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Assessment of fire watch towers by using visibility analysis: The case of Dursunbey, Balıkesir

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Abstract: The Mediterranean region is seriously affected by forest fires due to dry climate and fire sensitive tree species. Turkey, as one of the Mediterranean countries, is subject to number of forest fires every year. The coastline from the eastern Mediterranean region to the Marmara Region, which possesses approximately 5.5 million hectare of forested lands, is the most fire sensitive area in Turkey. Forest fire-fighting team can be listed under five groups: the first response team, alert-force team, the mobile team, fire-truck team, and air support team. In order to fight against forest fires effectively, fire-fighting team must arrive to the fire area in critical response time, in which the probability of controlling forest fires rises markedly. Therefore, it is very important to alert fire-fighting team immediately just after the beginning of forest fire. One of the most important tasks for early detection of forest fires is the fire observations from fire watch towers. Especially in fire sensitive areas, fire watch towers are built for monitoring large forested areas. At these towers, the fire lookout personnel work 7-24 bases to detect and announce fires during the fire season. Fire watch towers should be carefully located in such a way that ensures fire lookout personnel to monitor most of the forested areas in the region. This study aimed to evaluate locations of fire watch towers by using GIS techniques. The study area, Yayla Forest Enterprise Chiefs, is located in the border of Dursunbey Forest Enterprise Directorate in the city of Balıkesir. Three fire watch towers located in the study area were examined by using Visibility Analysis and then their locations were evaluated. The results indicated that 81% of the forested area was visible by available fire watch towers, while rest of the forests was out of side. Besides, it was found that 57% of the area was seen by more than one tower.
Keywords: Forest fires, Fire watch towers, Visibility analysis, Dursunbey

1. Introduction

Forest fires are one of the most detrimental factor that affect forest resources. The forested lands along the coastline of Turkey from Mediterranean region to Aegean and Marmara regions are classified as fire sensitive areas at the first degree (Akay et al., 2017). In order to fight with forest fires effectively, fire-fighting team should arrive to the fire area in the shortest amount of time. Especially in fire sensitive forested areas, arrival time should be within the critical response time, in which the probability of controlling forest fires markedly rises (Akay et al., 2012). Thus, it is crucial to detected forest fires and inform fire-fighting teams immediately for fire control.

For early detection of forest fires, General Directorate of Forestry establishes fire watch towers where fire lookout personnel observe forest fires 7-24 bases during the fire season (Gülci et al., 2016). Fire watch towers are located at the highest points at which forested areas can be seen clearly. The lookout personnel in the towers should be able to see all of the forested areas in flat ground, while visible forested area should be minimum 70% at the rough terrain (Çanakçıoğlu, 1993). The forested areas should be directly visible from at least two fire watch towers. Besides, lookout personnel should see the region at the visibility angle of 360^{o} and the distance between the watch towers should not exceed 25 km (Çanakçıoğlu, 1993).

Advances in Geographical Information System (GIS) and computer technology made it possible to utilize GIS based decision support systems in forest fire management stages including fire fighting activities, pre-fire precautionary measures, and post-fire operations (Küçük and Bilgili, 2006; Akay et al., 2012). Visibility analysis of GIS tools can be used to evaluate observation capacity of the fire watch towers (Singh et al., 2014). Besides, current locations of fire watch towers can be evaluated and alternative locations can be investigated for new towers by using visibility analysis (Aşkın, 2004; Akbulut and Özdemir, 2008).

The location of the fire watch towers plays important role in visibility range which is very important in effective observation of forest fires. In this study, the observational capability of fire watch towers located in Yayla Forest Enterprise Chief (FEC) of Dursunbey Forest Enterprise Directorate (FED) was evaluated by using Visibility Analysis function of ArcGIS 10.2.

2. Material and methods

2.1. Study area

The study area was Yayla FEC within the borders of Dursunbey FED which is classified as first degree fire sensitive area (Figure 1). The visibility analysis was run to evaluate locations of three fire watch towers in which two of them are within the

Yayla FEC. The third tower is located in nearby FEC called Candere and some part of the Yayla FEC can be observed from that tower. The information about these towers are provided in Table 1.

