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ANALYSIS OF FOREST ROAD NETWORK CONDITIONS BEFORE AND AFTER FOREST FIRE

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Abstract: *Forest roads are essential to forest conservation. They can be good barriers against for forest fires if they properly maintained and they provide access for fire fighting equipment. It is necessary that sufficient forest road network and maintained roads in forest areas having firesensitive vegetation types. Otherwise it is impossible to fire fighting and there are so many hectares forest covers disappearing every year. In case of fire, temporary transport lines have been constructed by fire fighting teams on the roadless land surfaces. After fire, it must be decided on which of these lines can be transformed to permanent forest roads. Because of need for the transportation of forest products from burned area, there are required new roads. The purpose of this study is to investigate the effects of old and new road network conditions before and after forest fire in relation to forestry activities. The study area is located in the west of Turkey, approximately 23 km south of the city of İzmir. The road network in the area before the fire was checked at appropriate standards. Which temporary lines constructed during the fire can be made into a permanent forest roads has been identified. In this study, it has been proposed that current road network plans should be re-examined especially for fire sensitive forest areas, emergency road plans should be prepared and these plans should be keep up to date.*

1. Introduction

Forest fire is one of the most destructive factors for forest ecosystems through short term. The polite ecosystem structure of the Mediterranean regions (Turkey, Italy, Spain, etc.) is sensitive for forest fire at high risk. Turkey has lost many forest lands, natural resources, and a bit human life because of forest fires occuring in every year. Forest fires can cause destruction of trees and the death or migration of wild animals and changes forestry structure, forest biology, climate, and soil performance as well (Demir et al, 2009). Forest fires are so ordinary and unavoidable circumstances for Turkey being Mediterranean zone. Every year, large amounts of forest area, 5 million ha in the world, 550000 ha in Mediterranean countries and 10000 ha in Turkey have been damaged by forest fire (Eroğlu, 2009).

In Turkey, coastal band is very sensitive area where is following 1700 kilometers (km) of Aegean and Mediterranean coasts and is 12 million ha area extending to 160 km depth from the coast for forest fires (Figure 1). Fire sensitive forest areas are 58% of total forest area and to be located in five different fire sensitive regions, for first degree sensitive region with 35%, for second degree sensitive region with 23%, for third degree sensitive region with 22%, for forth degree sensitive region with 15%, for fifth degree sensitive region with 5%. In Mediterranean and Aegean regions, forests consist of scrub species and Pinus brutia which are extremely fire sensitive species located in the first degree fire sensitive area on 0-400 meters altitudes have special conditions in terms of fires. As well as intensive human activities such as, agricultural, residential and tourism are also very important for this region (GDF, 2008a).

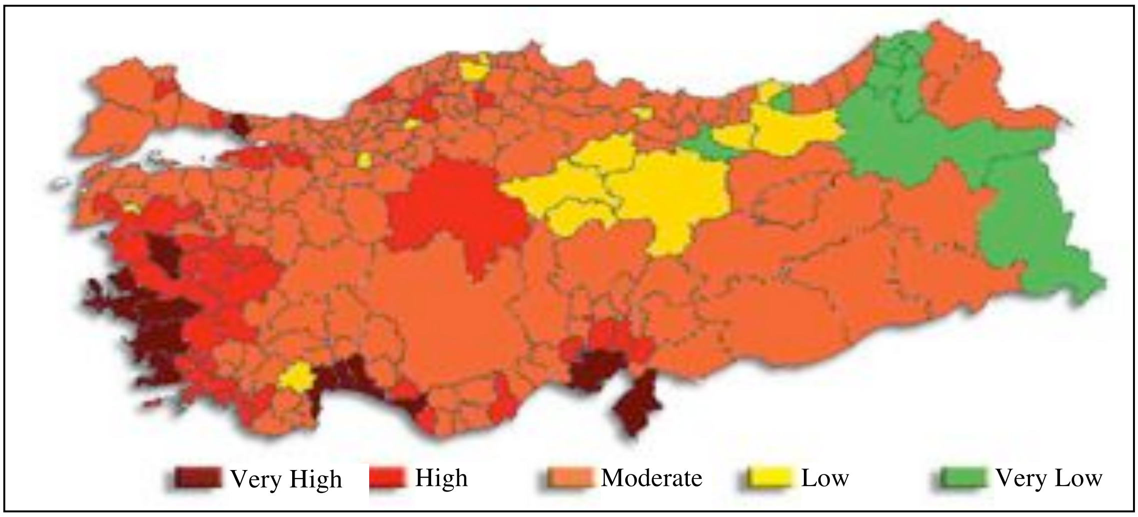

Figure 1. The fire-sensitive regions map for Turkey (GDF, 2008a)

