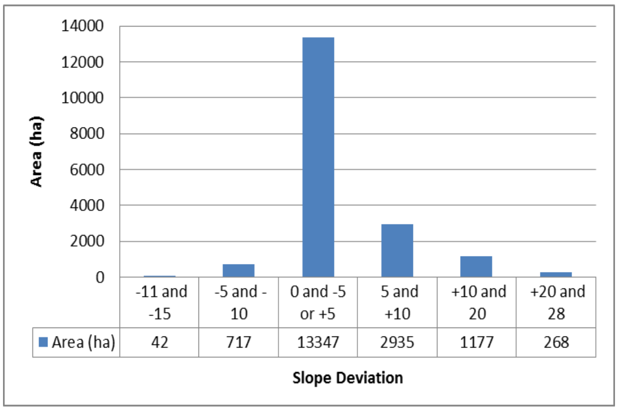
3. RESULTS AND DISCUSSION

As a result of analysis of the slope maps prepared by the two different methods, important differences were shown in the slopes in both study areas. In a small area of 209 hectares in Alahan FPU, much lower slope values were calculated via arithmetic mean than with the area weighted method. Furthermore, an area of 15701 ha was given a slope deviation classification of “5 and 10”, an area of 7686 ha a classification of “10 and 20” and an area of 1235 ha a classification of “>20” (Figure 4a, Figure 5). In this FPU, it was observed that the actual slope values had been exaggerated and thus, a subcompartment that would normally be determined a production function area had been erroneously assigned a protection function, consequently leading to the selection of incorrect logging techniques for the compartment.



a) Alahan FPU



b) Kızıltepe FPU

Figure 4. Slope deviation graphs of Alahan and Kızıltepe FPUs

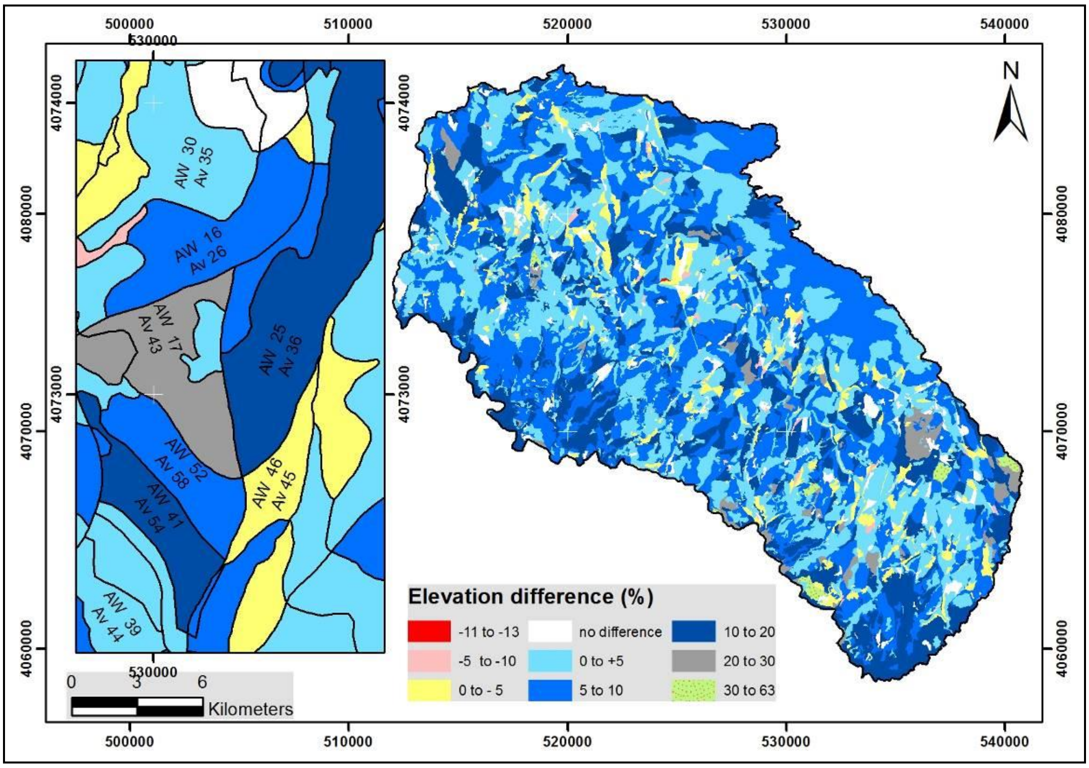


Figure 5. Slope deviation maps of Alahan FPU (AW, Area weighted; Av, Arithmetic)

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When the slope analysis in the Kızıltepe FPU was examined, in a small area of 759 hectares the slope values were very low when calculated via arithmetic mean rather than with the area weighted method. Moreover, an area of 2935 ha was given a slope deviation classification of "5 and 10", an area of 1177 ha a "10 and 20" classification and an area of 268 ha a ">20" classification (Figure 4b, Figure 6).

For the true determination of forest functions and other forestry activities it is a critical mistake to use this method to ascertain low and high slope estimates. Therefore, the area weighted method was chosen for these two planning units and also applied in the preparation stage of the management plans.

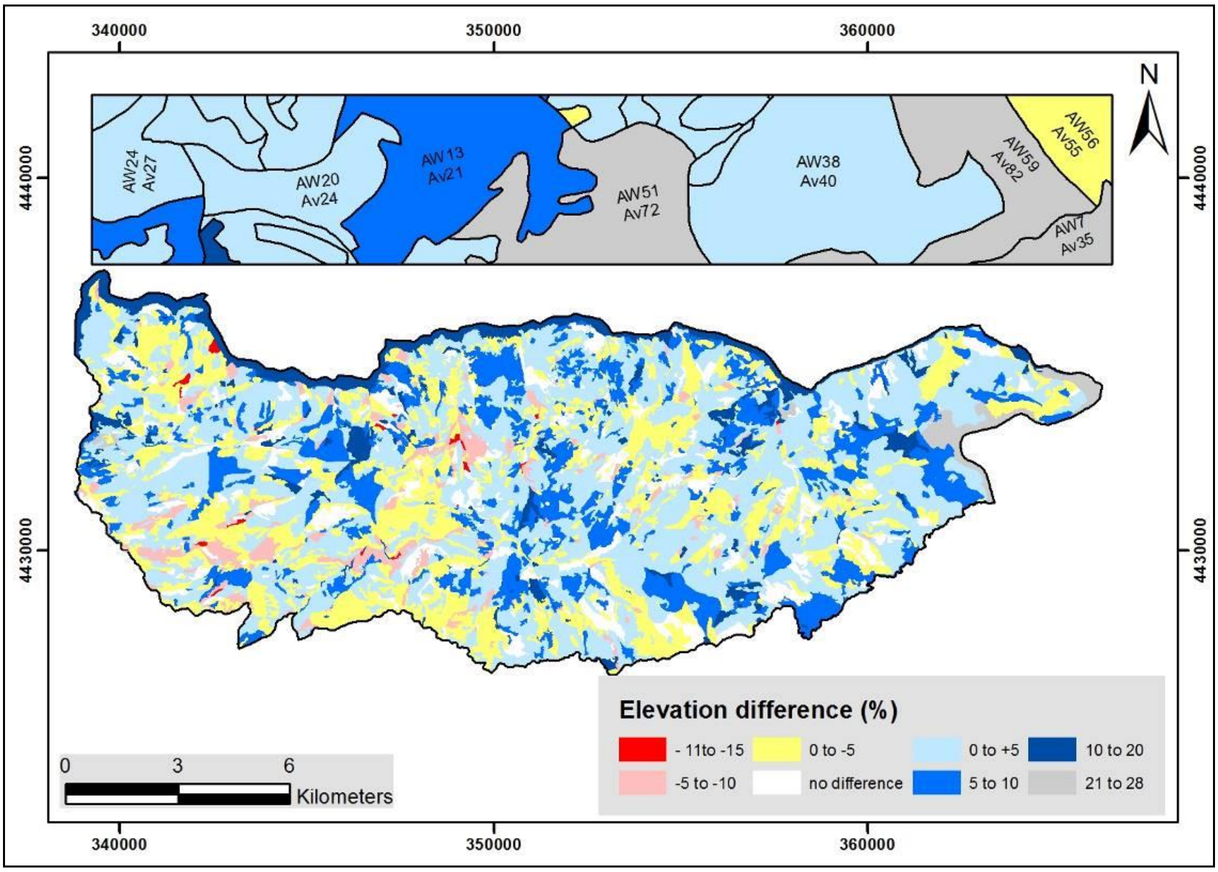

Figure 6. Slope deviation maps of Kızıltepe FPU (AW, Area weighted; Av, Arithmetic)

4. CONCLUSION

The accurate determination of slope values of subcompartments and the use of GIS for mapping in the planning of sustainable forest resources have become increasingly important factors during the preparation of ecosystem-based multiple-use forest management plans. Moreover, slope is important for the selection of logging techniques and is a priority for the regeneration and rehabilitation of degraded forests and other forestry activities. This study demonstrated that slope values based on the area weighted method and using GIS were capable of producing results close to the actual values in the Kızıltepe and Alahan FPUs. Therefore, the area weighted method should be applied when determining forestry activities based on slope.

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HARVEST SCHEDULING AND OPERATIONAL PLANNING FOR NATURE PARKS: A CASE STUDY FOR BEŞKAYALAR NATURE PARK

Uzay KARAHALİL*, Ali İhsan KADIOĞULLARI

Karadeniz Technical University, Faculty of Forestry, Tel: +90 4623772846, Fax: +90 4623257499
E-mail: uzay@ktu.edu.tr

ABSTRACT

Protected areas are designed for a broad range of missions from strict protection to give permission of utilization at a certain rate such as recreation. On the other hand, some of those areas should ideally have forest management plans to provide health and sustainability of forest ecosystems, serving goods and services to public. One of those protected areas is Nature Parks (NP). Turkey has more than 200 nature parks today. Forest and operational plans should be prepared for NP's when intervention is considered to maintain the sustainability, improvement or rehabilitation of forest ecosystem. However, the effects of harvesting and operational activities should be minimized to its environment. In this study, annual allowable cut and wood extraction system was determined for a mountainous Beşkayalar NP in Turkey using integer linear programming model. First, a model maximizing carbon storage at the end of the 100 year planning horizon was developed then, for the initial period, wood extraction systems were incorporated with 0-1 integer model. Two dissimilar operational planning strategies were generated and solved with LINDO™. Eventually, it is understood that the determination of allowable cut and wood extraction system in advance, could bring us benefits especially in environmental awareness, time, labor and timber loss when compared to the classical approaches.

Keywords: Forest management, Harvest scheduling, Operational planning, Wood extraction systems, Beşkayalar Nature Park

1. INTRODUCTION

Although various forest values is noticeable such as biodiversity, aesthetics, soil conservation and water conservation in protected areas, carbon storage is generally prominent and important for the public needs. Nature parks, one of the protected areas statutes, play a critical role in regional and global carbon cycles by storing large quantities of carbon in vegetation and soil and exchanging large quantities of carbon with the atmosphere through photosynthesis and respiration. However, some forestry activities such as regeneration and thinning should be carried out to sustain a broad range of forest values. But in this case, harvesting in NPs is generally limited and sensitive forestry is needed in terms of regeneration or maintenance of the forest ecosystems. During the harvesting operations, extraction of wood material is another important issue in the NPs.

Providing the best harvest scheduling alternatives and selecting the wood extraction system according to different conditions emerges as an important planning problem for many park managers. They find it difficult to determine which stands ensures the highest carbon storage and which system provides the lowest damage or lesser time as well as highest profit or minimum production loss. Various planning techniques such as linear programming, mixed integer programming, dynamic programming, genetic algorithm, tabu search or simulated annealing have been widely used to accommodate harvest scheduling or operational problems (Lussier, 1959; Bell, 1977; Davis, 1987; Oborn, 1996; Eker and Acar, 2006; Flisberg and Rönnqvist, 2007; Bredström et al., 2010; Bont et al. 2015; Çalışkan and Karahalil, 2015). However, it is so important to offer many alternatives using those techniques for NPs including both harvest scheduling and different mechanization techniques in wood extraction systems.