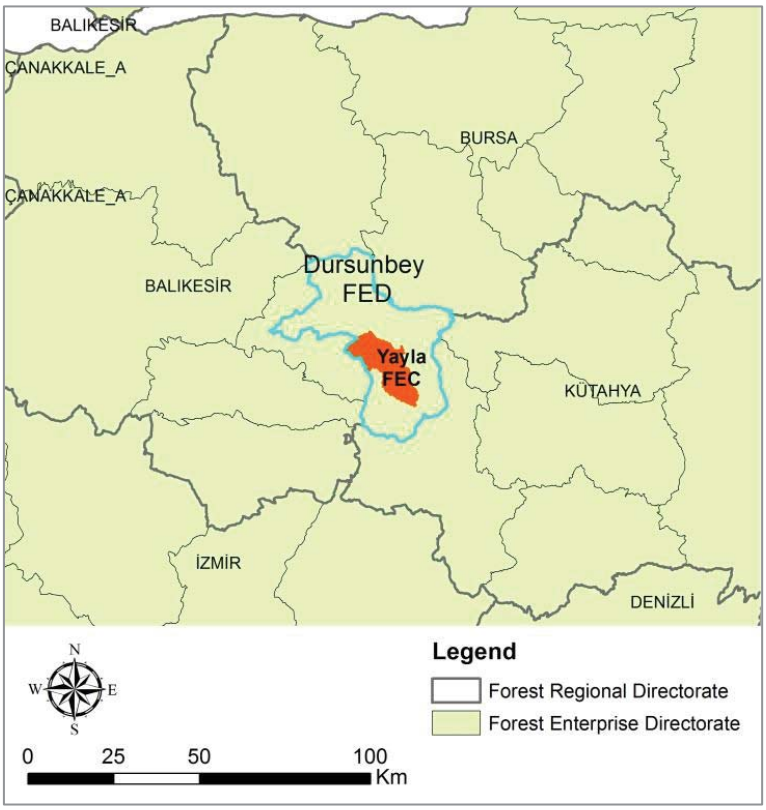

Figure 1. The study area map

Table 1. Fire watch towers

Towers	FEC	UTM Coordinates		Elevation (m)
		X	Y	
Tepepınar	Yayla	35 S 4372041	650489	917
Civana	Yayla	35 S 4360445	660081	1622
Kılıçoluk	Candere	35 S 4365300	650485	1110

2.2. GIS database

2.2.1. Digital elevation model

The accuracy of the visibility analysis mostly depends on reliable Digital Elevation Model (DEM). In this study, DEM (10 m x 10 m) was generated based on contour map (1:25000) with 10 m intervals (Figure 2). The contour map was obtained from Dursunbey FED.

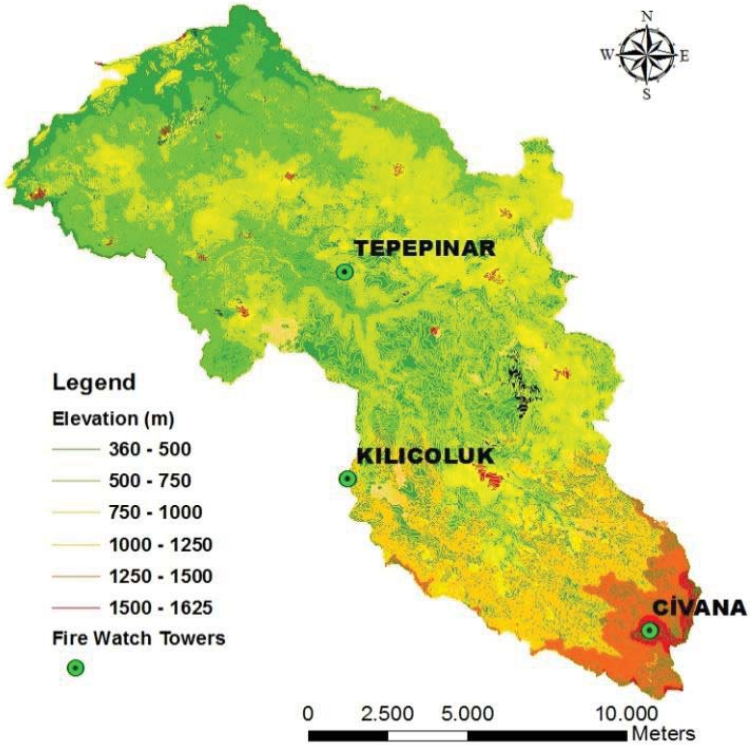

Figure 2. Contour map

2.2.2. Land use types

The land use type map was generated based on forest stand map (1:25000) which was also obtained from Dursunbey FED. Then, land use types (forest, agriculture, open areas, rocky areas, residential area, open areas-rocky areas, mines) within the study area was delineated (Figure 3). Then, a layer was generated representing the forested area and it was used in visibility analysis.