As of end 2007, there had been 82841 forest fires since 1937 and the burnt area was 1583273 ha in Turkey. The mean of forest fire number was 1167 per annual and it was burnt 22296 ha forest area. During this term, forest area burned per forest fire was 19,11 ha/fire. By the end of August of 2008, there had been 1624 forest fires and 25326 hectares forest area burned (GDF, 2008a; Hasdemir et al., 2009). Furthermore, while the burned area was 11664 ha in 2007, it was 28977 ha in 2008. Although this situation, the number of forest fires per year increased, but forest area burned per forest fire decreased. In Turkey, total extraordinary salvage cutting amount was 596519 m^3, in 2007. The recovery ratio of burnt forest area is 85 percent in Turkey (Öztürk et al., 2009).

In addition, Turkish General Directorate of Forestry spent 677,71 million $ over the last decade. For example, in the biggest forest fire in history of Turkish forestry, Antalya (Serik-Taşağıl) forest fire, when it started to burn in 31 July 2008 at 12:30 o'clock, it could be hardly stopped in 5 August 2008 at 17:00 o'clock. Then, it was paid to put out the fire as 2,73 million $ for only this area having 615000 m^3 tree volume and 15795 ha forest land.

Forest roads are the most important infrastructure foundation of the forest landscape to fulfill forest management practices and to supply all functions of forest resources. Undoubtedly, forest roads play a key role in forested areas and rural development, facilitate movements of human population over the forest land, and connect natural resources with societies and economies. Forest roads have many kinds of direct and indirect effects such that physical and ecological, landscape scale and socio-economics effects (Forman and Alexander, 1998; Gucinski et al., 2001). However, roads generate many collateral problems for the conservation of ecosystems (Forman et al., 2003) and landscape integrity (Jaarsma and Willems, 2002). As well, forest roads may influence fire regimes by way of increased fire ignition (Franklin and Forman, 1987) as a result of human activities that occur in the transportation corridors, reduced fire size as a result of physical barriers to fire movement, and increased accessibility for fire suppression activities (Covington and Moore, 1992).

Roads fragment the structure of entire forest structure, creating high contrast edges (Franklin, 1993) accompanied by changes in microclimate (Chen et al., 1993) and reductions in the amount of forest interior (Schonewald-Cox and Buechner 1992). Finally, roads allow access for resources of forest, i.e. timber and other products. In forested areas, the forest matrix dominates the landscape, but roads remove or disturb large areas through indirect effects that accumulate and interact at higher scales (Forman, 1998). Because of the multifarious functions and various effects, forest roads should be well planned according to all factors (Eker and Çoban, 2010; Eker et al., 2010). The forest road that are constructed during and after forest fire have an emergency road status should be appropriate for supply of the all positive functions and prevention of the adverse effects.

The chaotic situation affects the suitable decision making process on all operations during fire fighting. Therefore, various disturbances have been realized during fire fighting and post fire for rehabilitation of burnt area. Especially, a lot of forest road and fire strip have been constructed to put out the fire, afterward, the road and strips can be used in extraction of wreckage and burnt trees. The strips which is of bare land or vegetation that slows down fire were built in forest fires to fight and these can be used as forest road after fire if these were constructed according to technical standards. It is possible to say that when a forest road is planned and constructed in point of road length, road route, functions and technical standards, it is necessary to take into consideration the prevention, protection, salvage logging, and forest rehabilitation together.

This paper describes evaluation of metamorphosis on forest roads in context of forest transportation and fire fighting in Turkish forestry. In this concept, the aim of the paper was; i) to compare with pre and post fire road conditions by means of road criteria such as road length, road density, opening-up ratio, road quality, etc., ii) to emphasize the requirements of the emergency forest road and a risk plan before fire ignition, iii) to examine the potential adverse impact of forest roads built in chaos situation.