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Most researches frequently include minimization of cost in determining wood extraction studies and environmental comparisons or related analyses are generally ignored during the decision making process. On the other hand, those parameters should be integrated or added to the modeling procedure. Therefore, the aim of this study is to offer different harvest scheduling alternatives and achieve an integration of different wood extraction systems in harvesting in a number of different scenarios of analyses with time and timber loss as well as environmental considerations in a selected NP called Beşkayalar.

2. MATERIAL AND METHODS

2.1. Study Area

The area selected for study, Beşkayalar NP, is located in the Marmara region of Turkey, in the town of Kocaeli, (742950-748600 E and 4497100-4501150 N, UTM ED 50 datum Zone 35N). The study area is characterized by very steep and rough terrain which stretches across a total area of 1 210.6 ha. The average gradient is 63.4%, and altitudes range from 300 m to 1 100 m above sea level (Figure 1).

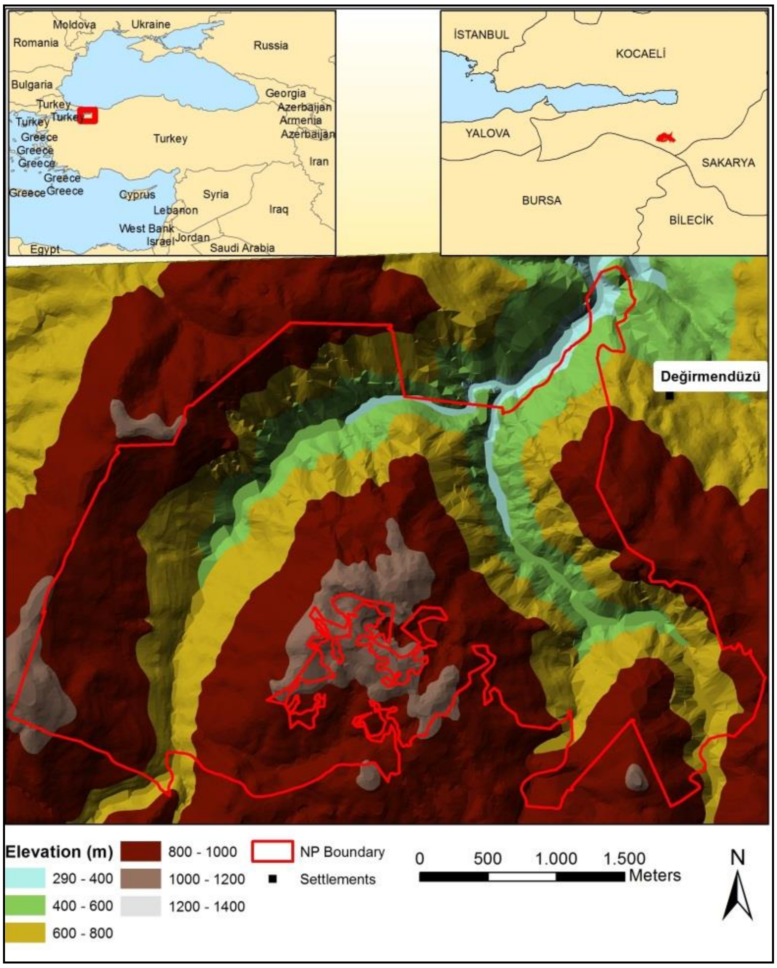

Figure 1. Spatial location of Beşkayalar NP

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Beşkayalar NP has a total of 1 149.4 ha forested and 61.2 ha open lands. The forest within the NP belongs to government and is managed by General Directorate of National Parks. The vegetation type of the study area is primarily composed of the association of Oriental beech (*Fagus orientalis* Lipsky) and Chestnut (*Castanea sativa*) (GDF, 2015a; GDF 2015b) (Figure 2). There is no settlement or population within the Beşkayalar NP (SIS 2016). Road density and road spacing is sufficient for harvesting and other forestry activities.

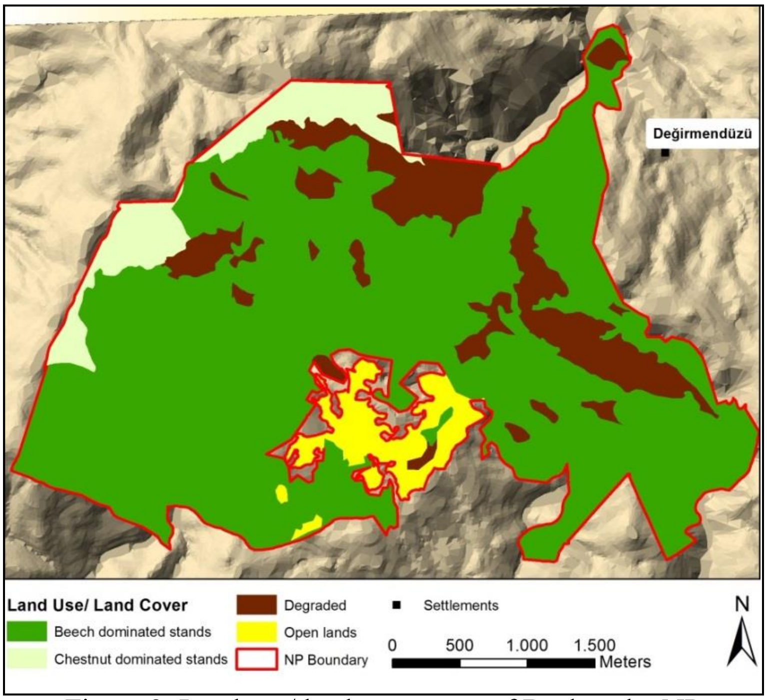

Figure 2. Land use/ land cover map of Beşkayalar NP

2.2. Method of Approach

In this study, our management goal was set as maximizing aboveground carbon storage via forest biomass therefore we determined the level of harvest using linear programming firstly. However, to sustain forest services as long as possible, a constraint was added to the linear programming model with the regeneration areas could not exceed 10% of the total area of stands. This means that every period (in 20 years) 115 ha could be regenerated. After obtaining the outputs, we took the results of the first period in terms of regeneration or thinning compartments and the level of harvest belong to those harvest areas. Then, we determined the wood extraction system in the selected areas. We considered six types of wood extraction systems in this study. In order to achieve the integration of different wood extraction systems in operation planning with a number of different scenario analyses considering environment, time or timber loss was tried.

2.3. Harvest Scheduling

To determine the level of harvest and control the compartments subject to regeneration or thinning, a 100 year linear programming model with a 20-year periods (5 periods) was developed for the study area. Stands were taken as the basic components of the model. Natural stands younger than 100 years were exempted from regeneration. Bare lands were allowed forestation any period during the planning horizon. The level of thinning of any stand was determined as the 10% of the growing stock of the

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related stand. On the other hand, degraded and loose canopy stands (canopy <40%) were only subject to thinning. Regenerated stands grow according to normal yield tables developed by Carus (1998) and Kapucu et al. (2002). Forest inventory data were updated to determine the current forest structure (forest composition) using Kadırga and Yuvacık forest management plans (GDF, 2015a; GDF, 2015b). Mid points of planning periods were used in calculation of yield curve data.

Forest inventory data were used in estimating C storage as the most practical and best approach. Those data are generally collected at landscape scale from population of interest, the regional forest resource, and are designed to be statistically valid. We used Biomass Expansion Factors (BEFs) to estimate the C stock of forest ecosystem (Fukuda et al., 2003; Hu and Wang, 2008; Keleş et al., 2012). When used in conjunction with conversion factors, BEFs convert readily available estimates of merchantable stem wood volumes (m^3 ha^{-1}) to total biomass C values (Mg C ha^{-1}) which can then be used to estimate C budgets. In this paper, C storages were estimated according to IPCC (2006) and FAO (2015). Biomass values for each species were calculated separately using BEFs from the literature. The coefficients by Tolunay (2011) were used for the estimation of C stocks in the above ground part of the forested landscape. These coefficients are valid for the region and have been used in numerous publications for a variety of purposes. To estimate above ground biomass, timber volumes of hardwoods were multiplied by species-specific wood density (WD) and biomass expansion factors. Afterwards, total dry weight biomass of stands was converted to total stored C by multiplying by 0.48 for hardwoods (IPCC, 2006) (Table 1).

Table 1. Some coefficients used to calculate carbon storage in Beşkayalar NP

Tree species	Wood Density	BEF	Carbon factor
Beech	0.530	1.228	0.48
Chestnut	0.480	1.320	0.48

Maximum carbon storage was the main forest management goal in Beşkayalar NP. Therefore, a planning strategy was developed with regeneration area constraints and solved with LINDO™. The following mathematical equations were used to build the model.

Objective Function:

$$Z_{max} = C \quad (1)$$

Subject to:

$$\sum_{j=1}^{n}\left(\sum_{i=1}^{m} a_{ij}x_{ij}\right) - C = 0 \quad (2)$$

$$\sum_{i=1}^{m}\left(\sum_{j=1}^{n} x_{ij}\right) <= T_i \quad (3)$$

$$\sum_{j=1}^{n}\left(\sum_{i=1}^{m} b_{ij}x_{ij}\right) - H = 0 \quad (4)$$

$$(RA_1) \leq 115 \quad (5)$$

$$x_{ij} \geq 0 \quad (6)$$

where,

x_{ij} : Area of stand i regenerated in period j (ha)

m : Number of stands (i=1 to 107).

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n : Silvicultural regenerations options (j=1 to 5, periods)

a_{ij} : Amount of one ha carbon storage value of stand i cut in period j (tonnes)

b_{ij} : Amount of one ha timber production from stand i cut in period j (m^3)

C : Total carbon at the end of the planning horizon (tonnes)

T_i : Area of stand i (ha)

H : Total harvest at the end of the planning horizon (m^3)

RA_1 : Regeneration area in the first period (ha)

2.4. Operational Planning

We considered six types of wood extraction systems. In order to achieve the integration of different wood extraction systems in harvest planning with a number of different scenario analyses considering environment, time, quantity, economic a broad range of information is required. Some factors such as working direction, slope limits, efficiency, costs or operation distance were found to be different according to the selected system. Therefore, to calculate efficiency or cost coefficients of the decision variables, studies previously conducted were used (Aykut et al., 1997; Acar, 1997; Acar, 1998; Çağlar, 2002; Öztürk and Şentürk, 2006; Şentürk et al., 2007). And a well-considered technical parameters of the selected systems using the mentioned literature were given in Table 2 and Table 3.

Table 2. Technical parameters of the selected wood extraction systems

System	Direction	Working Distance	Max. Slope (%)	Distance (m)	Min. carry amount (m^3)
Man power	1	250	30-50	<500	0
Animal power	1	250	0-30	<500	0
Forest tractor	1,2	50	0-100	<=100	0
Small size cable crane	1,2	150	0-100	<=300	300
Medium size cable crane	1,2	300	0-100	>300, <600	300
Sledge yarder	1,2	1000	0-100	<2000	300

In order to calculate the required technical parameter information for each stand, Geographic Information Systems (GIS) were used with ArcGIS 10.2 ™ software. Geographic data used in this study were acquired from topographical maps and digital stand type map. Besides, forest road and hydrology network, which are important for technical limitations for wood extraction systems were used. GIS queries or functions such as "TIN" (Triangulated Irregular Network) data "average slope" or "Generate Near Feature" were also handled in the determination of the working direction and calculating the maximum distances from the nearest roads. Moreover, it is generally known that forest soil, standing trees, and wild life were natively affected depending on the selected wood extraction system. These results or deterioration in forest lands have adverse effects on forest soils, erosion and environmental destruction. Therefore, it is so essential to integrate environmental parameters into the harvesting planning process as well as efficiency and financial considerations. Considered parameters were taken from the mentioned literature given for technical parameters (Table 3).