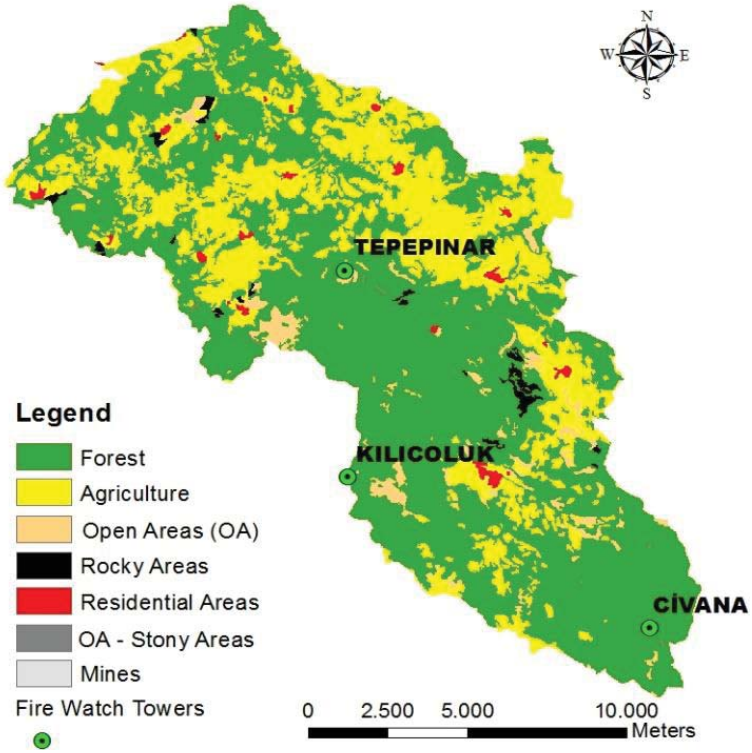

Figure 3. Land use map

2.3. Visibility analysis

Firstly, a data layer indicating fire watch tower locations were generated using UTM coordinates of the three watch towers. Then, Observer Points tool in ArcGIS 10.2 was used to run visibility analysis for the study area. This method requires a specific fields and data inputs in the attribute table of the watch towers. Table 2 indicates these data inputs entered in the attribute table.

In order to observe all of the forested areas around watch towers, horizontal visibility angle was set to 360°. In fire observations, fire smokes that are high above the ground surface are monitored. In this study, the smoke height was estimated as 100 m. Vertical visibility angles were set to +/-90 degrees. The visibility ranges of fire watch towers were also entered into attribute table. In the visibility map, firstly, visible and nonvisible areas from watch tower were indicated for whole Yayla FEC. Then, the map of forested areas was extracted from the map to evaluate visibility of forested areas.

Table 2. The data entered into attribute table of watch towers

Fire Watch Towers	Altitutes (m)	Tower height (m)	Smoke height (m)	Horizontal visibility angle (degree)	Visibility range (m)	Vertical visibility angle (degree)
Tepepınar	912	6	100	360	10000	+/-90
Civana	1622	6	100	360	15000	+/-90
Kılıçoluk	1110	6	100	360	15000	+/-90

3. Results and discussion

3.1. Digital maps

The DEM of the study area was indicated in Figure 4. It was found that the average elevation was about 860 m, with minimum and maximum elevations of 360 m and 1625 m, respectively. The land use type map was generated for the study area. Table 3 indicates the areal distribution of land use types. The results indicated that most of the study area was covered by forests (65.26%), and followed by agricultural lands and open areas. The data layer indicating forested areas was shown in Figure 5.