2. Material and Method

2.1 Study Site

The burnt forest is located in Menderes district of İzmir province which is the 3rd largest city of Turkey on the Aegean coast. The forest fire started 20 July 2008, continued throughout the three days, burnt approximately 1500 hectares than was extinguished on 22 July 2008. The study area investigated in this research covers 528.28 ha is in the south region of Gaziemir forest sub-district in İzmir forest division of İzmir Regional Forest Directorate (Figure 2).

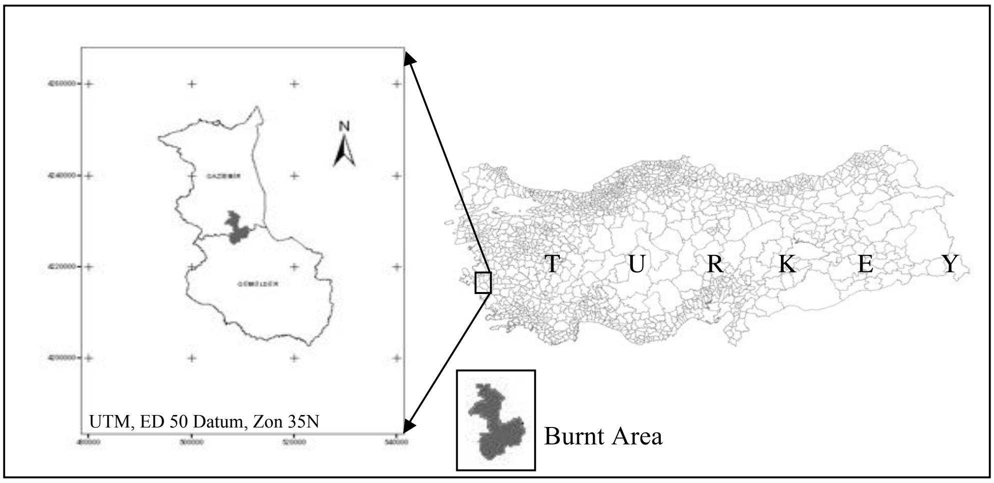

Figure 2. Geographic location of the study area (Özdamar, 2010)

The study site is a part of burnt forest area. The northern part of this burnt forest land was selected this study so that the forest road density was changed dramatically after forest fire in this area. In addition, satellite images, achieved from free Google Earth®, having high spatial resolution give opportunity to manipulate the old and new forest road network in the area.

Elevations of the study area extend from 115 to 318 meters on digital elevation model created from SRTM (Shuttle Radar Topography Mission) data. The distribution of slope and aspect class of the study site is shown in Table 1 and Figure 3. According to the aspect data, it can be observed that 60% of the total area is dominated by northwest, north, northeast and east aspects, which are also called “shadowed aspects”. As for slope groups, 53% of the total area is classified as moderate slope groups, while 47% of the area is classified within the high and steep slope groups.