Damage degree values ranges between 0 and 4, taken from Eroğlu et al. (2009). Damage degree of animal power system were not put into account in the study which has already been mentioned, therefore, the mean values of man power and forest tractor were used in animal power damage degree in this study. Timber loss quantities used in the model were taken from literature and some assumptions were also made to fill the gaps. For instance, timber loss from man power was taken as 17% (Gürtan, 1975). Other values were assumed as 5%, 3% and 1% respectively for the animal power, forest tractor and cable cranes.

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Table 3. Efficiency and financial parameters of the selected wood extraction systems

System	Efficiency (m^3/hour)	Cost (€/hour)	Loss (%)	Damage Degree	
				Standing trees	Saplings
Man power	0.74	26.87	17	1.73	1.92
Animal power	1.51	10.10	5	1.39	1.55
Forest tractor	3.90	10.49	3	1.05	1.19
Small size cable crane	5.29	13.95	1	0.41	0.57
Medium size cable crane	5.65	32.32	1	0.41	0.57
Sledge yarder	5.12	23.24	1	0.41	0.57

2.5. General Structure of the Wood Extraction Model

In order to determine the best suitable wood extraction system, Integer Linear Programming (ILP) was used that has been widely used in forestry and operational planning, as it is a powerful tool for generating an optimal solution. The following mathematical equations were used to build the integer 0-1 model.

Objective Functions:

$$Z_{min} = Damage;\ Z_{min} = Time; \tag{7}$$

Subject to:

$$\sum_{j=1}^{n}\left(\sum_{i=1}^{m} a_{ij}x_{ij}\right) - Damage = 0 \tag{8}$$

$$\sum_{i=1}^{m} b_{i1}x_{i1} - T_{mp} = 0 \tag{9}$$

$$\sum_{i=1}^{m} c_{i2}x_{i2} - T_{ap} = 0 \tag{10}$$

$$\sum_{i=1}^{m} d_{i3}x_{i3} - T_{ft} = 0 \tag{11}$$

$$\sum_{i=1}^{m} e_{i4}x_{i4} - T_{sscc} = 0 \tag{12}$$

$$\sum_{i=1}^{m} f_{i5}x_{i5} - T_{mscc} = 0 \tag{13}$$

$$\sum_{i=1}^{m} g_{i6}x_{i6} - T_{sy} = 0 \tag{14}$$

$$T_{mp}+T_{ap}+T_{ft}+T_{sscc}+T_{mscc}+T_{sy}-Time=0 \tag{15}$$

$$\sum_{j=1}^{n}\left(\sum_{i=1}^{m} h_{ij}x_{ij}\right) - Loss = 0 \tag{16}$$

$$\forall i \sum_{j=1}^{n} x_j = 1 \tag{17}$$

$$x_{ij} = 0 \vee 1 \tag{18}$$

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where,

x_{ij}: Wood extraction system *j* to be applied in stand *i* (man power, animal power, etc.)

a_{ij}: Environmental damage in compartment *i* using wood extraction system *j* (ranges from 1 to 4)

b_{i1}: Required total time in compartment *i* using man power (hour)

c_{i2}: Required total time in compartment *i* using animal power (hour)

d_{i3}: Required total time in compartment *i* using forest tractor (hour)

e_{i4}: Required total time in compartment *i* using small size cable crane (hour)

f_{i5}: Required total time in compartment *i* using medium size cable crane (hour)

g_{i6}: Required total time in compartment *i* using sledge yarder (hour)

h_{ij}: The amount of timber loss from compartment *i* using wood extraction system *j* (m^3)

Accounting variables:

$Damage$: Total damage factor

$Time$: Total spent time (hour)

$Loss$: Total loss (m^3)

T_{mp}: Total spent time for man power (hour)

T_{ap}: Total spent time for animal power (hour)

T_{ft}: Total spent time for forest tractor (hour)

T_{sscc}: Total spent time for small size cable crane (hour)

T_{mscc}: Total spent time for medium size cable crane (hour)

T_{sy}: Total spent time for sledge yarder (hour)

m : Number of stands (m=1 to 107)

n : Wood extraction systems (n=1 to 6; 1=man power, 2=animal power, 3=forest tractor, 4=small size cable crane, 5=medium size cable crane, 6=sledge yarder)

2.6. Developing Alternative Operational Planning Strategies

Different factors affecting wood extraction systems were integrated, and a number of operational planning strategies were developed and solved with LINDO™ to evaluate the trade-offs among wood extraction systems (LINDO, 2016). While one would generate tremendous number of strategies, we selected two reasonable ones to test and understand operational planning toward a better solution (Table 4). Local people have certain rights in timber production process, in Turkey. Therefore, due to the possibility of working local people in timber production, a strategy was generated with allowing certain hours for local people.

Table 4. Descriptions of the operational planning strategies tested

Strategies	Objective Function	Constraints
STR1	Min Damage	no constraints
STR2	Min Damage	*Tmp*>=5000 *hours*

3. RESULTS

Approximately 19 823 m^3 annual allowable cut was determined for the first period of planning horizon. Total regeneration and thinning harvest were 1 039 m^3 and 18 784 m^3 respectively. In addition to this, 57 897 tones carbon stored at the end of the first period. Regenerated stands also reached 115 ha in the same period.

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When all operational planning strategies are considered, and lower total damage was yielded by STR1 as 56.80, on the other hand higher was yielded by STR2 as 68.19. Strategy that generated the lowest time is STR1 (4 196 hours), followed by STR2 (7 372 hours). Total timber loss was the minimum in STR1 as 340 m^3) while generated higher by STR2 as 775 m^3. It was also interesting that, to 50 stands out of 107 could not be assigned a wood extraction system because of the technical parameters. Many factors such as legal arrangements, supply and demand, staff and economic conditions of the enterprise must be taken into consideration when determining the appropriate strategy to implement. The representation of the optimal solution of selected strategy as STR2 was given with the help of GIS in Figure 3.

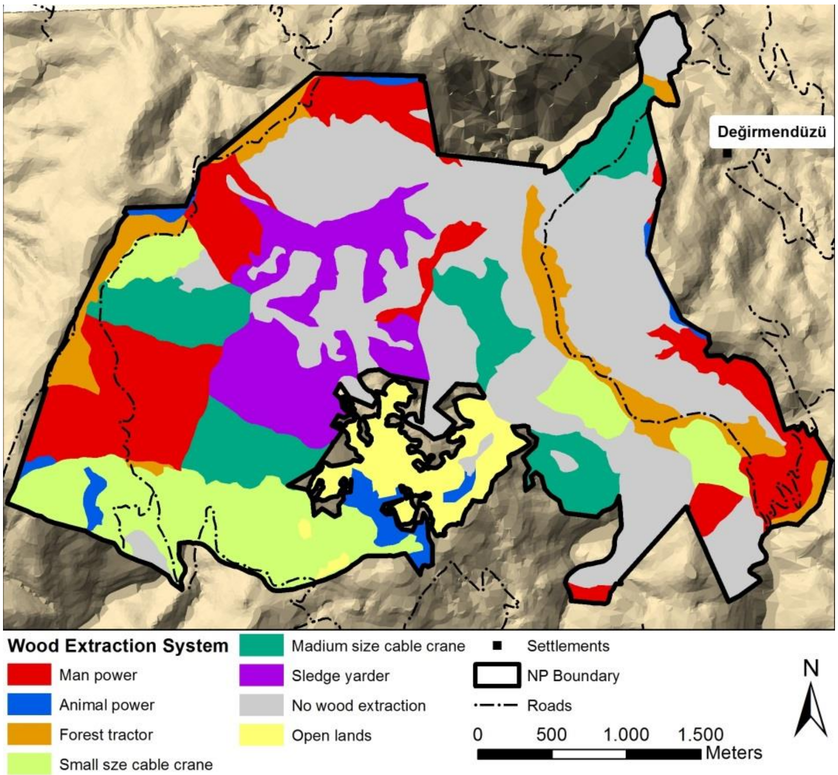

Figure 3. Wood extraction methods according to STR2

4. CONCLUSIONS

This study is out to combine harvest scheduling and operational planning approach with an attempt at observing the rationale behind the use of wood extraction methods, according to conditions which has already been considered. Six important wood extraction methods which are: man power, animal power, forest tractor, small size cable crane, medium size cable crane and sledge yarder were integrated in an operational model using integer linear programming technique. The model that was presented here produced solutions for a typically selected national park with different alternatives including environmental concerns, unlike the conventional approach, time restrictions as well as economical parameters. Approximately 19 823 m^3 annual allowable cut was determined for the first period of planning horizon. Among the developed alternatives, STR2 was selected for minimizing damage and including constraints more than 5000 hours for local people due to working demand and legal rights. When this strategy is implemented, 68.19 of damage will occur, while 7 372 hours will spent, and 775 m^3 of timber will be lost. Similar studies should be expanded with the preparation of wood extraction plans and environmental concerns should be integrated to operational plans numerically.

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EROSION RISK ANALYSIS BY USING ANALYTIC HIERARCHY PROCESS

Mahmut REIS*, Hurem DUTAL, Nursen BOLAT

Kahramanmaras Sutcu Imam University, Faculty of Forestry, Department of Forestry Engineering, 46060 Kahramanmaras, Turkey. Tel: +90 344 2801738 Fax: +90 344 2801961
E-mail: mreis@ksu.edu.tr*

ABSTRACT

Soil erosion which has negative effects on diverse ecosystems especially natural resources, agriculture and dams is one of the most serious environmental problems in the world. Beginning of rational and effective erosion control works is to determine priority areas that are very sensitive to erosion. The aim of this study is to determine and mapping erosion risk of study area by using analytic hierarchy process (AHP) which consider interaction among parameters. Study area is within Terbuzek Stream Watershed which is 100 km away from Kahramanmaras city and about 19696 ha. Slope, bedrock, land use and vegetation density parameters was used with the aim of determining erosion risk with AHP method. Remote sensing techniques (RS) and geographic information systems (GIS) were used for preparing maps regarding the parameters. Pairwise comparison matrix in among parameters and weight scores of the sub-factors were reached by the help of expert opinion and literature. According to results, 0.6% of area was subject to very high erosion risk, while 40.6%, 30%, 27.8% and 1% was subject to high, medium, low and very low erosion risk respectively in Terbuzek Stream Watershed. Consistency ratio of pairwise comparison matrix was 0.04.

Key word: AHP, soil erosion, GIS, RS

1. INTRODUCTION

Soil erosion and related degradation of land resources are highly significant spatio-temporal phenomena in many countries (Fistikoglu and Harmancioglu, 2002). In about one-third of OECD member countries, more than 20% of the agricultural land area is affected by moderate to severe soil erosion from water (OECD, 2008).

The adverse influences of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems, and environments, have long been recognized as severe problems for human sustainability (Lal, 1998). And it has far-reaching economic, political, social, and environmental implications due to both on-site and offsite damages (Grepperud, 1995). Erosion and degradation not only decrease land productivity, but can also result in major downstream or off-site damage than on-site damage (Chen et al., 2010).

The Mediterranean region is particularly prone to erosion. This is because it is subject to long dry periods followed by heavy bursts of erosive rainfall, falling on steep slopes with fragile soils, resulting in considerable amounts of erosion (Van der Knijff et al. 2000). In Mediterranean areas, developing efficient tools for decision making regarding land use management is a major objective (Simoncini, 2009) because of the multiple environmental

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problems arising from the intensive use of the land since long years ago (Tabara and Ihlan, 2008), particularly problems related to erosion (Bazzoffi, 2009).

Soil erosion risk and prognosis maps are an often used instrument for determining the political course-of-action planning in soil conservation. Accordingly, the demand for these maps in Europe has greatly increased within the scope of the Water Framework Directive, cross-compliance regulations and national soil conservation strategies. Usually soil erosion risk maps are obtained based on erosion models (Prasuhn et al., 2013). When dealing with soil erosion modeling one can choose from several different approaches ranging from indicator-based ones to advanced process-based models (Drzewiecki et al., 2013).

