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Forest fire risk analysis using GIS; Example of Geyve

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Abstract

Forests are ecosystems that have a very important place in terms of the continuity of life on earth. Forests are subject to the danger of fire for many different reasons such as accidents, negligence and climate changes. Although it is not possible to completely prevent forest fires, predicting forest fire risk areas and taking precautions are possible. Geographical Information System (GIS) is an important support system used in the production of risk maps. In this study, the Geyve district of Sakarya province, which has a lot of forest area, was examined in terms of fire hazard. Risk values were assigned according to their fire potential with parameters. The condition with the highest probability of causing a fire was given the value "5 - Very High Risk", while the condition with the lowest probability of causing a fire was given the value "1 - Very Low Risk". The maps produced from the parameters with these risk values were predominantly overlapped and the risk map was obtained. As a result of the analyses, the forest fire risk map was produced according to the five risk factors. It was determined that 0.05% was high risk, 9.03% was risky, 38.85% was medium risk, 48.45% was low risk and 3.62% was risk-free region in the study area.

1. Introduction

Due to global climate changes and human activities, forest areas are gradually decreasing. Unpreventable forest fires are also an important factor in the reduction of forest areas. Especially in rural areas, uncontrollable fires cause loss of life and property and damage the ecological system of that region to a great extent [1].

Since Turkey is located in the Mediterranean climate zone, forests are under fire threat [2]. In the last eleven years "in between 2011 and 2021", a total of 29104 forest fires broke out in Turkey and 230,457 hectares of land were damaged (Figure 1). In 2021 huge forest fires were occurred in Turkey and a total of 139503 hectares of forest area was damaged in just one year [3].

In the fight against forest fires, it is very important to determine the high-risk areas and to take precautions before a disaster occurs in these areas. It is easy, fast and economical to get the desired information with Geographical Information Systems (GIS) technologies.

Thanks to these advantages, data can be obtained and disaster studies can be planned not only at the time of the disaster, but also for the studies that need to be done before or after the disaster [4-6].

More than one spatial criterion (aspect, slope, distance to the road, etc.) must be combined under suitable conditions for starting and spreading a fire in forest areas. GIS is very effective systems in analysing multiple spatial criteria simultaneously and drawing effective conclusions [7]. In this study, forest fire risk areas were tried to be determined in the Geyve district by using GIS.

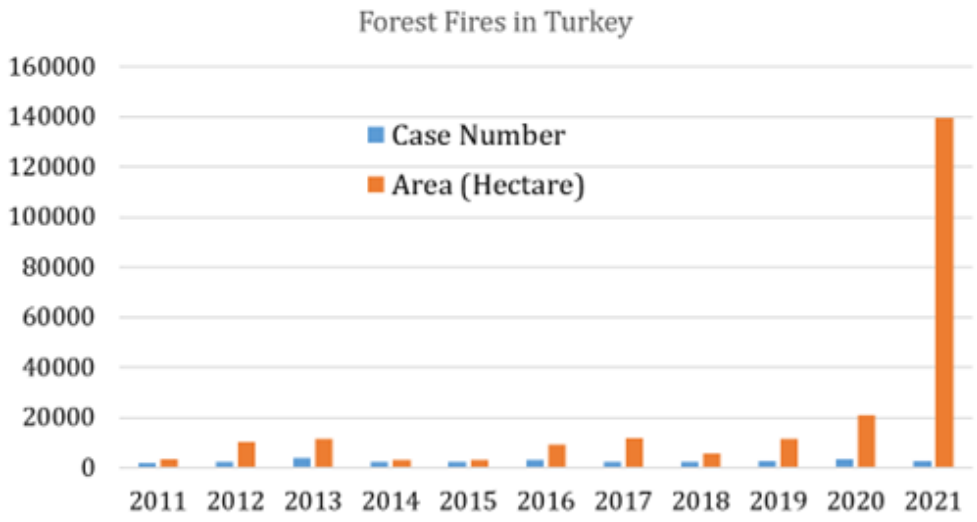

Figure 1. Number of fires and burned area by years [3]

1.1. Study Area

Geyve is a district of Sakarya province, which is located in the east of the Marmara Region. It is an important district in terms of its distance to the big cities (Figure 2). The area of the district is 780 square kilometres and its height from the sea is 74-80 meters. This height rises to 700-1500 meters in mountainous area.