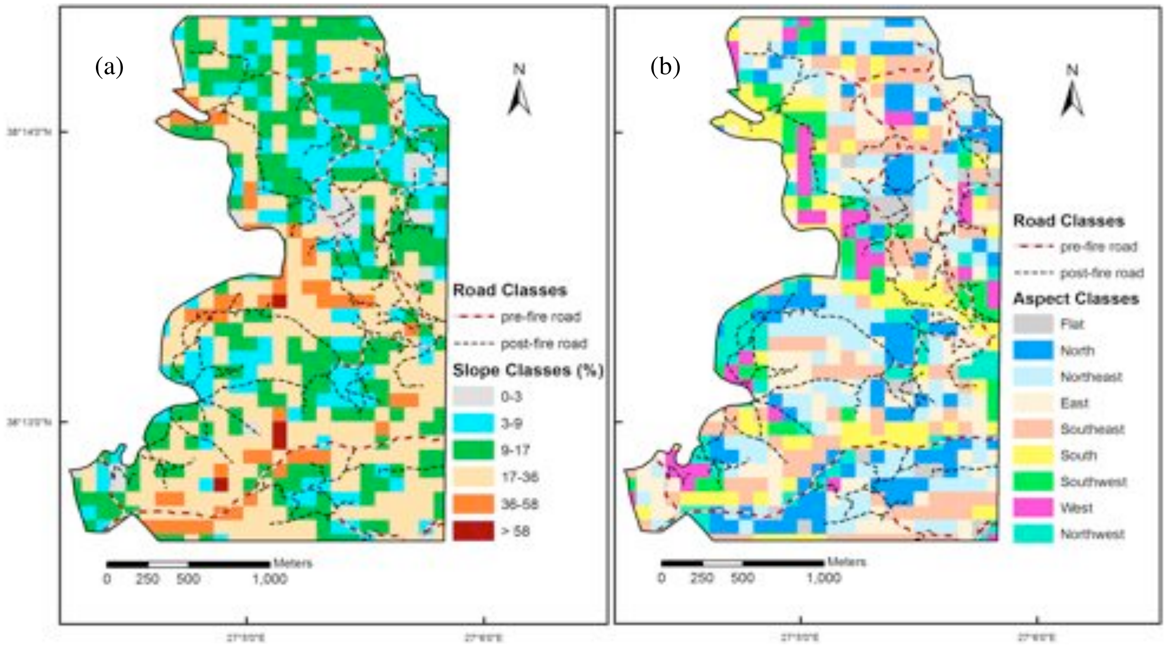

Figure 3. Slope (a) and aspect (b) map of the study area

Table 1. Distribution of aspect and slope classes in the study area

Slope class ID	Slope classes (%)	Features	Area (ha)	Aspect class ID	Aspect classes	Area (ha)
1	0-3	Flat	15,51	1	Flat	16,29
2	3-9	Low slope	106,43	2	North	74,25
3	9-17	Moderate slope	158,54	3	Northeast	89,82
4	17-36	High slope	208,30	4	East	109,48
5	36-58	Steep slope	36,26	5	Southeast	75,99
6	58-88,8	Very steep slope	3,24	6	South	60,86
				7	Southwest	31,90
				8	West	28,14
				9	Northwest	41,55

Tree species growing in burnt forest land was dominantly red pine (*Pinus brutia Ten*.). The study site damaged by forest fire has included young red pine trees with especially 20-30 years old. Natural development stages of forest stands range from; seedling and sapling stands (a < 7,9 cm in diameter at breast height/DBH), poletimber stands (b=8,0–l9,9 cm), thin sawtimber (c=20,0-35,9 cm) as respectively.

2.2. Data Used

In this study, digital elevation data, briefly known as SRTM, produced from a space shuttle radar sensing were used to make topographic analysis of the study area. The absolute vertical accuracy of this elevation data is 16 meters and spatial resolution of this data is 90 meters (JPL, 2008).

Forest management plan maps which are produced using geographic information system techniques by regional forest directorate of İzmir were also used. This geographic database including many stand characteristics such as stand type, canopy closure, age, administrative information etc. for the study area.

ArcGIS 9.2 version software which is the commercial geographic information system (GIS) software was used in the study. Topograhic analysis, producing of new graphic and attribute database, adding and editing on this database and queries were performed by using this software. SRTM data was processed by using ERDAS 9.1 software which is image processing software.

2.3. Method

First of all SRTM data, in other words digital elevation data, were used to produce tin (triangulated irregular network) data of study area. The tin model is the basis of topographic analysis (Koç, 1996). Then elevation and aspect analysis were made using spatial and 3D analysis tools in ArcGIS.

The free Google Earth programme was used to digitize forest roads before and after forest fire. The satellite images with high spatial resolution achieved from Google Earth are very effective to show and research road history, so this free software and its images were used for this study. The roads were classified according to road width, junction location, and segment length and then these roads were registered on geographic database using ArcGIS. The attribute table belonging to the data having vector format was formed and set up topology to make ready for analysis.

It was benefited from general road density formule to calculate forest road density (Erdaş, 1997; Eker and Çoban, 2010). It is dividing of road length (meter) to area (hectares). Opening-up ratio was calculated as proportion of area within 300 m buffer zone for full side of road lines to total study area. The buffer zone with 300 m double side of a road symbolizes both opening up forest and fire fighting distance of fire hose. If the opening-up ratio is between 80 and 100 %, opening-up ratio of road network or segment is excellent (Eker and Çoban, 2010).

In order that the forest road analysis can be done it was determined the road length, road density and opening up ratio before and after fire. The hierarchycal elimination process based on road width, position in forest land, the conjunction number with other roads, road slope, and opening-up ratio/accessibility index was used to determine which forest road can be permanent or temporary. It was taken into account the current technical standards of forest roads as a guide (Table 3).