In this study we choose GIS based-AHP method developed by Saaty (1980) to assess erosion risk. AHP allows interdependences between soil erosion decision factors to be taken into account and uses expert opinions as inputs for evaluating decision factors (Nekhay et al., 2009). According to Ramanathan (2001), some of the main advantages of AHP method over other multi criteria methods, such as point allocation and multi-attribute utility theory, are its flexibility, its ability to check inconsistencies and its appeal to decision makers. Moreover AHP is considered to reduce bias in decision making and supports group decision-making through consensus by calculating the geometric mean of the individual pairwise comparisons (Zahir, 1999). Finally the AHP method gives the chance to assess and map soil erosion risk (Alexakis et al., 20013).

AHP has various advantages, but involves disadvantages also. The most important one of the disadvantages is to cause mistakes due to stating subjective judgment with number sharply. Therefore, criteria should be evaluated as “high”, “medium” and “low” e.i. The more you have factor, the more you have pairwise matrix. This situation may lead to mistakes and boredom during grading, so selecting fewer factors is recommended for more accurate results (Cengiz and Çelem, 2003).

In this study, it was aimed to generate erosion risk map by using GIS and AHP method which is one of the multiple decision methods and widely used in risk assessments for Terbuzek Stream Watershed located in Kahramanmaras city in Mediterranean Region of Turkey. Parent material, slope, NDVI and land use parameters were used to assess erosion risk in the area.

2. MATERIAL AND METHOD

2.1. Study area

Terbuzek Stream Watershed is located in Goksun district of Kahramanmaras city in Mediterranean Region of Turkey (Figure 1). Study area is 19696 ha and in transition area between mediterranean climate and continental climate. Average annual precipitation is about 613 mm. The average annual temperatures is 8.81 °C, while maximum and minimum temperatures are 36.8 °C (July) and –8.9 °C (January), respectively (GDMS, 2010). Study area has (C2 B'3 s2 b’3) sub humid, mesothermal with first degree, large summer water deficiency and near maritime condition climate type, according to thornthwaite climate classification. The average side-slope and elevation are 29.26 % and 1798 m, respectively. Study area is dominated by forest ecosystem, grasslands, agricultural systems, bare areas and rocky habitats.

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Figure 1. Study area

2.2. Material

In this study, parent material, slope, NDVI and land use parameters were considered to generate erosion risk map.

Table 1. Data type, data source and produced data used in the study

Data type	Data source	Produced data
Contour map (Scale: 1/25.000)	Regional Directorate of Forestry	Slope map
Forest management plan	Regional Directorate of Forestry	Land use map
Parent material map (Scale: 1/25.000, jpeg format)	General Directorate of Mineral Research Exploration	Parent material map
Landsat 8 Satellite image (Date: 2015-07-26)	USGS(General Directorate of Mineral Research Exploration)	NDVI

In order to generate map belonging to these parameters, 1/25000 scale contour maps and forest management plan taken from Regional Directorate of Forestry, 1/25000 scale parent material map provided from General Directorate of Mineral Research Exploration and Landsat 8 satellite image for determining vegetation coverage were used (table 1). ArcGIS/arc Map 10.0 software was used in producing factor maps and RS was used satellite image analysis. Pairwise matrix calculations required for AHP method was made in excel packaged software.

2.3. Method

A GIS based AHP method was used to generate erosion risk map in this study. This method is a robust and flexible decision-making tool that is used for finding solutions of complex multicriteria problems such as a determining the priority of conservation practices (Valente and Vettorazzı, 2008), landslide susceptibility mapping (Pektezel, 2015) or soil erosion risk assessment (Wu and Wang, 2007; Rahman et al., 2009).

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The AHP method consists of four steps:
(1) Structure the problem into a hierarchy having different levels, i.e., goal, criteria, sub criteria, and alternatives
(2) Make pair-wise comparison matrix $A=[aij]n\times n$, where n is matrix size and $aij \geq 0$ $aij \times aji=1$, aij – importance of the ith decision factors over the jth decision factors by using Table 2.
(3) Calculate the relative weights (priorities) of decision factors using prioritization method, e.g. eigenvalue (EV) method (Srdevıc, 2005).
(4) Make synthesis of the priorities. All matrix must satisfy consistency test by using formula 1, i.e., judgment matrix are accepted if consistency ratio (CR) obtained using consistency index (CI) and random index (RI) is less than 0.10 (Vulević et al., 2015) or if also first eigen value equals matrix size (Arslan, 2010) (Table 3).

Table 2. The fundamental scale of absolute numbers (Saaty, 2008)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation A reasonable assumption

$$CR = CI / RI \quad (1)$$

where; CR = Consistency Ratio)
CI = Consistency Index, CI= $(\lambda max-n) / (n-1)$
RI = Random Index, λmax = First eigen value, n = Numbers of factor

Table 3. RI values for different values of n. (Triantaphyllou and Mann, 1995)

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

After obtained matrix consistency, weight points of alternatives (Table 4) were entered maps of alternatives which are vector data in gis environment. Then, these vector maps were converted into raster based grid maps with 10x10 m resolution. Finally, raster based grid maps were overlaid using weighted overlay tool.

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Table 4. Weighted values for factors and alternatives used in model

Criteria	Weight	Alternatives	Weight	Consistency Ratio (%)
Parent material	0.06	limestone	0.173139	8
		micaschists	0.192421	
		marble	0.173139	
		alluvion	0.23065	
		Old alluvion	0.23065	
Slope (%)	0.56	0-3	0.045486	0.25
		3-12	0.09077	
		12-20	0.181562	
		20-35	0.272889	
		>35	0.409293	
Land use	0.12	Dry farming	0.285721	0.16
		Ligneous crops	0.178579	
		İrrigation	0.249997	
		Forest	0.035708	
		Shrub	0.142851	
		Range, sparse shrub	0.107144	
Ndvı value (%)	0.26	<25	0.475079	6.2
		25-50	0.29693	
		50-75	0.178149	
		>75	0.049842	

All maps were generated as 10x10 m resolution in this study. Also, grading of analysis results was made as very low, low, moderate, high and very high according to Jenks optimization.

3. RESULTS AND DISCUSSION

Erosion risk map generated with AHP method by using slope, parent material, NDVI and land use maps was presented below (Figure 2). Major part of the study area has moderate and above moderate erosion risk. 1.17% of study area was subject to very low erosion risk; 27.7%, 30.3%, 40.7% and 0.08% of the area were subject to low, moderate, high and very high erosion risk respectively (Table 5).

Parent materials in study area were mica schist, limestone, marble, alluvion and old alluvion. A major part of study area comprises limestone (Figure 4). Mica schist, especially limestone, and marble generally have high clay ratio, so they were prone to weathering (Yilmaz, 2010).

Slope has a major effect on the ratio of soil erosion (Figure 4). As the slope gets steeper, the higher is the velocity of overland flow, thus increasing the shear stresses on the soil particles. Moreover as slope length increases, the overland flow and flow velocity is also steadily increase, leading to greater erosion forces applied to the soil surfaces (Ranzi et al., 2012). Various researchers determined that erosion increases in parallel with increase in slope under same condition. For example, increase in slope from 5% to 10% leads to increase erosion 3 times (Balcı and Ökten, 1987). Van Zuidam (1985) reported that the steep slopes (30% to 70%) are very susceptible to intensive erosion process.

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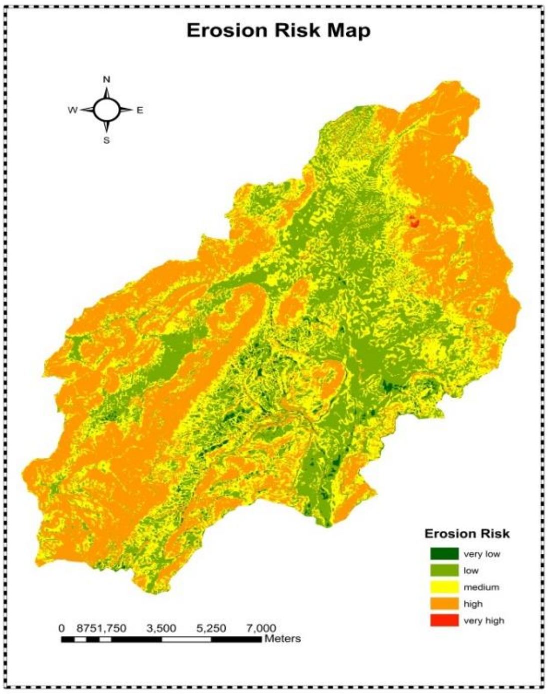

Figure 2. Erosion risk map

Table 5. Erosion Risk Distribution

Erosion risk	%
Very low	1.17
Low	27.7
Moderate	30.3
High	40.7
Very high	0.08

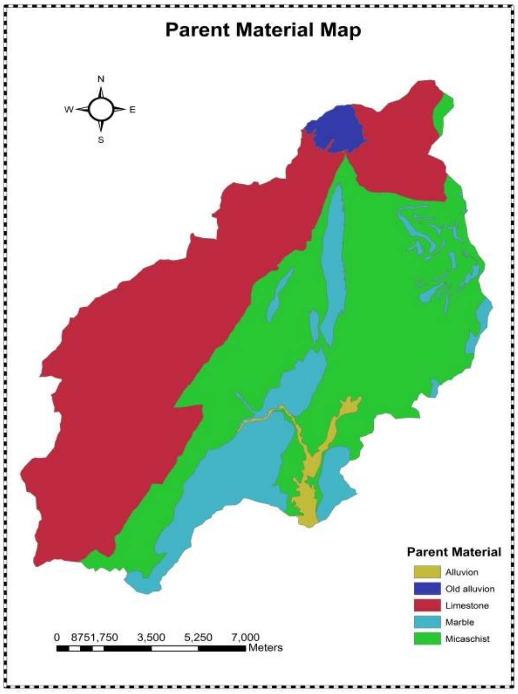

Figure 3. Parent material map

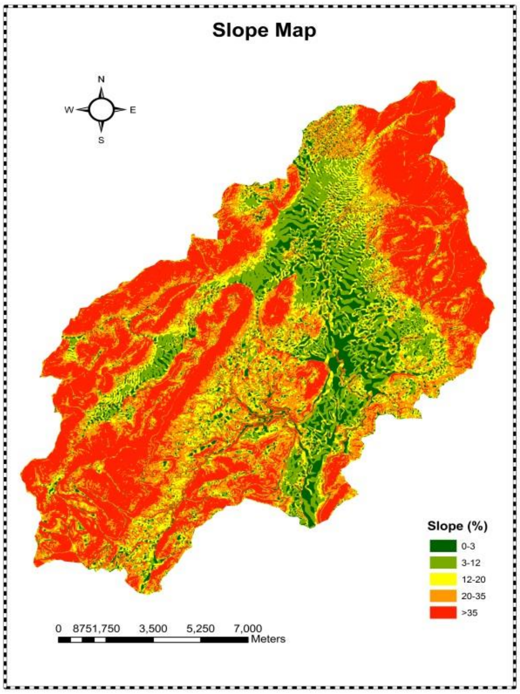

Figure 4. Slope map

Vegetation coverage plays a very important role as a factor mitigating soil erosion by water. First of all, if rainfall is intercepted by a canopy, the impact of raindrops on soil erosion is much lower (Jones et al., 2004). Interception also decreases the amount of runoff. A

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vegetation canopy reduces the flow power as well as its transport capacity (Drzewiecki et al., 2013). Berney et al. (1997) and Ahlcrona (1988) indicated the importance of vegetation coverage and its effect on controlling erosion (Figure 5). Lower vegetation coverage in their study area was one of the most important factors behind higher erosion ratio.