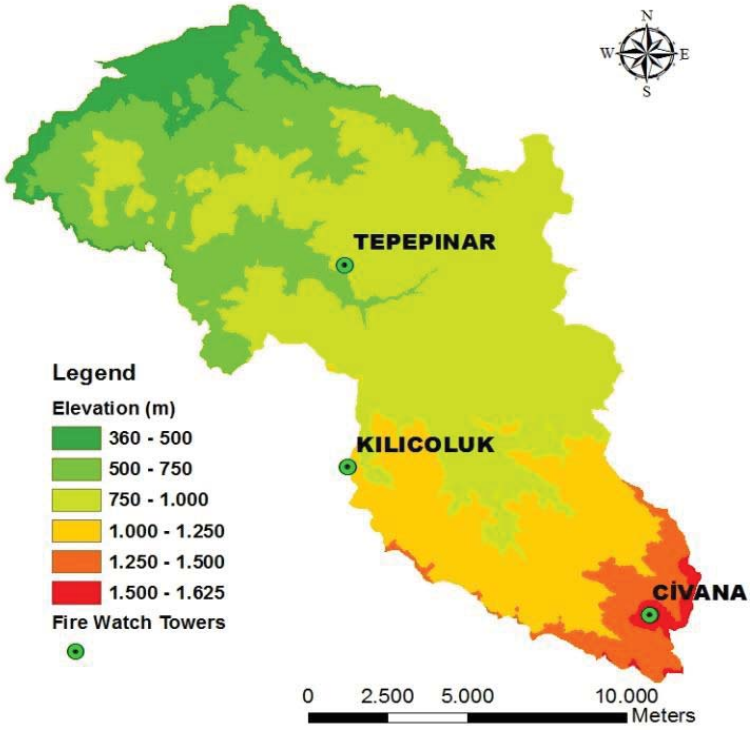

Figure 4. DEM of the study area (10m x 10m)

Table 3. Areal distribution of the land use types

Arazi kullanim tipi	Area (%)
Forest	65.26
Agriculture	29.54
Open Areas (OA)	3.46
Rocky Ares	0.85
Residential Areas	0.81
OA-Stony Areas	0.07
Mines	0.01

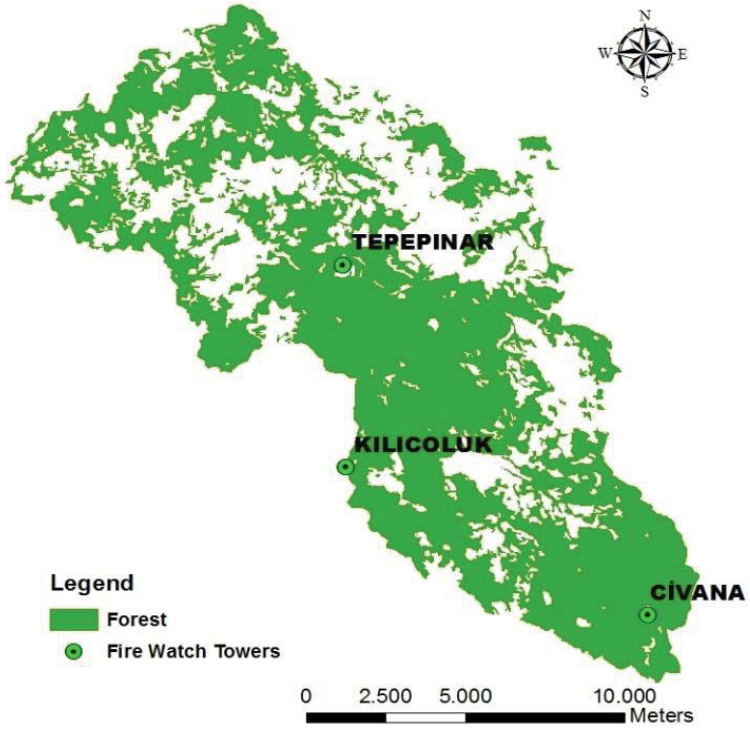

Figure 5. Forested area

3.2. Visibility analysis

The visible forest areas and areas observed by the towers were determined based on the visibility analysis (Table 4). The visible forested areas by the fire watch towers were indicated in Figure 6. It was found that 79% of the whole Yayla FEC was visible from the watch towers, while 81% of the forested area was observed by the towers. The tower with greater visibility was Tepepınar tower, followed by Kılıçoluk and Civana tower. Tepepınar and Civana tower together was able to see 20% of the forest area.

Table 4. The forest areas visible from the fire watch towers

Number of Towers	Watch Towers	Area (%)
-	Not Visible	18.85
1	Tepepınar	16.06
1	Civana	2.23
1	Kılıçoluk	5.72
2	Tepepınar - Civana	20.26
2	Tepepınar - Kılıçoluk	8.22
2	Civana - Kılıçoluk	7.47
3	All Towers	21.18