Figure 2. Location map of the study area

Geyve has a rainy climate. The region receives precipitation in all months of the year, but the most common rainy months are during winter and spring. Although the climate of the region is similar to the Mediterranean climate, the reason for the precipitation in the summer months is the humid air caused by its proximity to the Black Sea [8]. Considering the geographical location of the district and its surface forms, it is seen that Geyve is located on the foothills of the Samanlı Mountains and south of the Sakarya River. The district is plateau-rich due to the presence of several plateaus, such as Soğucak and Çataltepe plateaus. Geyve's forest lands are the natural vegetation of Geyve. There are torch pine, red pine, beech and mixed-leaved tree species in the region. By nature, these trees belong to the dry forest type. This increases the likelihood of forest fires.

2. Material and Method

2.1. Material

In this study, to produce the forest fire risk map, slope, aspect, distance to roads and settlements, and humidity ratios of tree species were used as the parameters, which based on the previous studies [9,10]. The slope and aspect maps were obtained from 1/25,000 scaled DEM data that is available from the U.S. Geological Survey (USGS). Road and settlements data are taken from Google Earth. Tree species were obtained from the studies of the Sakarya Regional Directorate of Forestry and the humidity ratios of tree species in the region were determined by research. ArcGIS software was used to analyse the data and produce a forest fire risk map of the Geyve district produced.

2.2. Method

Some parameters, must come together under appropriate conditions for the possibility of fire in forested areas. In this study, parameters that can increase the risk of forest fire were brought together and analysed in GIS and possible results were tried to be predicted. The parameters used in the study of determining the fire risk zones were first assigned a coefficient according to the degree of importance. Considering their effects on fire, the most important parameter is forest type. The slope, aspect, road and distance from the settlement parameters, follow the forest type parameter, respectively. These five parameters were evaluated among themselves and ranked as in Table 1 according to their effects on the fire. Areas such as water, lakes, and streams are designated as non-risk areas. In order to determine the fire risk areas according to these parameters, Equation 1, [9] was used.

$$RC = 7*FT + 5*(S+A) + 3*(DR+DS) \quad (1)$$

In this equation, RC expresses the fire risk zones into five classes; high risk, risky, medium risk, low risk and no risk. FT shows forest types consisting of 3 classes. The S and A parameters, which have the same effect on the spread of the fire, show the slope and aspect analysis. The distance parameters to the road and settlement, which include the human element in the fire risk model, are also expressed with DR and DS [9,11]. First of all, risk values were assigned according to their fire potential with parameters, which are shown in Table 1. The condition with the highest probability of causing a fire was given the value "5 - Very High Risk", while the condition with the lowest probability of causing a fire was given the value "1 - Very Low Risk". The maps produced from the parameters with these risk values were predominantly overlapped and the risk map was obtained.

Table 1. Parameters and factor weights [9,10]

Parameters	Weight	Class	Factor	Risk Class
Tree Species	7	Very Dry	5	Very High
		Dry	4	High
		Medium	3	Medium
		Humid	2	Low
		Very Humid	1	Very Low
Slope	5	>35	5	Very High
		25-35	4	High
		10-25	3	Medium
		5-10	2	Low
		0-5	1	Very Low
Aspect (%)	5	South	5	Very High
		West	4	High
		East	3	Medium
		North	2	Low
		Flat	1	Very Low
Distance to Road (m)	3	0-100	5	Very High
		100-200	4	High
		200-300	3	Medium
		300-400	2	Low
		>400	1	Very Low
Distance to Settlement (m)	3	0-1000	5	Very High
		1000-2000	4	High
		2000-3000	3	Medium
		3000-4000	2	Low
		>4000	1	Very Low

2.2.1. Classification of slope and aspect parameters

Slope and aspect characteristics are important factors in the occurrence and spread of forest fires. The spread time of forest fires is shorter on sloping lands. On the aspect feature, the possibility of fire increases due to the strong sun rays on the south oriented slopes [7]. Therefore, these two factors are very valuable in fire risk maps. In the study, the slope and aspect maps were obtained from the DEM map using ArcGIS and classified (Figure 3 and Figure 4).