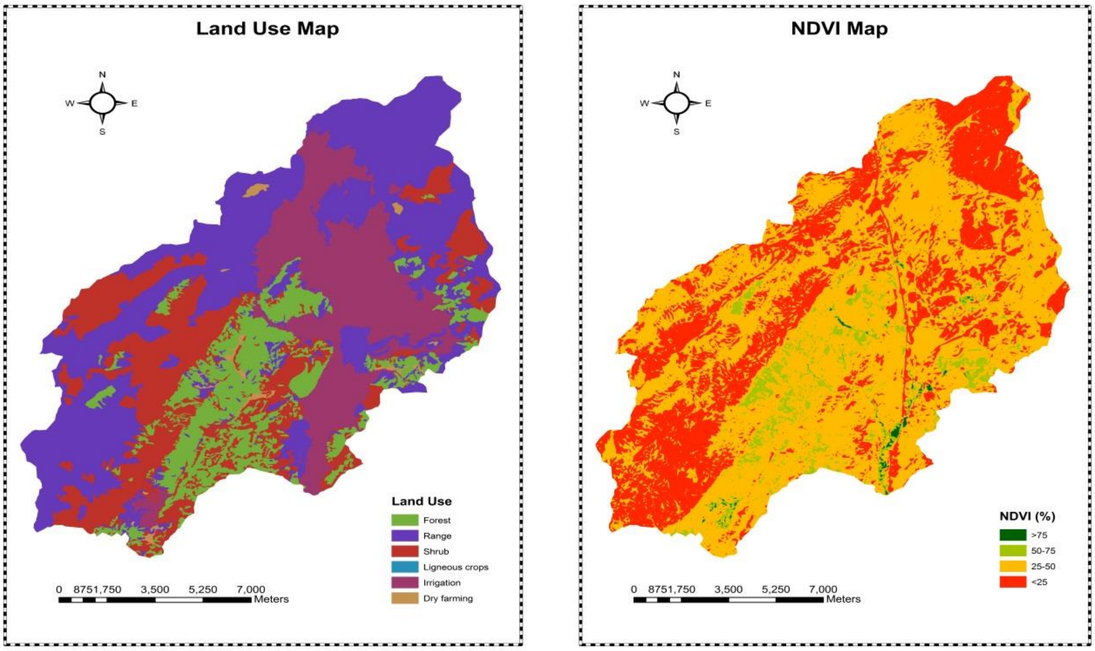

Figure 5. Land use map (left) and NDVI map (right)

Forest litter has an infiltration capacity which can easily infiltrate severe rainfall (Yilmaz, 2010). The vegetation is very prominent in determining the soil erosion by water. The vegetation canopy is effective in controlling runoff effect on soil erosion (Morgan and Duzant, 2008). Consequently, erosion rate in forested area is lower than less vegetated area (Shrestha, 1997). High vegetation coverage in shrub rangeland reduces run off velocity (Morgan and Duzant, 2008). Liang et al. (2003) stated that inappropriate land use practices such as deforestation, overgrazing, intensive crop production, mining, and construction projects aggravated the soil loss. Converting grassland into cropland intensified soil erosion severity (Hao and Dang, 2003).

4. CONCLUSION

This study demonstrated that a major part of study area, especially occupying steep slopes and has lower vegetation, has high erosion risk. Berney et al. (1997) specified that Mediterranean ecosystems are susceptible to soil erosion. Similar opinions stating that semi-arid regions have higher erosion problems were also submitted by the ICONA report (1991).

The AHP method is very useful for forming erosion risk assessment studies in large areas, as long as pairwise matrix of factors and criteria are accurately determined. Because of the spatial and temporal variability of landscape and land use, high labor costs, and the time needed to collect data, there are difficulties in measuring soil erosion over large areas with conventional methods.

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RUNOFF AND SOIL EROSION ON UNPAVED FOREST ROAD

Tuğrul VAROL

Bartın University, Faculty of Forestry, 74100 Bartın, Turkey.
Tel: +90 378 2235171 E-mail: tvarol@bartin.edu.tr

ABSTRACT

This study investigates the studies on the formation of the surface flow on the forest roads without superstructure and the transportation of sediments in Bartın. In order to compare the data from different parts of forest roads, mobile precipitation simulator was used. 30 precipitation simulations were carried out in 15 sample plots. The breakdown of 30 simulations on road parts is as follows: 15 roadbeds and 15 cutslopes. Surface flow coefficient at cutslope is almost 67% whilst it is and 52% in roadbed. Due to high slope and sparse vegetation, the highest soil loss was seen in cutslope with 158 g/m^2. This rate is almost 8 times more than the results from roadbed. It was found that sediment concentration increased in the first 6-8 minutes as of the start of the simulation but then with the decrease of loose surface material, it started to decrease steadily. Statistical analyses revealed that slope, vegetation and rocks, organic material content had a significant impact on surface flow on the parts of the road. As a result, it was revealed that road banks were the main sediment sources in the field of study.

Key words: Forest road, rainfall simulation, runoff, soil erosion, Bartın

1. INTRODUCTION

The forest road construction has increased in Turkey after 1964 with the advent of planned construction period. The then existent forest roads of 20691 km reached to 108808 km in 1998 and 126840 km in 2012 (OGM, 2012). The majority of these roads are unpaved. As a major sediment source in the mountainous areas (Madej, 2001; Best et al., 1995), the role of unpaved roads on the runoff and sediment delivery which were highly ignored later became significant (Jordan-Lopez et al., 2009).

The unpaved forest roads promote the sediment yield in the basin and cause some changes in the soil characteristics and hydrological behavior of slopes (Luce and Wemple, 2001; Jones et al., 2000, Gucinski et al., 2001; Sidle et al., 1985). The change in the natural hill-slope profiles, the nature of cutslope, surface interception, subsurface runoff, vegetation density and soil compaction on the surface may be considered as the determining factors in the process (Swift, 1984). The well-trodden or unmaintained forest roads contribute to the sediment yield more than other land uses do in the basin (Reid and Dunne, 1984; Jones et al., 2000; Megahan, 1988). It is encountered the increase in the sedimentation and peak flows in the basins where road network is of heavy traffic. Since the surface runoff moves from cutslope to the stream bed, it acts as the linearly related systems (Jordan-Lopez et al., 2009; Arnaez et al., 2004). Therefore, the unpaved forest roads may contribute to the hydrological erosion process even in the light rainy weather (Ziegler et al., 2001).

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The unpaved forest roads also have such negative effects as reducing yield, impairing soil structure and changing closure as well as accelerating erosion activity in the forests (Jordan-Lopez et al., 2009). This study aims at ascertaining the amount of surface runoff and soil erosion caused by unpaved forest roads in Bartın region. Rainfall simulation tests were used in the study. Firstly, the measurements were made in different parts of unpaved forest roads (cutslope and roadbed) and the data obtained was correlated with the field characteristics. Lastly, the findings were compared with the data obtained in similar research. Although it is hard to correlate the findings acquired as a result of rainfall simulation tests used in the study with the outcomes of natural events, it is commonly used due to the ease of use and low cost (Miller, 1987; Seeger, 2007).

2. MATERIAL AND METHODS

2.1. Study Area

This study was carried out at the Arıt Sub-District Directorate of Bartın Forestry Department positioned approximately at the longitude of 32˚ 24'E and the latitude of 41˚ 45'N. The approximate size of the study area is 24048 ha. The relief of the area is irregular and the highest part of the territory reaches up to the 1700 m from the sea level. The region is constituted of terrains date back to Primary Carboniferious Period, Secondary Cretaceous Period and Quaternary Period. These terrains involve limestone, sandstone, clay, gravel, schist, marn, serpentine, conglomerate, andesite, spilite and pyrophillite (MTA, 1993). While the geological structure is complicated in the coastal line, it is plainer inlands. The research area is of six different big earth groups (KHGM, 1989).

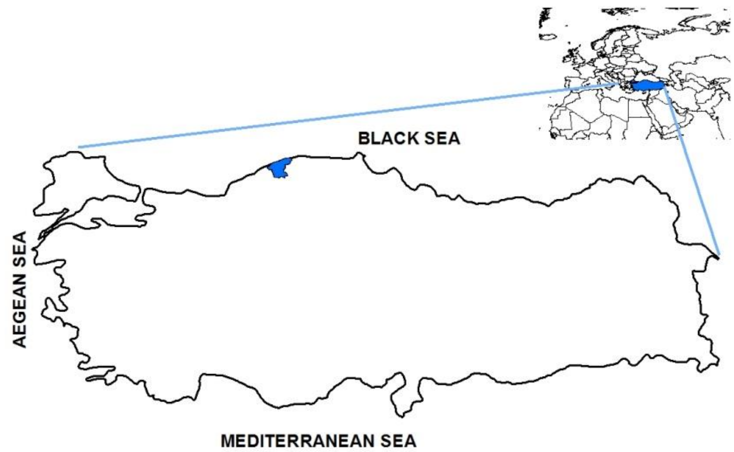

Figure 1. Study area

In the study area (Figure 1), annual rainfall averages between 740 and 1300 mm. When the climate data from 1970s up to date is analyzed, more than 62% of total rainfall is seen in fall and winter season. The amount of precipitation is very similar to each other in spring and summer seasons. The region faces heavy winter conditions in the higher parts where snow melts and is piled up repeatedly. The lowest and highest monthly average temperature has been respectively 4˚C in January and 22˚C in July in the last 40 years.

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Vegetation differs depending on the variety of human activities, soil characteristics, altitude and sunlight exposure. Beech (Fagus orientalis) is predominantly existent among the forest vegetation, and hornbeam (Carpinus betulus) and oak (Quescus sp.) are prevalent species.

2.2. Method

In the study, the methods also previously used by Arnaez, Cerda, Jordan-Lopez and Lasana were administered. Such methods may be categorized into three as the ones used in simulation tests, soil analyses and data analyses.

2.2.1. Simulation tests

The unpaved forest roads are encountered especially at the high altitudes and those between 300 m and 550m above sea level were chosen in this study. They are 4 m wide as B type side road and the mean slope of them is 10%. The roads are generally used by land vehicles and light vehicles, a range of 5 to 10 of which use it daily. Rainfall simulation tests were utilized in order to specify the sediment yield of the runoff and the three different parts of the road (roadbed and cutslope). The study was carried out in 30 road segments. The cutslope is steeper than natural slopes because the section is formed by engraving them. The cutslopes, being of a slope of 30-50%, are generally plain and slightly concave. The cutslopes are up to 3 m high and of a little vegetation. The roadbed is the unpaved part where vehicles are on the move. As sample plots, the parts where ditches and culverts appear were purposefully selected.

It was identified the surface characteristics of sample plots in each part of the road examined. In the study were used the methods administered in the studies of Jordan-Lopez, Arnaez and Cerda by making use of rainfall simulator. The simulator in the study was in the form of square prism. The simulator was surrounded by glassware in order not to be affected by winds. The rain drops were allowed to fall in a limited area of 40x40 cm^2 by means of a steel frame. This frame was positioned in a way to lead the runoff to outlet of the sample plot. By digging a pit in the lower edge of the sample plot, the runoff led to this point was consolidated in the plastic frame. The runoff water and sediment samples for each rainfall test were recorded every 3 minutes. Besides, for each sample plot, the runoff time, the runoff coefficient, mean runoff, sediment yield and total soil loss were measured.

As Agassi et al. (1994) suggest, distilled water was utilized since the chemical structure of water might possibly affect the soil reactions. Soil samples from 1 m below and above each sample plot were collected before the simulation. These samples enabled to determine the content of organic matter in the surface soil, the soil texture and humid. The vegetation on the surface and stone cover were measured by using grid cells of 0.25 m^2’. The slope of each sample plot was measured by using clinometer. The duration of simulation tests was calculated as 30 minutes. They were carried out from June to August in 2012.

2.2.2. Soil analysis

Before simulation tests, earth samples of 0-20 cm from the sample plots were taken for physical and chemical analyses. The distribution of particle sizes and organic matter content of soil were determined with the earth samples taken 0.5 m underneath the surface in the

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sample plots. The particles greater than 2 mm were identified with wet sieving while smaller ones were identified according to USDA (USDA, 1996).

2.2.3. Data analysis

The effects of slope, percentage of stone and vegetation cover on soil erosion on different road parts were evaluated with the correlation, regression and ANOVA analyses. The relationship between the runoff and simulation period were identified with a logarithmic function (y=a In(x) + b). All the calculations in the study were made through R programme (R Software, 2013).