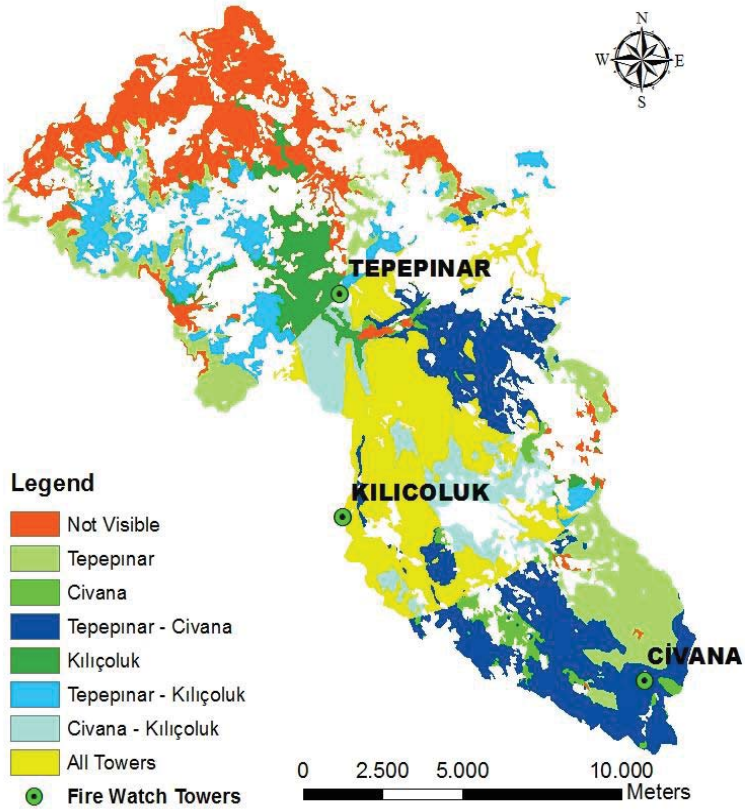

Figure 6. The forest areas seen by the watch towers

It was also found that about 57% of the forest areas was visible from more than one fire watch tower (Figure 7). About 21% of the forest area was visible from all tree towers. On the other hand, 24% of the forest areas was seen by only one fire watch tower.

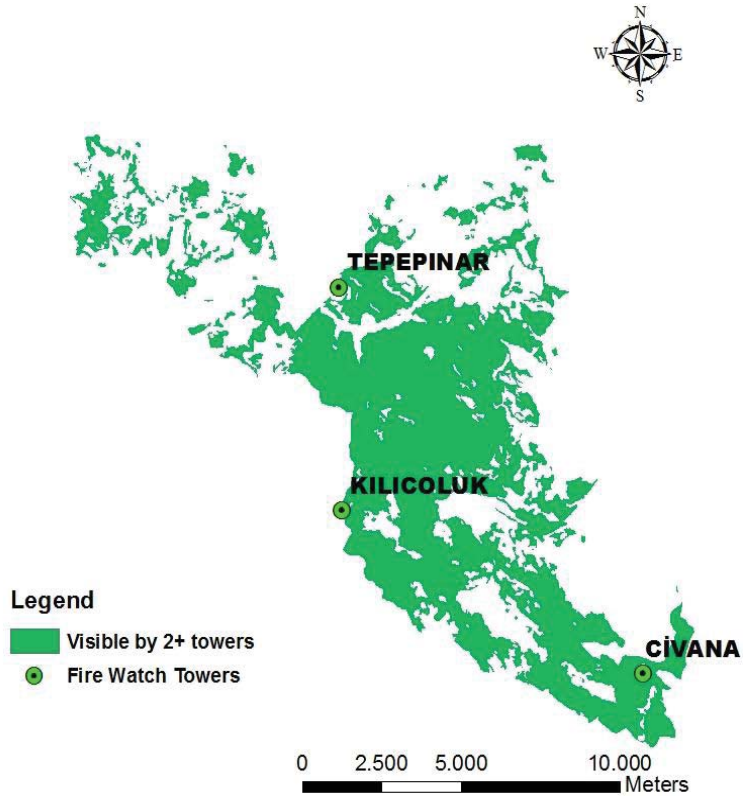

Figure7. The forest areas seen by more than one watch tower

4. Conclusions

GIS based visibility analysis was used to determine visible and nonvisible forest areas from fire watch towers. The visibility of three watch towers was evaluated considering the forest areas in Yayla FEC where two watch towers were within the FEC, while the third one was in the border of nearby FEC. Through the visibility analysis, it was aimed to determine the forest areas that can be seen from each individual watch tower, forest areas visible by more than one tower, and the forest areas that cannot be seen from any of the towers.

The results indicated that 81% of the forested area was visible by available fire watch towers, while rest of the forests (19%) was not visible. Besides, it was found that 57% of the area was seen by more than one tower. Based on these results it can be concluded that watch towers located within the study area was sufficient and their locations were suitable in order to monitor potential forest fires effectively.

Refererences

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