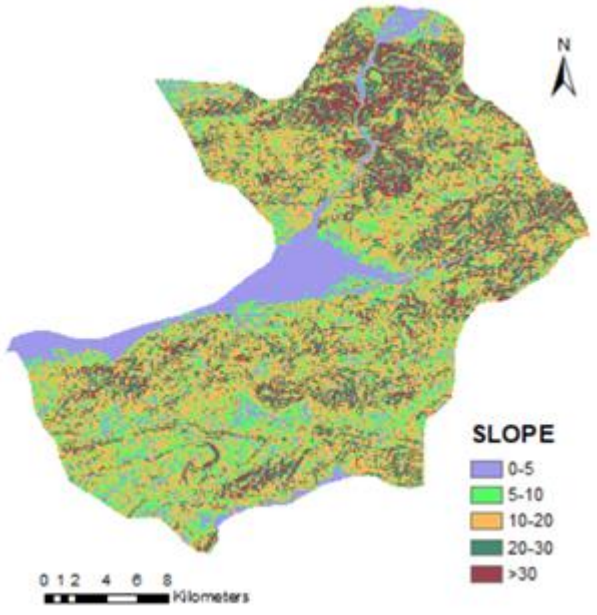

Figure 3. Slope map

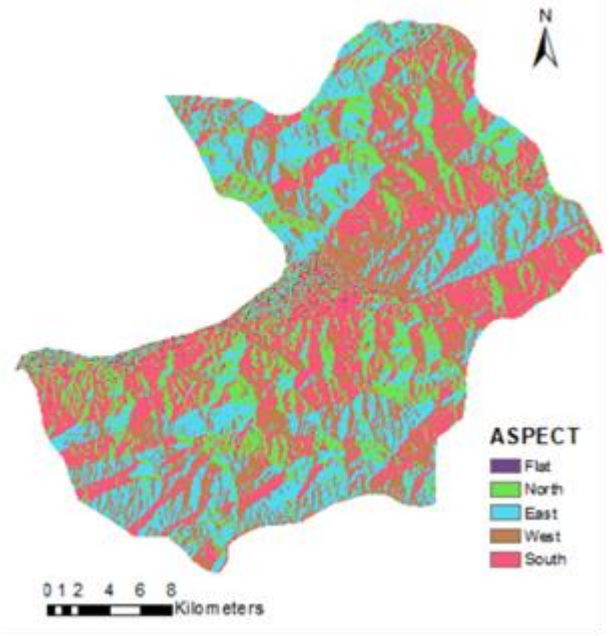

Figure 4. Aspect map

2.2.2. Classification of distance parameters to road and settlement

Distances to roads and settlements represent the human factor in fire hazard. In forest areas close to roads, the probability of fires as a result of accidents and the negligence of people is quite high. Likewise, forest fires occur frequently as a result of human activities in areas close to settlements [9-12]. Therefore, these two factors should be considered in fire risk analysis. The risk classes of the distance to the road and settlements were obtained by Euclidean distance analysis in GIS and can be seen in Figure 5 and Figure 6.