3. RESULTS AND DISCUSSION

3.1. The data of sample plots

The topographic and other characteristics of sample plots were briefly introduced in the Table 1. As the ANOVA test suggested, it was identified that there were differences between the different parts of the road in terms of slope and vegetation cover. The mean values for cutslope and roadbed were respectively 34.23%, 5.67%. While the rock fragments were 9.80% on the roadbed, in the cutslope were 17.70%. Rock fragments were seen to be placed in line with the road surface. The frequent vegetation was seen 9.00% on the cutslopes. Because of the low traffic in the area, the roadbed was of a vegetation cover of 7.40%.

The physical characteristics of soil are listed in the Table 2. The soil is mainly loamy or silty loamy. The highest rate of clay is seen to be on the cutslope and the analysis results of variance show that there are no changes between the different parts of the road in terms of sand, silt and organic matter but in terms of clay. Two parts of the road is rich in silt (cutslope 46.10%, roadbed 52.34%) and silty loamy. It was also identified that these roads are no different than one another in terms of the contents of organic matter.

Table 1. Properties of sample plots

	Cutslope	**Roadbed**	**ANOVA, p**
Slope			
Avarage	34.23	5.67	0.004
Standard deviation	5.08	4.26	
Rock %			
Avarage	17.70	9.80	0.245
Standard deviation	7.11	8.62	
Plant cover %			
Avarage	9.00	7.40	0.013
Standard deviation	5.92	4.35	

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Table 2. Soil characteristics

	Cutslope	Roadbed	ANOVA, p
Sand			
Avarage	31.23	30.53	0.834
Standard deviation	1.61	6.60	
Silt			
Avarage	46.10	52.34	0.103
Standard deviation	1.69	4.76	
Clay			
Avarage	22.67	17.14	0.016
Standard deviation	0.99	3.06	
Organic matter			
Avarage	1.16	1.13	0.962
Standard deviation	0.27	1.10	

3.2. The data belonging to the simulation tests

In Figure 2 is the progress of data of the runoff obtained in the simulation tests. The data in the graphic connotes the mean rate of on-the-spot simulation test results. The runoff skews are logarithmic and the runoff for each road part is seen to increase swiftly. Later in the process, the runoff progress horizontally as a result of soil saturation on the surface and weak absorption by capillarity.

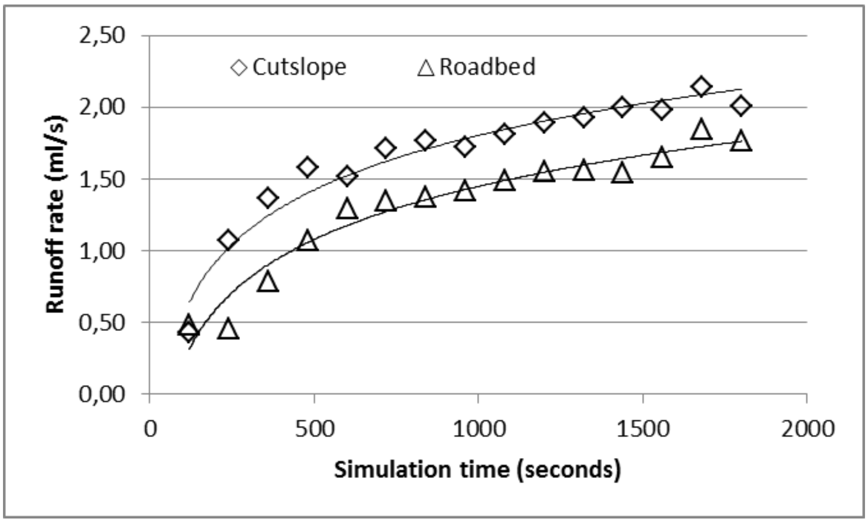

Figure 2. Runoff values belonging to the section of forest roads (Cutslope: y=0.547In(x)-1.978; r^2= 0.951, p=0.000, Roadbed: y=0.533In(x)-2.237; r^2= 0.944, p=0.000).

In 30 minutes, the earliest move for the runoff in time is after 47.26 seconds on the roadbed while it starts in 64 seconds on the cutslope. The analyses of variance suggest that there are significant differences in terms of runoff data among these two parts of the road. On the cutslope, the runoff is limited within 52 and 75 seconds, it is limited within 30 and 64 seconds on the roadbed. The highest coefficient of runoff, as seen in the Table 4, is encountered with

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67.18% on the cutslope, which is of values at the interval of 59.40%-76.80%. The same coefficient is designated to be 51.89% for the roadbed.

3.3. The effect of the field characteristics on runoff

When analyzed the R-spearman and p values between the runoff and field characteristics, it was found out that there is a significant positive correlation the runoff and slope for the cutslope (R-spearman=0.632, p=0.011*) and statistically no significant correlation for the roadbed. It was also specified that the aspect has no impact on the runoff for each part of the road. It shows that the percentage of stone affects the correlation negatively (respectively R-spearman -0.731, -0.698, and p values 0.0002*, 0.024*, 0.005*) for each part of the road (cutslope, roadbed). The greater stone percentage on these road parts is, the more delayed the runoff is. It was determined that one of the most efficient factors on road parts was vegetation cover (R-spearman and p values for the cutslope: -0.757, 0.001*, for the roadbed; 0.046, 0.870). Vegetation density on the roadbed is low because of even slight traffic mobility and vegetation cover is not effective on the roadbed. Vegetation also increases the infiltration rates but decreases the runoff coefficient. It could not be measured that the content of organic matter does not statistically affect the cutslope while it was determined that another part of the road have a negative correlation with the runoff (Table 3).

Table 3. The results of rainfall simulation tests.

	Cutslope	Roadbed	ANOVA, p
Runoff time (s)			
Avarage	64.05	47.26	0.000
Standard deviation	6.45	26.61	
Runoff (ml/s)			
Avarage	1.66	1.31	0.000
Standard deviation	0.42	0.41	
Coefficient of runoff (%)			
Avarage	67.18	51.89	0.000
Standard deviation	9.67	5.01	

3.4. Sediment yield

The highest sediment yield and erosion values were seen on the cutslopes. The total soil loss on the cutslopes varies from 148.44 to 181.44 g/m^2 and the mean rate is 158.25 g/m^2. The soil loss on the roadbed is approximately 20 g/m^2. These distinctions stems from slope, stone cover and vegetation cover. A similar case is valid for peak points of sediment data and the highest value is seen to be 16.05 g/L on the cutslope.

The variance in the sediment concentration on the runoff water is seen in the Figure 3. The sediment concentration for each part of the road is in a linear increase in the first 6-8 minutes and then the increase is immobilized. While the sediment concentration on the cutslope is 5.65 g/L after the start of rainfall, it reaches up to 16.05 g/L in 8 minutes. The maximum sediment yield on the roadbed is 3.90 g/L in the first 8 minutes.

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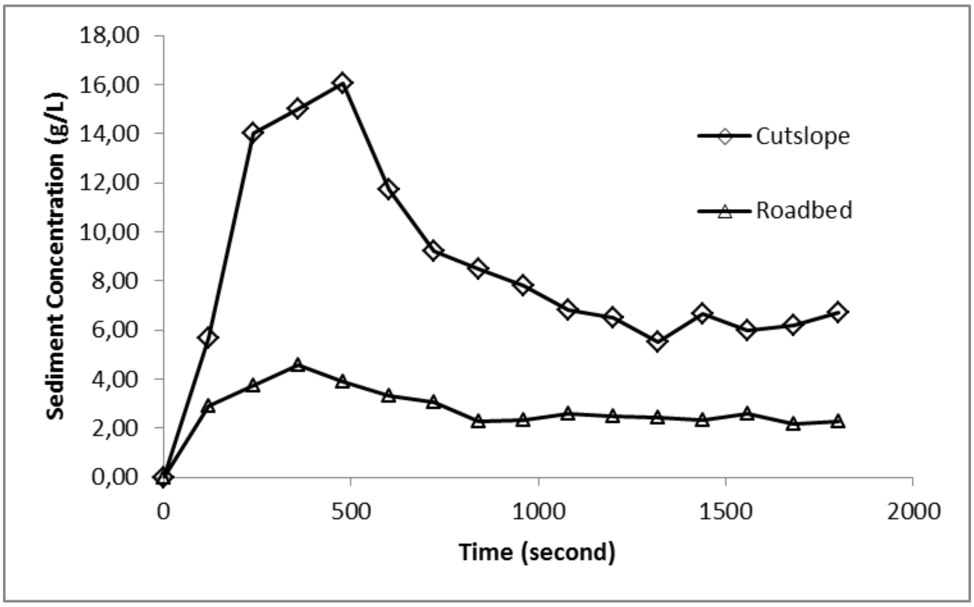

Figure 3. Sediment yield in unpaved forest roads

It was found out that there are no significant correlations for the cutslopes between the soil loss and field characteristics but some significant correlations for the another road part. There is a negative correlation between the percentage of soil loss and stone cover on the roadbed (R-spearman=-0.671, p=0.006*) and the amount of sand (R-spearman=-0.647, p=0.009*) and organic matter (R-spearman=-0.616*, p=0.014*) but a positive correlation with the amount of clay (R-spearman=0.569, p=0.026*).

Both the runoff coefficient and the soil loss are high on the cutslopes (an average of 87% and 157 g/m^2). The cutslope, having a high percentage of mean slope, is influenced more by the runoff. The impact of slope on the runoff is also emphasized by (Diseker and Sheridan, 1971) and (Luce and Black, 1999). As a result of freezing and thawing process, the loosening of the material on the cutslope and the plant cover on it mitigates this erosive activity (MacDonald et al., 2001). As seen in the Table 1, the cutslopes in the study area include a limited ratio of vegetation.

The sample plots on the roadbed show high percentages of runoff and low soil loss because the compaction on the roadbed reduces the capacity of infiltration and increases the runoff yield on the unpaved roads. Stone particles embedded on the surface both increase the surface runoff and mitigate the infiltration (Descroix et al., 2001; Jordan-Lopez et al., 2009).

The average data for runoff on the roadbed and runoff coefficients are higher than the data soil loss and sediment concentration. The compacted soil and surface layer increase the generation of surface runoff by reducing the capacity of infiltration (Gregory et al., 2006). Meanwhile, the existent stone cover augments the runoff while the compacted surface layer reduces the sediment concentration in the runoff (Reid and Dunne, 1984).

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3.5. Comparison of this study with other resources

The data obtained from the simulation tests correspond to those from other research studies. When analyzed the data from other research (27 studies carried out by (Cerda, 1993; Cerda, 1997; Cerda, 2007; Jordan-Lopez and Martinez-Zavala, 2008; Arnaez et al., 2004; Arnaez et al., 2007; Lasanta et al., 2000; Lasanta et al., 2001; Jordan-Lopez et al., 2009) and that of this study, there is a correlation between the runoff coefficient (%) and the soil loss (g/m^2h) as $y = 0.1045x^{1.6385}$ (x signifies the runoff coefficient and y signifies the soil loss) and the R^2 value of this correlation is 0.704.

4. CONCLUSION

The simulation method is practical for measuring the runoff and sediment yield but it provides with the limited data. It is hard to estimate the sediment yield with this method on a large scale. Despite its deficiency, the simulation results may be utilized so that the data from different parts of the road could be compared with one another (Arnaez et al., 2004; Jordan-Lopez and Martinez-Zavala, 2008).

The soil loss is usually due to the road (Wemple et al., 2001; Fransen et al., 2001). The unpaved forest roads contribute a lot to the amount of sediment by changing hydrological functions of the slopes (Arnaez et al., 2004). Especially cutslopes, compared to other parts of road, have more potential to be exposed to erosion (Jordan-Lopez and Martinez-Zavala, 2008). One reason for this may be considered that the unpaved forest roads change the hydrological behavior of cutslopes and cause the runoff to accelerate ((Luce and Wemple, 2001; Jones et al., 2000, Gucinski et al., 2001; Sidle et al., 1985).