Table 3. Technical/geometrical specifications of forest roads in Turkey

Technical Specifications	Units	Main Forest Road	Road Types (Secondary Forest Roads) A-Type Forest Roads	Road Types (Secondary Forest Roads) B-Type Forest Roads	Skid Roads
Road bed wide	m	7	6	4	3,50
Maximum slope	%	8	10	9-12	18
Minimum curve radius	m	50	35	10-12	8
Number of band	number	2	1	1	1
Band wide	m	3	3	3	3
Shoulder wide	m	0,50	0,50	0,50	-
Ditch wide	m	1	1	1	-
Pavement wide	m	6	5	3	-

It was accepted that the junction of public road and main forest road having road slope between 2-12 % was the starting point could be decided on permanent and temporary roads. Elimination process was hierarchically realized step by step. At the each step, the road atrributes was analyzed according to opening- up ratio and road density until optimal condition was obtained (GDF, 2008b).

3. Results

The forest roads have a critical task for fire prevention and fire fighting in addition to other functions of which. Therefore, particularly in fire sensitive regions, forest roads act role of main infrastructure to fight fire and cleaning the burnt areas to regenerate again. In this study, it was attracted attention this hypothesis. The results of the study were abstracted in Table 4.

There has been B-Type forest road with 10,2 km length before forest fire in order to carried out routine forestry operations. After fire, it was determined that 34,3 km forest road had been constructed, as well. By adding of the new roads, the opening-up ratio of the study site was increased more 31,5 % and then all of the study site area could be completely opened up. The forest roads constructed before fire, had been built to geometrical standards as planning road with 4-5 m width for other functions of the roads. After fire, the unplanned forest road was immediately constructed to discharge salvage material with 3-6 m road width. Furthermore, while the shortest road segment length was 179 m before fire, it decreased to 20 m after fire. It was found out that the number of road segments was 12 prefire and 78 postfire. Thus, mean road segment length decreased to 310,2 m post fire from 955,8 m.

Table 4. Forest road and relevant attributes in pre and post-fire conditions

ID	Attributes	Unit	Pre-Fire	Post-Fire	After Elimination*
1	Area	ha		528,28	
2	Road Length	m	10173	34335	22564
3	Road Density (1/2)	m/ha	19,26	64,99	42,7
4	Opening-up Ratio**	%	75,8	99,7	99,4
5	Road Quality Type***	-	A	A+B+C	A+B
6	Mean Road Wide	m	4 - 5	3 - 6	4 - 6
7	The Number of Road Segment	m	12	78	27
8	Mean Segmen Length (2/7)	m	855,8	310,2	835,7
9	Minimum Segment Length	m	179	20	255
10	Maximum Segment Length	m	3134	1557	2867

** Elimination process was thirdly repeated*
*** Buffer zone with double way as 300 m*
**** A: Type-B forest road B: Skid road C: Contact road*

However, a part of the forest road constructed during and after fire for urgently cleaning of the burnt area was tractor roads had with low technical standards to access only tractors and fire trucks, and the other part of which was connection roads. Therefore, it was decided to remove the roads with low standards because of no having B-Type forest road standards. From this point of view, the removing iteration has been hierarchically conducted according to technical standards of the new roads built up post fire which was far from and nearest to main access road. The iteration process was repeated three times. The result of the iterations abstracted in Table 5, and the left forest road was given in Figure 4.

Table 5. Alterations in road attributes through eliminations

Road Attributes	Post-fire	1st Iteration	2nd Iteration	3rd Iteration
Length (m)	34335	28884	25610	22564
Density (m/ha)	64,99	54,67	48,5	42,7
Opening-up ratio (%)	99,7	99,7	99,4	99,4

It has been shown when road length was decreased to 28884 m at the first iteration step, the road density also decreased to 64,99 m per hectares and the opening up ratio was static as 99,7 % like that former situation. At the second iteration, although road length was decreased to 25610 m, the forest road density decreased 54,67 m/ha and opening up ratio changed very small as to 99,4 %. Whereas forest road length was cut down in 22564 m in third iteration step, the forest road density was 42,7 m/ha and the opening-up ratio was static as former step. That is, although the road length was removed 11771 m, the opening-up ratio was stable as excellent.

