Examining Service Area of Fire Stations in Forest Fire with Network Analysis

Yasemin OZKAN, Aziz SİSMAN, Ridvan E. YILDIRIM

SUMMARY

Forests which are our primary recyclable sources must effectively be protected so as to meet the needs of current and next generations. As in the whole world, in Turkey, the main factor endangering the continuity of forests is forest fires. Forest fires are not only ecologically but also economically dangerous and environmental problems mostly threatening human life.

In order to early and effectively fight against forest fires, fire fighters have to arrive at the area on fire in critical time. The processes of taking emergency call, processing it and moving to scene of fire in critical time might be decreased to the most ideal periods through a successful fire management. However, the most crucial part of critical time is arrival time. Arrival time is affected by several factors which cannot be controlled. The most important one of these factors is the location of station and potential fire area. Additionally, traffic jam, average speed of the fire vehicles, habits of driver, situation of road network, time of the day, and the season may be the factors affecting the length of time of fighting fire.

Being able to successful in firefighting is possible thanks to taking necessary precautions properly at the right time and utilizing the sources effectively and economically. Moreover, developed technologies have to be utilized at every stage of firefighting. In this respect, multi-disciplined workings are required and Geographic Information Systems, which is the most significant part of decision support systems, are used.

This study was conducted for Atakum town in the province of Samsun. Taking the existing fire statistics and the location of the stations into consideration, the functions of locational analysis of Geographical Information Systems and possible fire areas which may be responded to a fire in 40-minute time period were tried to be determined. The method of network analysis was used in this study. In this study, the locations of existing fire stations and the locations of needed fire stations were determined. Accordance with these necessities, taking the existing fire statistics and the location of the stations into consideration, with the functions of service area analysis of GIS the areas which are sensitive to fire and, new service fields to be arrived at these areas and their numbers may be identified. Therefore, source use in fires and late intervention to fires might be minimized.

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1. INTRODUCTION

Forest fires are the leading factors which endanger the continuity of forests in the world due to their effects and results. It has been estimated that annually fires burn across up to 500 million hectares of woodland, open forests, tropical and sub-tropical savannahs, 10-15 million hectares of boreal and temperate forest and 20-40 million hectares of tropical forests (Rowell and Moore, 2004) Moreover, along with financial damages they have resulted in casualties (Küçükosmanoğlu, 1987). Particularly, Turkey where is mostly in the effect of Mediterranean climate which has the most appropriate conditions for forest fires has been damaged because of forest fires. With the influence of the relationship between human and forest, more than 2000 forest fires take place and thousands hectares of forests are wiped out annually (Bilgili, 1996).

Fight against forest fires must safely be carried out. Determination of the precautions in pre and post-fires in advance provides less casualties and successful results in fight against forest fires (Çanakçıoğlu, 1993). In pre-fire planning, finding and classification of the areas which are sensitive to fire are significant for planning. Past statistics on this type of areas should be evaluated together with the factors causing and spreading forest fires. These factors might be exemplified as people-driven social pressure situations, road conditions, population and socio-economic situations, topographical conditions, meteorological features and quantity and quality of inflammable matter belonging to that area.

To be able to respond to forest fires effectively and early, fire-fighters must reach to the fire area in critical time. Critical time might become the most ideal one through taking and processing urgent call, moving to the scene and successful fire management. However, the most crucial period here is the reaching time and this time period is influenced by several factors which cannot be controlled. The most important one of these factors is the location of station and potential fire area. In addition to that, the other factors affecting the response time are traffic density, average velocity, habits of drivers, situation of road network, intra-day time period and season (Şişman,2015).

So as to become successful in fight against forest fires, necessary precautions need to be taken at right place and time and resources should be used effectively and economically. High technology should also be used at every stage of fire process. In this context, multi-disciplined studies are needed and Geographical Information Systems (GIS) which is the most significant part of decision support systems has been used. New service areas and their numbers and possible fire areas might be determined via the functions of locational searching and analysis of GIS. Therefore, the use of resource in fires and late responses to fires may be minimized.