The data obtained from the study show that cutslopes yield more sediments compared to other road parts. The percentage of slope, vegetation and stone cover on the road parts can explain the percentages of runoff and soil loss. The density of vegetation is seen to reduce the soil loss on the cutslopes. No correlation is identified since there is a low density of vegetation on the roadbed. Similarly, Cerda (2007) also states that natural vegetation reduces the soil loss. Stone cover and vegetation stand out as important factors for cutslopes.

Batalla et al. (1995) suggests that the unpaved forest roads make approximately 10% of contribution to the sediment yield in the basin. In these studies, it is explained that 70-80% of the suspended sediment amount stem from the unpaved forest roads (Froechlich, 1995). For that reason, the forest roads need designing in accordance with topography in order to reduce sediment yield. Hence, protecting the slope surfaces plays a crucial role in controlling erosion (Jordan-Lopez et al., 2009). It is needed for reducing the soil loss to narrow the slope angles, vegetate or cover with protecting materials. Moreover, it would be a complementary role that drainage system is suitably designed.

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POSTER PRESENTATION

COMPARISON OF FOREST PLANNING SYSTEMS IMPLEMENTED IN TURKEY SO FAR

İnci ÇAĞLAYAN

İstanbul University, Forest Faculty, Department of Forest Management, İstanbul, Turkey.
Tel: +90 544 4005097 E-mail: inciyaylaci@istanbul.edu.tr

ABSTRACT

Forest management plans were made with traditional planning approach from 1918 until 2008 in Turkey. The Plans were completed across the whole country in 1972. After 1978, it has begun to implemented different planning systems in some regions. Forest management plans have began to be made with functional planning approach since 2008. In this study, traditional plans implemented according to the principles of the Forest Management Regulations in 1973 and model plans implemented by different organization groups in different regions of our country (Operational management plans organized within the framework of the Mediterranean forest utilization project, Model plans organized within the framework of the Western Black sea broadleaved species project and Functional plans) were reviewed. Review of plans were compared in terms of forest inventory, planning unit sizes, the management objective, the criteria for distinguishing working circles, the rotations, the periods lengths, the optimal forest structure, the regulation of silviculture practices, the management regulation, and functions. As a result, similarities and differences between the plans were analyzed.

Key words: Planning systems, traditional plans, model plans

1. INTRODUCTION

In the 1960s, the solution to the underdeveloped state of forestry was sought in the promotion of industrial forestry activities. However, increasing deforestation and energy crisis in the 1970s led the sector to consider and resort to reforestation. Following the ecological crises of the 1980s, the 1990s was characterised by efforts to ensure the development of “sustainable” forestry, with international support (Rio92) (Mayers & Bass 2004). Democratization efforts beginning in the early 2000s have led to increasing “social participation” in forestry planning. Conventions signed by Turkey on the environment and forestry have, first of all, harmonised Turkey’s regulations with the European Union’s forestry regulations, and also made Turkey assume important obligations at an international level. All these developments have engendered new planning concepts in forestry. To ensure the integration of the forestry sector with other sectors, the narrow production-based perspective has been abandoned in favor of a multi-objective and multi-function planning that utilises decision-support systems.

All of these have revealed in the beginning of 1990s that planning the forests of Turkey only for a single goal is not a realistic approach (Asan, 1995). Asan and Yesil (1993) indicate that there are four different types of forestry plans in Turkey and different procedures are being followed while prepared; and that these plans are separated into two groups as classical and model plans. Classic plans are prepared with same procedure all around Turkey. Model plans are separated into three different groups by the geographical regions and their appearance, these groups are: 1- Mediterranean region planning models, 2- Western Black Sea region planning models, 3- Ecosystem-based functional planning (ETFOP) (Asan and Yesil, 1993, Zengin et al. 2013).

The aim of this study is to reveal and examine the phases passed by the four different planning systems since the beginning. For this objective, the classic plans and model planning samples (Gazipasa-Mut, Turkish-German collaborative projects, FRIS project, ETFOP based on 2008 regulations, ecosystem-based multiple use forest management planning approach (ETCAP)) were prepared by taking 1973 and 1991 forest management regulations, systematized and examined.

2. MATERIALS AND METHODS

We examined the 1973 and 1991 Forest Management Regulations and model plan practices in Turkey, which were prepared according to a classical planning approach. Comparisons were performed according to the following criteria: applied inventory methods, the adopted planning unit sizes, the management objective, the criteria for distinguishing working circles, the rotations, the periods lengths, the optimal forest structure, the regulation of silviculture practices, the management regulation, and functions The results of these comparisons were then tabulated.

3. CONCLUSION

An examination of periodic information and data reveals that planning systems in Turkey have generally followed changes around the world. As shown in the Table, these changes included: the diversification of the inventory for different forestry resources and management objectives; digital processing of data; the addition of satellite images and aerial photographs to remote sensing methods; the use of decision support systems in organizing utilisation; and studies on ecosystem-based planning (Table 1a).

Developments in the field of forestry inventory: According to timber harvesting understanding of classical planning in 1973, sample plot number and sizes are determined by forest management committees. Systematic sampling was put into operation in 1991 regulation. For model plans, sample measurements in different intervals and distances that will serve the management objective were made. Although similar to classical planning approach, the inventory at a different intensity was originated from the fact that forests were separated into the statuses of "production" (coppices and even aged forests) and "preservation" (continuous forests and uneven aged forests) (Table 1a). In FRIS (Forest Resource Information System) project, by considering the development age and supporting by point measures (relascope), the systematically distributed sample plot number was reduced in inventory. In functional planning, all types of inventories were used in order to reveal the functions of forests (Table 1b).

As management objectives in the Gazipasa-Mut plans and other plans done according to 1973 regulation were focused on timber harvesting; objective of Ecosystem Based Planning was remarkable in Turkish-German collaborative project. In functional planning, management

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objective were determined, including the criteria of Ecosystem based Planning, by considering the functions of the forests (Table 1c).

The rotations in "classical" planning were determined according to the criteria of forest yield and forest health used in timber harvesting. In order to obtain the highest amount of logs in the shortest time at Gazipasa-Mut planning, short rotations (40 years) was used first, but it was extended later. In Turkish-German collaborative project, rotations were determined according to the functions of forest and the quality increases of the product classes to be obtained. The rotations are generally shortened in Turkey; whereas they were tried to be extended with this project. In functional planning, even though the rotations are required to be determined according to the functions of forests; this is being decided according to classical criteria such as forest health, type of tree, site class etc. In spite of these, the criteria of determining the rotations on functional planning approach have the widest array among other plans (Table 1d).

The determination of optimal forest structure in the classic planning generated by 1973 regulation was only based on existing yield tables or empirical results. The optimal forest structure in Gazipasa-Mut planning were determined by using "temporary" yield tables with no determined accuracy rates and a simulation model of which the applicability was argued later. The indetermination brought in Turkish-German collaborative project by the foreign yield table used for tree types; and the silvicultural bases of planning did not permit the revealing of target forest and optimal forest structure. In functional planning, the optimal forest structure of timber harvesting are determined from yield tables etc. But the lack of information in order to maximize the service functions of forests does not allow the determination of optimal forest structure (Table 1e).

In classical planning, management regulation is made according to the necessities of the management method used according to the forest form and target forest. As annual area method based on clearcutting and planting is applied in Gazipasa- Mut planning, no potential case was determined but ETA 100 annual simulation was revealed. The management regulation in Turkish-German collaborative project was determined with "the yield regulation by age classes" in even aged forests and "silvicultural methods" in continuous forests. In functional planning, utilization of all management methods are anticipated according to different functions of forests and forms of forests (Table 1f).

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*Table 1a. Comparison of Forest Planning Systems Implemented in Turkey so far

Comparison Criteria		CLASSIC PLAN		GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP	
		1973 Regulations	1991 Regulations					Classic	ETÇAP - Simulation & Optimisation
Plan Type		Classic Plan	Classic Plan	Model Plan	Model Plan	Model Plan	Model Plan	Classic Plan	Model Plan
Forest Inventory	**Sampling Method, Circular Plot Grid And Size**	1-Systematic sampling 2-Non-systematic sampling		1-Simple random sampling	1-Systematic sampling 2-Non-systematic sampling	1-Systematic sampling 2-Non-systematic sampling	1-Systematic sampling, 2- the six tree method, 3-the angle count method…etc.	ETÇAP Classic planning are consistent in all planning requirements made with wood production objective in the functional planning, (Classical Planning Approach) The only difference at ETÇAP software is associated with GIS	There is currently no multi-faceted inventory that would enable ecosystem planning. According to ETÇAP simulation and optimization, the ecosystem inventory must be prepared dynamically according to the form and intensity of utilisation, and in a way that allows classification on a stand basis, determines numerical values relating to the ecosystem, and demonstrates time-related changes.
		1-Circular plots 2-Square plots (Coppice forest)		1-Square plots	1-Circular plots 2-Relascope plots	1-Circular plots 2- Relascope plots	1-Circular plots 2-Square plots (Coppice forest)		
		The number of sample plots and the interval distances should be determined by the forest management committees.	In all types of forests, the interval distances should be 300 m x300 m	17 sample plots used in good site class, while 18 sample plot used in poor site class.	Increased from 100 m x100 m in 1990 to 100 m x 300 m in 1995, and to 300 m x 300 m in 1997, later being reduced to 250 m x 250 m.	Systematic circular plot grid is 600 m*600 m and plots are located only productive forest (Circular plots are needed only for models). From a sub-compartment standpoint, the inventory is meant to create a solid database for management planning.	Systematic circular plot grids are 300 m x 300 m in even aged forests, 150 m x 300 m in selection forest, 300 m x 300 m in continuous forests, and 600 m x 600 m in protect and forests utilised for service objectives.		
		Forest management committees determine the size of the sample plots. In coppice forests, 1 to 3 square-plots with an area of 100 m^2 each will be used.	Sample plot size, depending on level of cover: 200, 400, 600 and 800 m^2. In coppice forests, 1 to 3 square-plots with an area of 100 m^2 each will be used.	Sizes of circular plots: 1000 m^2 (31.6 m x 31.6 m)	Sample plot size, depending on level of cover: 400, 600 and 800 m^2.	Sizes of circular plots: 400 m^2, 600 m^2 and 800 m^2. Circular plot for vegetation covers and high saplings (>1m height), and all afforested areas the size is 50 m^2. Elsewhere the circular plot for small saplings (≤1m height) is 10m2. Coppice forests: 100 m^2	In even aged forests, depending on the level of cover: 400, 600 and 800 m^2. 600 m^2 in uneven aged forests. In coppice forest; on condition that each compartment has completed its rotation or is close to the term of their rotation period, 1 to 3 squares of 10x10 m, equaling 100 m^2, will be used.		

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*Table 1b. Comparison of Forest Planning Systems Implemented in Turkey so far

	Comparison Criteria	CLASSIC PLAN		GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP	
		1973 Regulations	1991 Regulations					Classic	ETÇAP - Simulation & Optimisation
Forest Inventory	Inventory Unit	Stand type		Stand type	sub-compartments	sub-compartments	Stand type		sub-compartments
Forest Inventory	Inventory Method	(Aerial photographs + terrestrial measurements) Combined inventory method					(Aerial photographs + satellite images + terrestrial measurements) Combined inventory method		
Forest Inventory	Inventory Type	1) Area 2) Growing stock and increment 3) Site 4) Accessory Products		1) Area 2) Growing stock and increase 3) Site 4) Accessory Products (resin) 5) Managed forest economics	1) Area 2) Growing stock and increment 3) Site	1- Area 2- Growing stock and increment 3- Site 4- Accessory product	1) Area, 2) Growth stock and increment,3) Non-wood forest products, 4) Site, 5) Biological diversity, 6) Health status, 7) Socio-economic status, 8) Non-product functions of the forest	ETÇAP Classic planning are consistent in all planning requirements made with wood production objective in the functional planning. (Classical Planning Approach) The only difference at ETÇAP software is associated with GIS	1) Ecosystem Inventory
Plan Unit	Compartment / Sub-compartment Sizes	Compartment sizes are preferably 50 to 100 ha Sub-compartment size at least 3 ha however, smaller sub-compartments may be used	Compartment sizes are 50 to 70 ha in even-aged forests and 20 to 50 ha in uneven aged forests. Sub-compartments at least 3 ha However, smaller sub-compartments may be used	Compartment size are not change . But no information about sub-compartment size	Compartment Size 4 to 35 ha	With the exception of coppice forests, the sub-compartments should be at least 1 ha, and at most 25 ha. In clearing or damaged areas, sub-compartments can be larger than 25 ha. In continuous and selection forests, maximum sub-compartment size are 40.0 ha.	If objective of Compartment is wood production, compartment sizes are 50 to 70 ha for even aged forest and coppice forests and 25 to 50 ha for uneven aged forests. Sub-compartments minimum 0.5 ha however, in areas with status, minimum level can be 0.3 ha.		Since technical interventions are generally concentrated on areas of certain sizes (depending on the nature of the work being performed), the compartments will be formed accordingly.
Plan Unit	Planning Unit Sizes	Planning unit areas are on average 10,000 ha, and encompass the working range areas.	Planning unit areas will be large the encompasses as many working ranges as possible.	Planning is performed on a Forest District basis. Between 115,000 and 140,000 ha. On average, working ranges will be 110,000 ha.	Although generally kept at around 5000 ha, planning unit sizes have varied over time.	Planning unit will be large enough the encompasses as many working ranges as possible.	Performed on a working range basis. Minimum 5000 ha. Maximum 10,000 ha		No limitation defined for planning unit sizes. The current planning unit limitations are accepted as is.