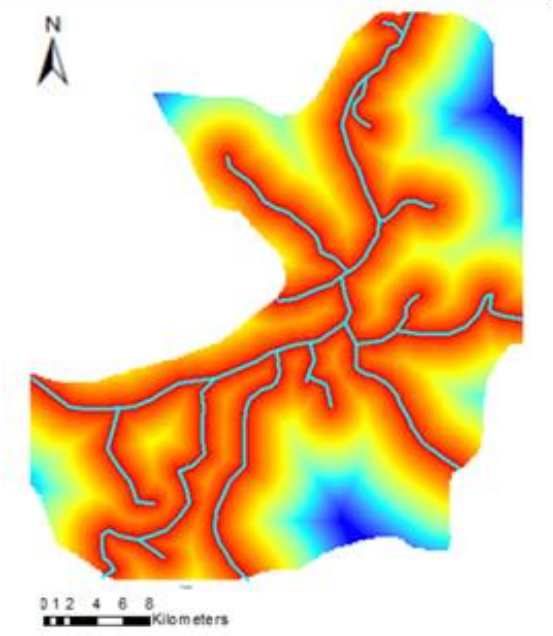

Figure 5. Distance to road

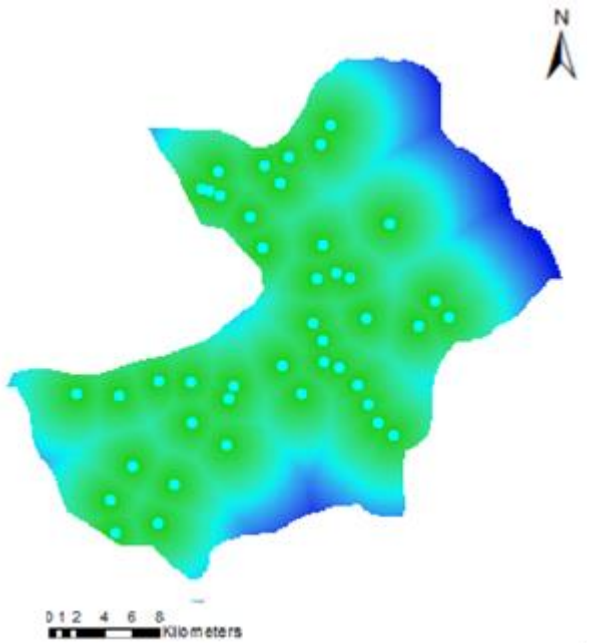

Figure 6. Distance to Settlement

2.2.3. Classification of humidity ratios of tree species

Forest areas are the natural vegetation of Geyve. There are Red Pine (Pinus brutia), Beech (Fagus), Torch Pine (Pinus nigra), Mixed-Leaved, Mixed Coniferous Leaf, Hornbeam (Carpinus) species in the region. These trees constitute the dry forest type by nature. This increases the likelihood of forest fires [8].

The flammability characteristics of tree species in forests are important for predicting the starting point of forest fires and how the fire will continue [7]. Dry tree species such as Torch Pine and Red Pine create a favourable environment for fire. For this reason, the map of tree species in the Geyve district is shown in Figure 7.

3. Results

According to the tree species in the study area, it is seen that 26.56% of the region is covered with Mixed-Leaved, 12.92% with Red Pine, 12.95% with Beech and 6.37% with Torch Pine trees. The distribution of tree species in the region is shown in Table 2 and the map of their division into risk classes is shown in Figure 8. Where the Mixed Leaf species with low flammability are seen, the probability of fire is low, while the probability of fire is high in places where Red Pine, which is a highly flammable species, is seen.

Table 2. Distribution of tree species

Tree Species	Area (%)
Open Space	% 37.16
Mixed-Leaved Trees	% 26.56
Red Pine	% 12.92
Beech	% 9.25
Torch Pine	% 6.37
Mixed Coniferous Leaf Trees	% 5.09
Hornbeam	% 2.65

Due to the slope of the land and the steep south and west slopes, it greatly increases the risk of forest fires [13]. Considering the slope levels in the field of the study, the rate for more than 30 degree high-risk areas is 7.61% (Table 3). The aspect factor, on the other hand, is 29.97% of the southern slopes, which are the areas with a high fire hazard (Table 3).