This study was conducted for Atakum Forest Sub-district Directorate located in the borders of Samsun Forestry Operation Directorate which is bound to Amasya Regional Directorate of

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Forestry. In case of fire within the borders of Sub-district Directorate, accessible areas in critical time period were found by service analysis based on the locations of the existing fire stations. Fire station points' capability to respond to the events in the determined time period was examined by conducted service area analysis.

2. MATERIALS AND METHOD

2.1. Study Field

Atakum Forest Sub-district Directorate located in the borders of Samsun Forestry Operation Directorate which is bound to Amasya Regional Directorate of Forestry was chosen as study field (Figure 1).
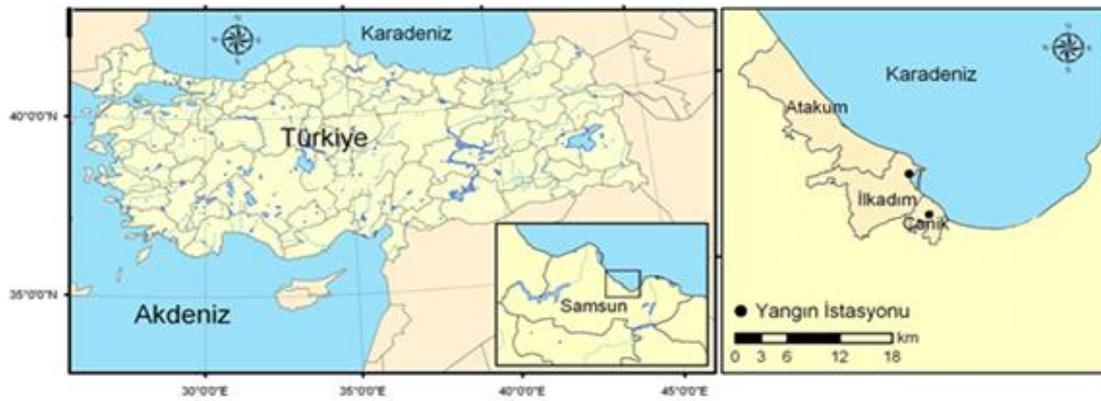
Figure 1: Study field

Atakum Forest Sub-district Directorate is 28.689.60 ha in total, 11.871.00 ha of it is forestland and 16.818.60 ha of it is non-forested land. In terms of fire sensitivity, the area is sensitive to fire in 3rd degree (OGM, 2013). There are 2 intervention teams in study field: one of them is the main fire station belonging to Samsun Metropolitan Municipality within the borders of İlkadım town and the other one is first intervention unit belonging to Forestry Operation Directorate in Canik town.

In this study, 1/25000 scaled topographic maps were used. Forest areas, road network and fire stations were digitized on GIS. Average velocities determined for all roads were assigned to road layer as data of attribute. In the light of information obtained from literature review, earth roads were examined with 30km/h average velocity, stabilized roads were viewed with 50km/h average velocity and asphalt roads were analyzed with 60km/h average velocity (Erdaş, 1997; Bilici, 2008; TDŞM, 2010). In this context, travel time for each road section was calculated depending on speed of car and length of road. Furthermore, benefiting from literature review it was determined that the area is sensitive to fire in 3rd degree (OGM, 2013). Based on this sensitivity critical response time was computed (Yücel, 1998). Being analyzed datum recorded on the system on GIS, a variety of determinations were made through examining the locations of fire stations via network analysis.