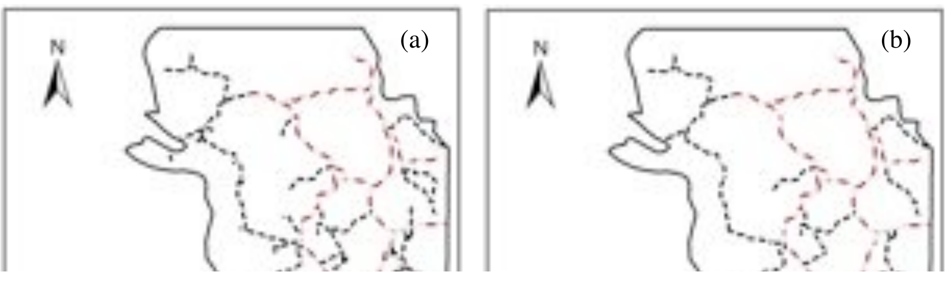

Figure 4. Forest road network maps during elimination process with iteration; post-fire (actuel condition) (a), first step (b), second step (c), third step (d).

4. Discussion

According to current forest law and principles about prevention and fighting of forest fires, in Turkey, the forest roads has the functions that are: i) Road is a defence line for fire figting, ii) Application place for opposite fire ignition, iii) Barrier for forest fire, iv) Transportation during and post fire (Alkan, 2009). The forest roads having various functions should be connected with the forest strips and firebreaks constructed and successfully used in fire fighting in Tukish forestry. Then, terrestrial fire fighting operations via forest roads can be regularly achieved in fire sensitive areas. Furthermore, it is required that the road density should be high level for protection and prevention forest fire in fire sensitive area. For example, it was stated that the absence or lack of forest roads caused the growing of forest fires and more burnt araea in Antalya (Serik-Taşağıl) fire happened in 2008 (15800 ha was burned in) (Kaşan, 2009).

One of the critical problems occurring in postfire is how salvage material is harvested, where it is transported, where the storage place is, where the landing location is, etc. After forest fire, there can be a chaotic ambiance. On no circumstances, the landing locations in road side acts as a key role for collecting salvage material to ready for transportation. If the road density is unsufficient and the road must be open to traffic for another activity, then the forest road can not been used as landing place and discharge route. Immediate salve logging and transportation is very vital after fire in red pine forest especially summer season.

Turkey has two characteristic fire season types: a short fire season for the Black Sea and Marmara regions and a long fire season for the Mediterranean and Aegean regions. The critical forest fire season in Turkey has gone out thorough six months from May to October (GDF, 2007). Forest fire prevention activities are based on interdisciplinary studies. The absence of adequate road infrastructure will be lead to be decreased success in fire fighting. It is very important to get equipment and forestry workers quickly to a forest fire to impede its spread. This is made possible by adequately planned and constructed forest roads and firebreaks (Demir et al., 2009). Therefore, when planning forest roads in fire sensitive areas, fire fighting and salvage logging should be taken into consideration as a priority. However, it has shown that the actual forest road planning concept as in this study area had not been included the criterion of fire fighting, prevention and postfire salvage logging operations in emergency situation, before forest fire.

In actual manner, forest roads have been planned and constructed according to these criteria that are road density (m/ha) and yield/forest area (m^3/ha) equation to meet the needs of Turkish forestry. The literature, in Turkey, has indicated that the forest road density might be also 20 m/ha for fire fighting and forest prevention (Demir et al., 2009). It was established that the road density which was 19 m/ha though, was not sufficient to clear the salvage and debris of burnt area, before forest fire. The judgement was supported by finding of that the road density increased 65 m/ha after fire. Therefore, it will be no sufficient that the road density is to be 20 m/ha in fire sensitive forest region. Furthermore, it was reached the result of that the opening-up ratio is useful indicator more than road density especially in fire sensitive regions. In the study site, while opening-up ratio was 76 % before forest fire, it reached to 99 % after fire. This stated that the opening-up ratio of burnt area must be excellent (between 100 and 80 percent) to clear for rehabilitation.

For example, it was summarized the functions and requirements of forest roads in Table 6 for Antalya forest fire (GDF, 2008a). This results show that the forest road is necessary not only fire fighting but also salvage logging and rehabilitation for the burnt araea.