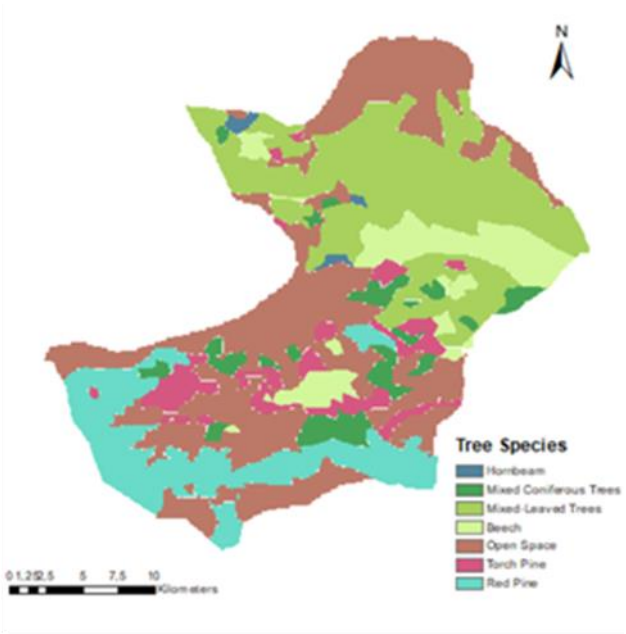

Figure 7. Tree Species map

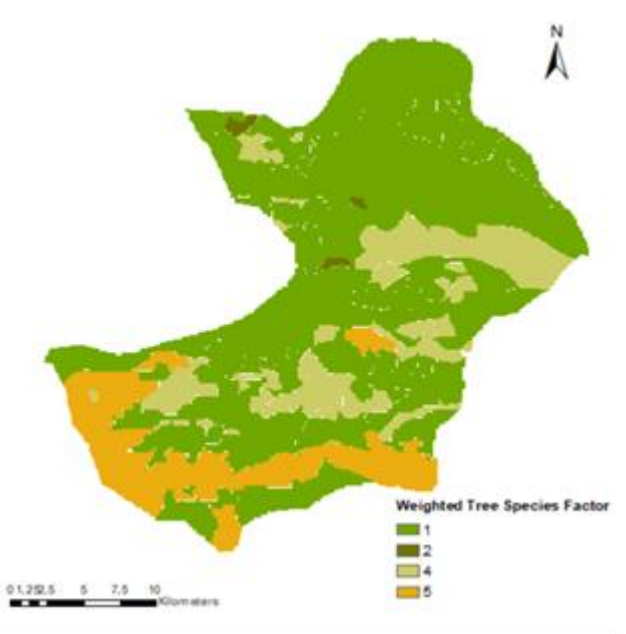

Figure 8. Weighted Tree Species Factor map

There are many main roads in the Geyve district, and Geyve has 73 neighborhoods. For this reason, the distance to the road and the settlement is important for mapping the fire risk. The area less than 400 meters from the road is 8.93% of the whole total study area. This area has the highest fire risk. The area with a distance of less than 4000 meters to the settlements covers 6.44% of the entire area.

Produced criteria maps were overlapped based on the weight of them and a forest fire risk map for Geyve was obtained. The risk map is shown in Fig.8, and the spatial distribution of fire susceptibility classes are presented in Table 4.

Table 3. Aspect and slope

Factor	Aspect	Area (%)	Slope	Area (%)
1	Flat	% 0.93	0-5	% 12.83
2	North	% 20.27	5-10	% 18.18
3	East	% 25.58	10-20	% 40.25
4	West	% 23.25	20-30	% 21.13
5	South	% 29.97	>30	% 7.61

Table 4. Spatial distribution of fire susceptibility classes

Fire Risk Region	Area (%)
High Risky Area	% 0.05
Risky Area	% 9.03
Medium Risky Area	% 38.85
Low Risky Area	% 48.45
Risk Free Area	% 3.62

