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Research Article

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Planning Response Times of Fire-Fighting Vehicles to Forest Fires on Active Fire Protection Organization

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Abstract Turkey 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 Turkey, 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.

Keywords 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. Fast and effective detection is a key factor in forest fire fighting. To avoid uncontrollable wide spreading of forest fires it is necessary to detect fires in an early state and to prevent the propagation [1]. 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).

Figure 1: Forest Fire

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) around Mediterranean [2]. 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 [3].

When considered generally, it is seen that more than half of our forests are ranging through fire-sensitive areas [4]. 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) [5].

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).

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 [6]. 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 [7]. 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 [8]. 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 [6]. Despite all, it is not possible to completely prevent fires although there are wide precautions taken in order to protect forests against fire.

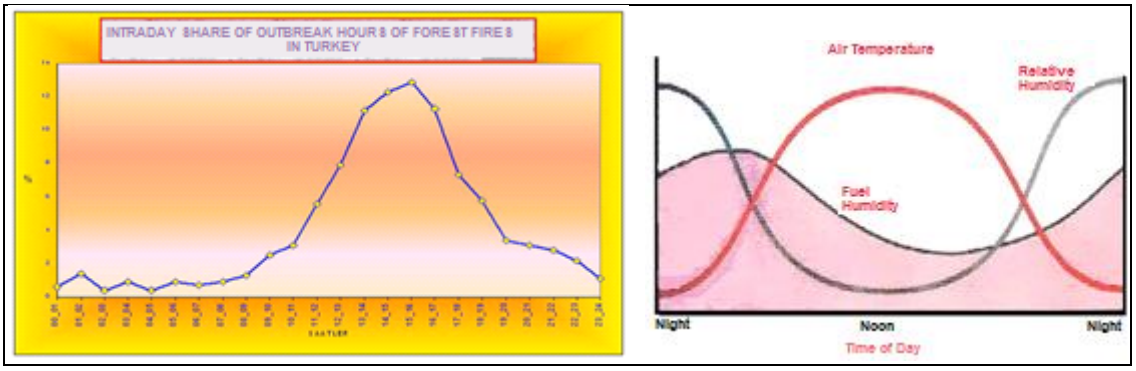


Figure 3: Intraday Share of Outbreak Hours of Forest Fires in Turkey (MGM - General Directorate of Meteorological Services)

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 [9]. 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 [10].

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 [11]. 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 [12].

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 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. Material and Methods

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 firesensitive areas [13]. 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).

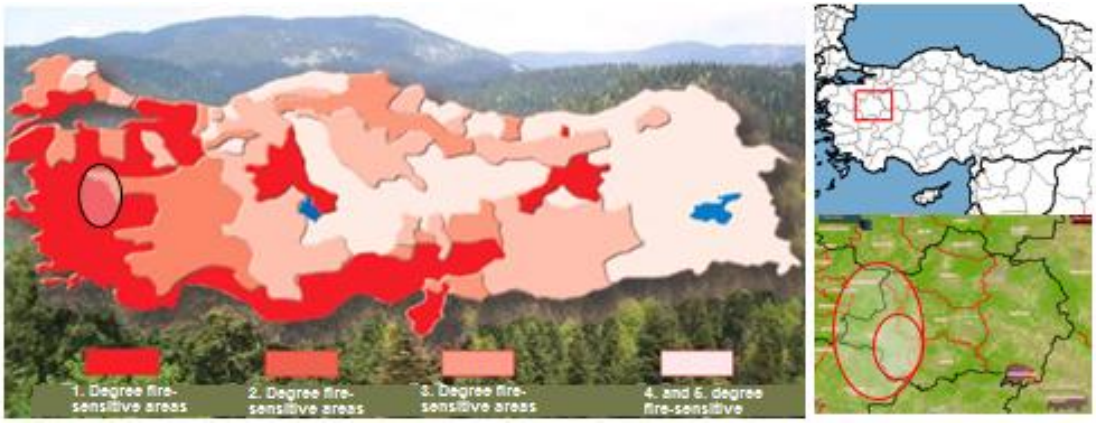


Figure 4: Location of Protected Areas Being Forest Fire-Sensitive (General Directorate of Meteorology) and Sub-District Forest Directorate

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.

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).

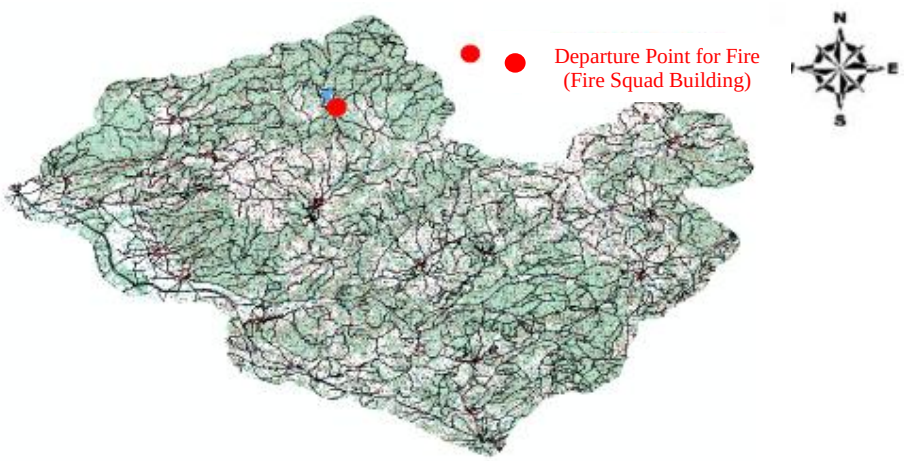


Figure 5: Present Road Network of the Forest Area within the Borders of Sub-District Directorate