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| Road type	Velocity of vehicle (km/h)
Earth road	30
Stabilized road	50
Asphalt road	60
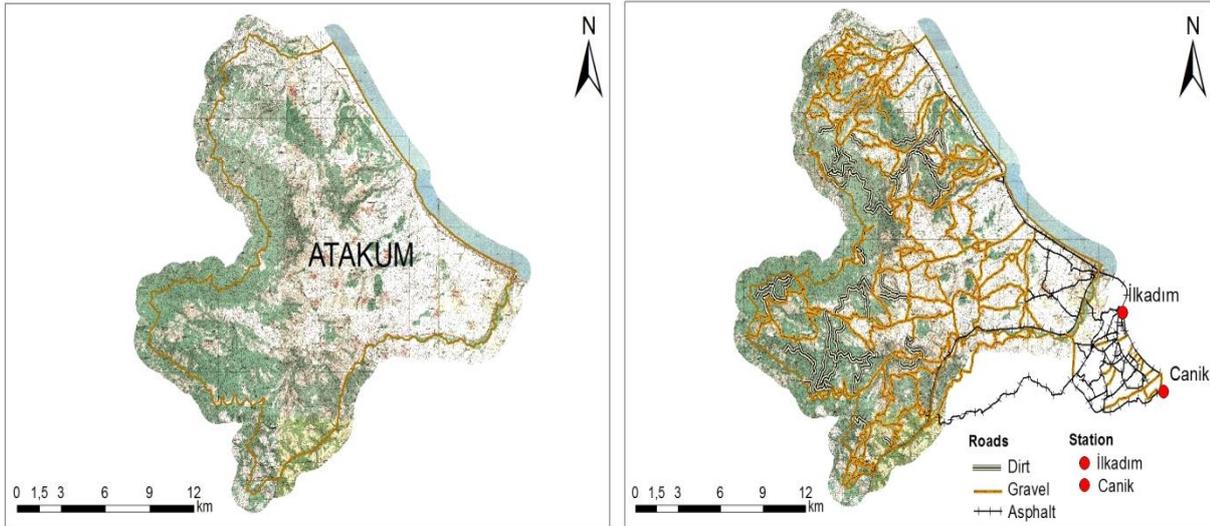
Figure 2: Atakum Forest Sub-district Directorate, road layers and demonstration of stations

2.2. Network Analysis

Problems with optimally being positioned of services in net so as to meet the needs at the point of demand are known as analysis of service area. It aims to minimize total or average travel time in overall system. Coverage model is concerned with the problem of servicing to all possible demand points in a stable time (Smith et.al, 2007).

Coverage models were made up for the study field in intervention time determined in literature review. The areas that can be assessed in the result of the analysis of service area carried out in 40 minutes –based on average velocities- based on GIS network analysis are given in Figure 3. According to these results, 2 existing stations can respond to 24 480. 90 ha of total area, which is %85.3 of total area, in 40 minutes. If only the main station in İlkadım town is used, it may be responded to 23 332.50 ha of total area, which is %81.3 and if the intervention unit in Canik town joins, it might be responded to 24 121.30 ha of total area, which is %84.1. The results obtained under these circumstances are shown in Figure 4.

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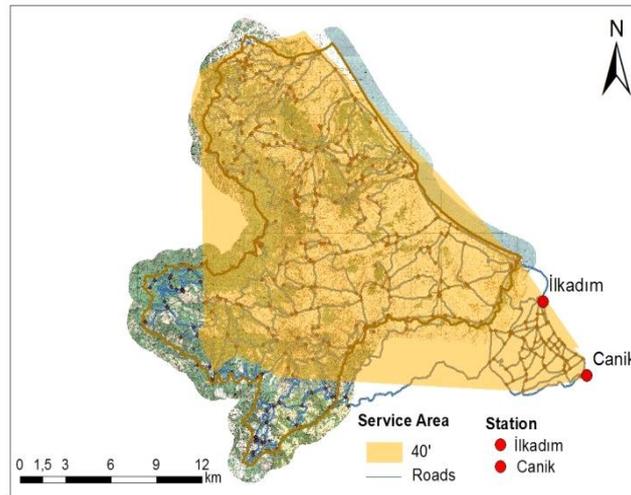
Figure 3: Coverage area of 2 stations