Table 6. New forest road requirements after Antalya forest fire

Location	Road Length (Pre-Fire) (m)	Road Length (Planned) (m)	Road Density (Pre-Fire) (m/ha)	Road Density (Planned) (m/ha)
Taşağıl Forest District	69,5	140,06	9,93	23,42
Serik Forest District	87,4	73,5	15,9	29,2

On one hand the forest road is necessary for fire prevention and debris cleaning; on the other hand the forest road density should be minimum level to remove adverse impacts of roads. Therefore, the unnecessary forest road that are narrow, having high sloping, with low technical standards, and having low opening-up ratio should be closed and removed from forest land, when the roads is eliminated, unless the opening-up ratio do not change. In Table 4, it was defined that the roads amount was 11711 meter was unnecessary (34%) for the study site. This result was obtained by using only three iterations. If the iteration process was continued, total road length could be decreased. But, it was aimed that the opening-up ratio should have been 99% in this study.

Unnecessary forest roads, especially constructed during and after forest fire, have high construction cost and potential environmental impacts for forest ecosystem. So, to determine optimal forest road length and density, it is required to make an emergency road plan with together fire fighting action plan drafted each year.

The forest roads supply access of vehicle and people to inner forest area, and then the risk of fire ignition increase. Thus, there is a drawback because of high forest road density. The statistical data exposed that 96 percent of the causes of the forest fire was belonging to human effects. Therefore, in fire sensitrive region, fire resistant tree species are planted in forest road sides. Thus, it was objected to minimize the fire risk factors. Furthermore, although forest road are fragmented entire forest area to small polygons (Eker and Çoban, 2010), the small polygons is appropriate to perevent the forest fire and confine it in small area (Kılıç ve Cebeci, 2009).

The forest fires are the component of the forest ecosystem particularly in Mediterrenean Region of the world. Every year many forest fires occur and it burns to forest lands, and cause loss of standing tree volume. But, it is the more important subject that is focused on immediately and efficiently fire fighting, wreckage removing, and rehabilitation in burnt areas. Therefore, the forest roads are the physical infrastructure of a forest as transportation and fire prevention network, as well. The high road density, optimal distribution of the road to area, and optimal opening-up ratio influence the efficiency of fire fighting and all forestry operations after fire. Furthermore, after forest fire, it is needed accessing of personnel to determine damage level resulted from fire and to clear debris and salvage. If the burnt area is immediately purified, the forest area can be recovered in the following vegetation period. For that reason, it is necessary to compete to time. Because the damaged salvage trees can be exposed to bark bettles and other detrimental beetles. Thus, the all wreckage material should be promptly removed from burnt area to protection salvage trees and near healthy trees form harmful effects. For example, in the Mediterrenean region of Turkey, in Antalya (Manavgat), it was defined that the bark beetles had been covered damaged trees within 17 days after forest fire (Baş, 1965). In addition, last learnt from the biggest forest fire of Turkey, where 15800 ha forest area and 1,6 million m^3 tree volume burned, show that it is necessary excellent forest road network in fire sensitive region (GDF, 2009; Eker and Çoban, 2009).

5. Conclusion

- Forest roads should be planned according to risk plans in fire sensitive regions. This road network should be applied and constructed as sson as possible. Regular maintenance of these roads should be performed during the year. In this way, a systematic spatial pattern can be obtained in forest area. This network is provide infrastructure continuity of the area and will be used for fire fighting. Otherwise these new roads will be created in chaos environment during the forest fire. Emergency forest road plans should be made and even these emergency roads constructed as to considering forest fire frequency/period and fire risk plans prepared in the beginning.
- Roads required urgently for debris removal and rehabilitation works after fire should be effective for forestry studies in future, fit for road standarts (tractor, contact or B type secondary roads) and considered as the strategic planning concept.
- Firebreaks which are fire suppression zones adjacent to forest roads should be made on both sides of the roads.
- Forest roads should be tied to fire prevention roads/strips and this network should be planned together.
- Especially in fire season, vehicle traffic and human activities are raised in forest area. So, the traffic should be getting under control in dangerous season for decreasing or preventing of forest fire about fire sensitive regions. Moreover, for some more critic regions, it can be completely deactivated the forest roads.
- Human activities (smoking, carelessness, accidents, or deliberate fire setting) are very important causes of forest fires in Turkey. These risky human activities can be decreased by using both forest fire suppression techniques and preventative measures such as social, cultural, and economic.

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