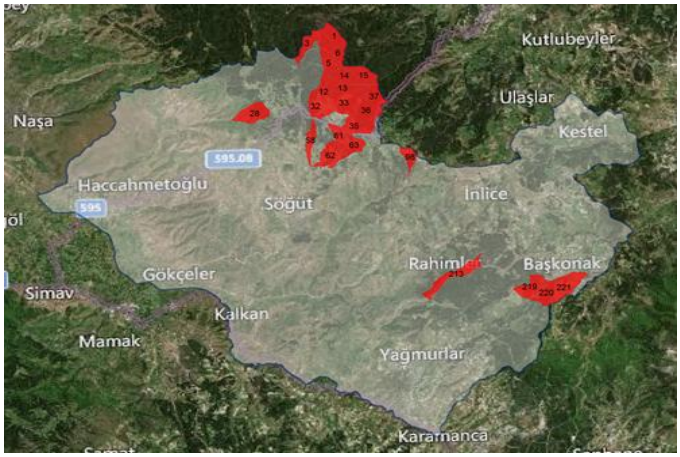


Figure 6: Share of Forest Fires within the Last 10 Years

Share of forest fire outbreaks within the last 10 years in the borders of Söğüt Forest SubDistrict 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).

Table 1: Information of Forest Fires within Last 10 Years

	Year	Compartment No	Fire Start		Area	Tree	Cause	Responsible
			Date	Hour	(ha)	Species		
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	0.01	Black	Negligence	Unknown

9	2015	32	01.11.2015	PM 2:40 PM	0.02	Pine 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 [14]. 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-fireseason. Besides this, with their water capacity of 2.5 tons and 100 meters of hose, multipurpose 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 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.

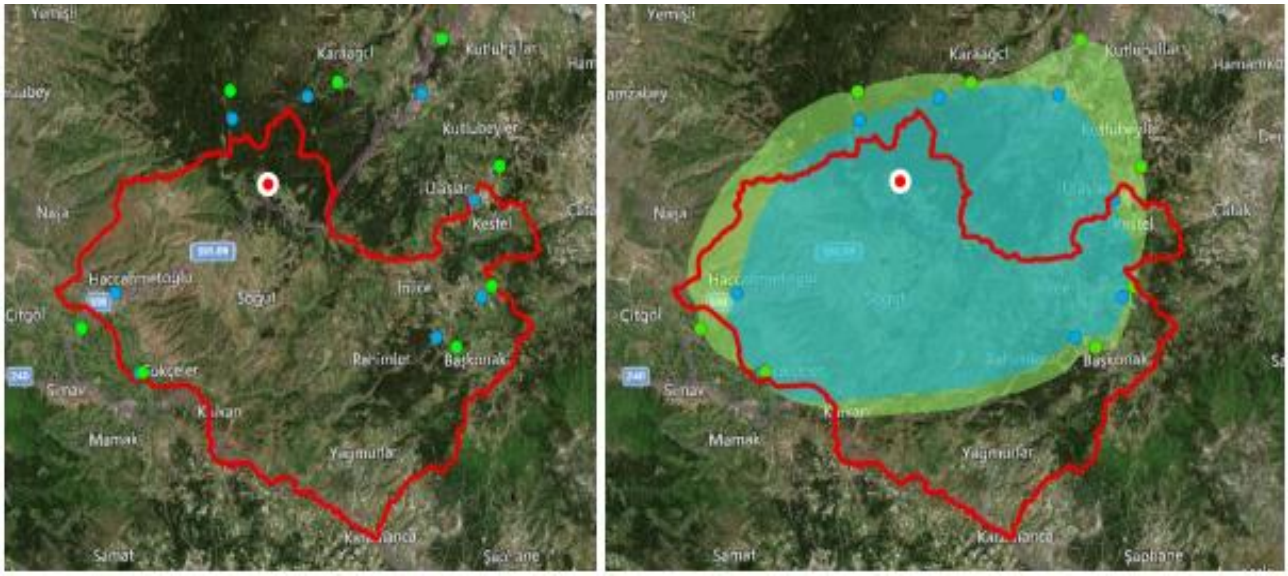
Gölcük First Fire-Responder Squad Building and Fire Departure Point based within the borders of Forest Sub-District Directorate are located at 5.1 km north of Söğüt and on 1326 m altitude. Gölcük First Responder Squad, of which geographical location is 39° 09’ 57,2” north latitude and 29° 05’ 11,8” east 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 Minute 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 firefighting 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

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

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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