<div style="display:flex">(a)   (b)</div>
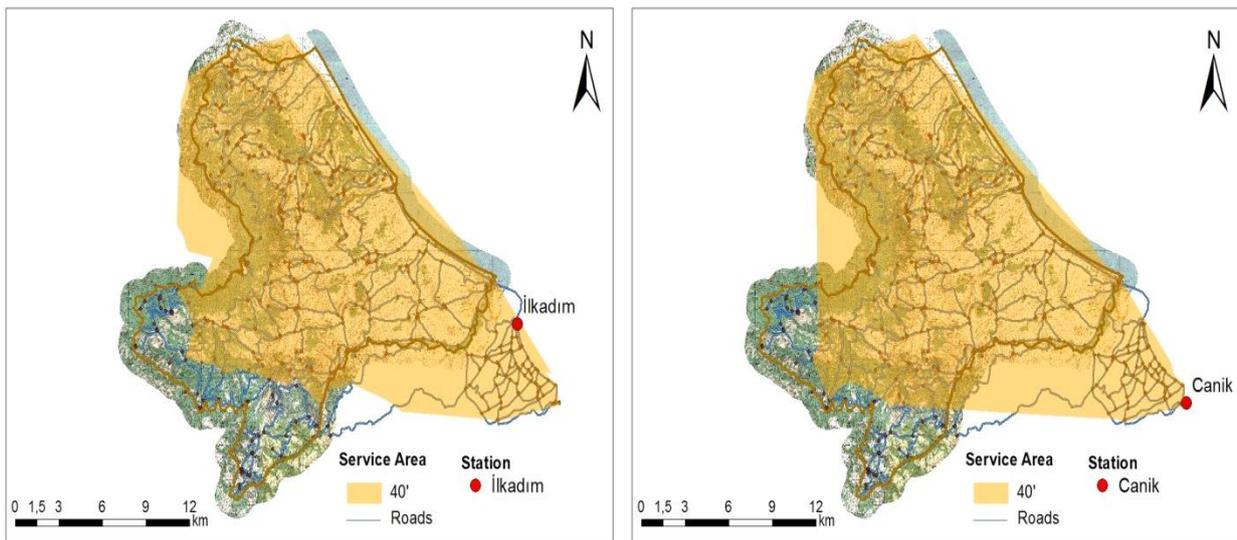
Figure 4a,b: Coverage area of intervention teams in İlkadım (a) and Canik (b)

3. FINDINGS

Road condition and existing fire operation centers of Atakum town which is in the study coverage area were examined. According to the results obtained, total length of road network in the study field is calculated as 602.1 km. Most (%60.2) of these roads is stabilized roads which are followed by asphalt roads (%22.6) and earth roads (%17.2). The method of service area analysis is used to find the districts that first intervention teams may access in critical time period (40 minutes) when taking total study field into account. The results indicated that first intervention teams are able to reach to %85.3 of total area in 40 minutes. In separate intervention of İlkadım and Canik towns, coverage areas are found as %81.3 and %84.1 respectively.

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Table 2: Coverage Area of Intervention Teams

Name of station	Responded area (%)
İlkadım-Canik	%85.3
İlkadım	%81.3
Canik	%84.1

4. RESULTS

In this study, decision-support system based on GIS, network analysis was used. In case of fire, the suitability of numbers and locations of fire operation centers within the borders of Atakum Forest Sub-district Directorate was analyzed. The areas that first intervention teams might reach were determined. The location of intervention teams were established in an appropriate place for the study field. It was found that intervention teams are capable of arriving in critical time period. It was observed that, intervention teams can't access to almost %15 of study area in 40 minutes. These unacceptable areas located in high level region of the study areas and these areas covered densely forest and also has weak road network such as earth road. Therefore, it is predicted that the risk of fire for these region is likely to increase, considering the road condition and population needs of these inaccessible regions. It is estimated that a fire taking place in these regions may not responded in 40 minutes called as critical time. It can be beneficial to a solution of this problem that intervention teams are located in particularly Atakum town or through improve the standards of earth roads, arriving speed is increased.

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