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*Table 1c. Comparison of Forest Planning Systems Implemented in Turkey so far

Comparison Criteria	CLASSIC PLAN		GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP	
	1973 Regulations	1991 Regulations					Classic	ETÇAP Simulation & Optimisation
CRITERIA FOR DISTINGUISHING WORKING CIRCLES	1) Management types, 2) Forest form, 3) Management objective 4) Rotation, 5) Tree species, 6) Terrain structure, 7) Site class differences, 8) Ease of product transportation, 9) Differences in the management regulation methods.		Working circles were distinguished according to site class• Calabrian pine good site class working circle (1st, 2nd site class) • Calabrian pine poor site class working circle (3rd site class)•Larch + Fir + Cedar + Oak good site class (1st, 2nd site class)•Larch + Fir + Cedar + Oak poor site class (3rd site class)	No concept of working circle; instead, silvicultural working unit: 1) Forest functions 2) management type and objective, 3) Tree species, ages, 4) Development and structure of forest	No concept of working circle; instead, silvicultural working unit: 1) Tree species or mixtures of species, 2) Forest growing stock quality, 3) Forest functions and management objective, • Objective of production (production of cover or assets for cutting)	1) Forest Functions 2) Type of Forest 3) Type of Management	ETÇAP Classic planning are consistent in all planning requirements made with wood production objective in the functional planning. (Classical Planning Approach) The only difference at ETÇAP software is associated with GIS	It will be more effective to reorganise the plan by thinking of the planning units as a single working class according to a holistic approach, and by establishing the planning model in a way that optimises the entire planning unit.
MANAGEMENT OBJECTIVES	To ensure the sustainable production of forest products at the highest level and quality, and to optimise the benefits provided by forests to their surroundings.	To ensure the sustainable production of forest products at the highest level and quality, and to optimally benefit from the other functions of forests.	• Logging Wood Production • Timber Production • Industrial Wood Production • Fuel Wood Production	•Preserving the current character of natural forests • Ensuring that current tree species will be present in the same ratios within mixed forests • Increasing quality • Preserving the richness of the current fauna and flora • Taking into account other aspects and functions relating to preservation (soil, water).	Management objectives are identified for economic functions, while preservation objectives are identified for ecological and socio-cultural functions. Aim is to ensure continuity of product or service.	Management objectives are identified for economic functions, while preservation objectives are identified for ecological and socio-cultural functions. Aim is to ensure continuity of product or service.		Management objectives are identified for economic functions, while preservation objectives are identified for ecological and socio-cultural functions. Aim is to ensure continuity of product or service. The identified objectives and preservation goals are prioritised by using multi-criteria decision-making techniques.

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*Table 1d. Comparison of Forest Planning Systems Implemented in Turkey so far

Comparison Criteria	CLASSIC PLAN		GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP	
	1973 Regulations	1991 Regulations					Classic	ETÇAP - Simulation & Optimisation
ROTATION	Rotation is determined by taking into account the rotation, objective, tree species, site class, maintenance type, regeneration type, and pathological factors.	Rotation is determined by taking into account the rotation objective, tree species, site class, maintenance type, regeneration type, pathological factors, and quality and health factors.	For Gazipaşa, the rotation for Calabrian pines in good site classes is defined as 40 years. With the Mut plan, the rotation periods were brough closer to normal levels.	• Rotation determined according to vitality, increment and quality.• 160 to 200 years for good quality fagus, larch, scots pine and spruce; 250 to 300 years for oak • 60 to 120 years for poor quality fagus, and 100 years for poor quality larch, scots pine and oak • This period is 60 to 120 years for coppice forests being converted to high forests.	Rotation is determined for forests with even ages. In forests that will be operated using a selection range or single-tree range, "target diameter" is taken into account rather than the rotation.	Rotation is determined by taking into account, the objective of preservation, tree species, site class, maintenance and regeneration, pathological factors, quality, and market demands and conditions.	ETÇAP Classic planning are consistent in all planning requirements made with wood production objective in the functional planning. (Classical Planning Approach) The only difference at ETÇAP software is associated with GIS	A planning model is established for the entire forest area, and the level, time and location of intervention for each stand is then determined. The rotations are then determined by taking alternative scenarios into consideration.
PERİOD LENGTHS	For working circles with a rotation of 70 years of less, period length will be 10 years; and for working circles with a rotation of more than 70 years, period lenght will be 20 years.		Over a 20 year planning horizon, 5 year plans and 1 year implementation plans are used.	No specified period lengths. Implementation period is 10 years.	Over a 30 to 50 year planning horizon, period length covers 10 years.	Ecological and sociocultural functions: 20 to 40 years Economic Functions: 10 years for rotations of up to 100 years, and 20 years for rotations longer than 100 years.		Different period lengths can be used The ideal period that will provide the optimal solution is determined based on the model.
FUNCTIONS	Wood Production		Hydrological, erosion prevention, climatic, public health, preservation of nature, aesthetic, recreational, national defence, scientific.	Wood Production (Economic Function) Resin Production (Economic Function)	1- Continuous Forest (forest areas with other functions) 2- Production Fores (function)	Economic Function Ecological Function Socio-Cultural Function		Positional planning: the functions of the planning units (stand, sub-compartment) are determined through numerical methods, independently of working circles.

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*Table 1e Comparison of Forest Planning Systems Implemented in Turkey so far

Comparison Criteria	CLASSIC PLAN (1973 Regulations / 1991 Regulations)	GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP: Classic	ETÇAP: ETÇAP - Simulation & Optimisation
REGUATION OF SILVICULTURE PRACTICES	In even aged and uneven aged stands: (1) The forest community is first identified; (2) A decision is taken concerning the "target forest" to which each stand will be brought to in accordance with the management objective; (3) The "silvicultural operation" is determined with the aim of achieving the target forests, and the silvicultural processes to be implemented during the planning period are determined; (4) The "amount of product to be obtained" is determined.	The model plan has no Detailed Silvicultural Plan. With regards to regeneration and maintenance methods, "regeneration through clearcutting, harvest felling and plantation, and the use of intensive maintenance techniques" are recommended for all tree species.	The objective is determined according to stand types. Stand silviculture plans are made for each stand. Stand that have similar structures and management objective are collectively administered with the same types of interventions; a single intervention approach is developed for all of them. Future trees are selected.	Different silvicultural interventions (regeneration, maintenance) are recommended for each separate sub-compartment.	In even aged and uneven aged stands: (1) The forest community is first identified; (2) A decision is taken concerning the "target forest" to which each stand will be brought to in accordance with the management objective; (3) The "silvicultural operation" is determined with the aim of achieving the target forest, and the silvicultural processes to be implemented during the planning period are determined; (4) The "amount of product to be obtained" is determined.	ETÇAP Classic planning are consistent in all planning requirements made with wood production objective in the functional planning. (Classical Planning Approach) The only difference at ETÇAP software	Different silvicultural interventions (regeneration, maintenance) are recommended for each separate sub-compartment. Silvicultural interventions are determined based on natural processes.
OPTIMAL FOREST STRUCTURE (COMPOSITION)	In even aged forests: The yield table method is used for forests with optimal forest structure, while the Empirical method (the mean harvest increment method) is used for forests without such tables. In uneven aged forest: the Inductive (Empirical) method is used.	The temporary yield tables developed by Forestal Company (and whose accuracy are uncertain) were used. To achieve optimal forest structure: simulation model based on time intervals with non-changing increment. Optimal Area, Optimal Growing Stock, Optimal Increment	The larch, oak yield tables in Europe were used to calculate the optimal growing stock. No concept of optimal forest structure No concept of target forest	Determined by using optimal forest structure yield tables.	In even aged forests whose main objective is wood production, the optimal forest structure are determined based on yield tables or average increments in cutting. The optimal forest structure cannot be determined in case there are no yield tables available relating to the objective of operation.		The target (optimal) forest structure is determined numerically.

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*Table 1f. Comparison of Forest Planning Systems Implemented in Turkey so far

Comparison Criteria	CLASSIC PLAN 1973 Regulations	CLASSIC PLAN 1991 Regulations	GAZİPAŞA (1978-1982)-MUT (1980-1984) MODEL PLAN	TURKISH-GERMAN PLAN (1990-Present)	FRIS (Forest Resource Information System) (1998-Present)	FUNCTIONAL PLAN (2008-Present)	ETÇAP Classic	ETÇAP - Simulation & Optimisation
MANAGEMENT REGULATİON	In even aged forests; the yield regulation by age classes, in uneven aged forests; the yield regulation by diameter classes for clearcutting coppice forest; the annual area method, for coppice selection system; the selection method		Forest community is undetermined, while the potential forest has been determined. Main method used in the management regulation is the annual area method based on clearcutting and planting. 100 year of yield determination calculated with simulation technic by forming matrices for the growing stock and increment, (a simulation based on a time interval where increment remains constant). Although it is not clearly mentioned in any part of the plan, the yield regulation by age classes is used.	1- There is no temporal or spatial criteria regarding management regulation 2- Planning in even aged forests is performed according to the yield regulation by age classes 3-Planning in uneven aged forests are organized according to silvicultural practices.	Even aged forest: The yield regulation by age classes (equal yield) is used. The planning process is divided into two stages: 1) Long-term planning: to ensure wood production sustainability; 2) Short-term planning: to ensure that the tasks planned for the initial periods/stages of the long-term plan are completed. Simulation technique is used Increment and growing stock estimation. Uneven aged forest: FRİS formula developed by using the Hufnagl's formula.	Even aged forests: The yield regulation by age classes is used. In selection forests; Hufnagl's Diameter Classes Method. In continuous forests with ecological and sociocultural function, the French Volume Method and the Hufnagl's Diameter Classes Methods are used. Coppices in forests with ecological and sociocultural functions are converted to high forests. For industrial plantation and standard clear cutting coppices, the real annual and the equal yield annual area methods are used.		Multi-purpose modelling is used. Operation research techniques are used (Simulation and linear programming)

*In preparation of these Table 1a, Table 1b, Table 1c, Table 1d, Table 1e and Table 1f is utilized these sources (Eler, 1992), (Asan, 1989), (Asan and Yeşil, 1993), (Asan, 1995), (Başkent et al., 2008) (Eraslan, 1985), (Orman Amenajman Yönetmeliği, 2008), (Orman Amenajman Planlarının Düzenlenmesi, Uygulanması, Denetlenmesi ve Yenilenmesi Hakkında Yönetmelik, 1991 and 1973), (Köse et al., 2002a), (General Directorate of Forestry, 2014), (Durkaya, 1996),(Köse et al., 2002b),(Değirmenci, 2010), (Sivrikaya, 2008), (Zengin et al., 2013).