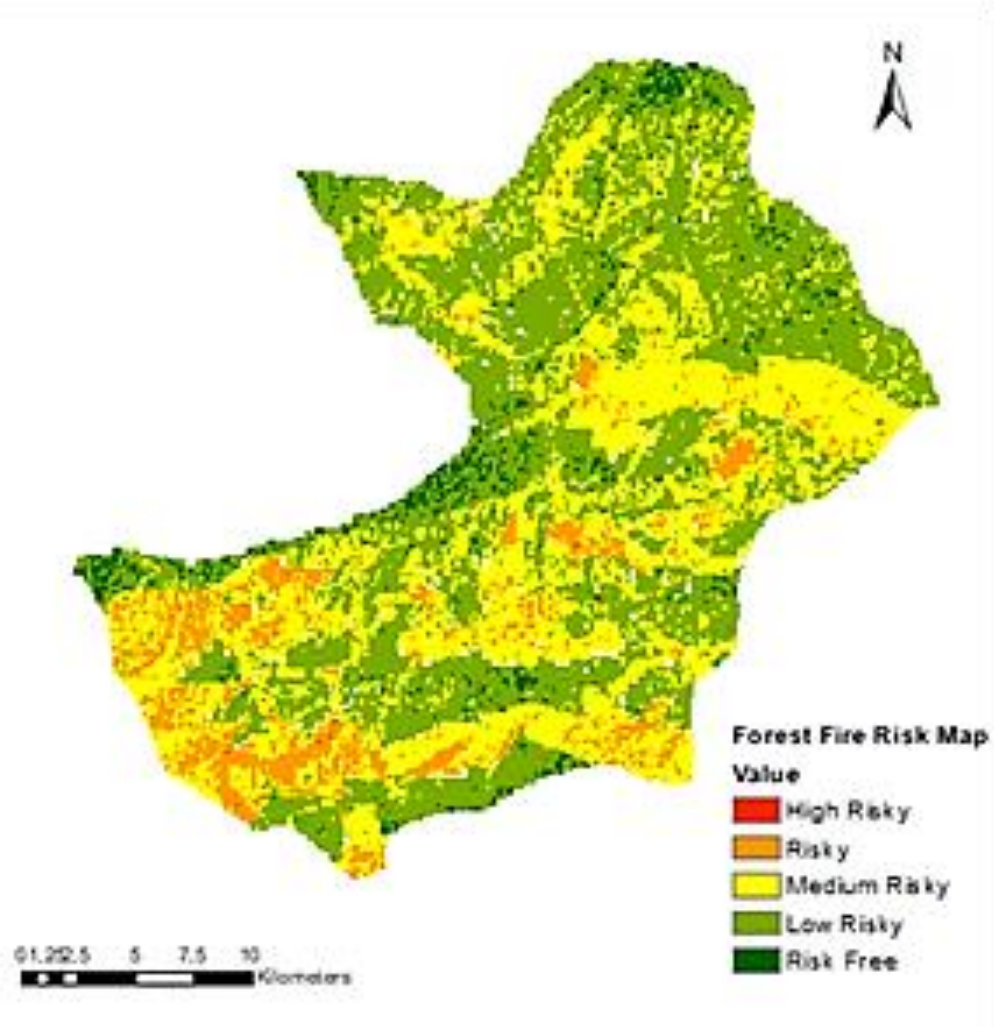

Figure 9. Fire risk map of Geyve

4. Discussion

The aim of this study is to determine the forest fire risk areas in the Geyve district of the Sakarya province. In the light of other studies, the same parameters and the same method were used in this study, but due to the different study area, the fire risk data and map preserved their subjectivity.

In the study conducted by Bingöl [14], forest fire risk areas were determined for Burdur province. They were used the same parameters in their study. As a result of the study, a forest fire risk map was obtained for the province of Burdur. According to the fire risk map, 12.3% of the area is very risky, 20.2% is risky, 20% is medium risk, 31.5% is low risk, and 16% is risk-free. In the current study, high risky and risky area is 9.08 % but it is 32.5 % in the Burdur province study. It was observed that, the rate of the risky area is getting increase in the regions to the south. As the forest fires that occurred in Turkey in 2021.

5. Conclusion

While our world is facing global warming and its effects, being prepared for these effects and their results is essential. Forest fires damage both our green areas and the species living in the forest. We must be prepared and take precautions against this type of disaster that threatens our nature. GIS technologies are very useful in analysing the factors that cause fires simultaneously and in producing effective results. In this study, the slope, aspect, plant species, distance to the road and settlement were used as the risk factors for forest fires and a Geyve district forest fire risk map was produced based on these factors. As a result of the analyses, it has been seen that the fire risk in the Geyve District changes depending on the tree species. It was observed that the fire risk is higher in the Southwest region, compared to the other regions. High risk areas cover 0.05% of the total area.

With the produced fire risk maps, knowing which areas have a fire risk and which factors cause them will make an important contribution to predicting and preventing fires.

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Author contributions

Şeydanur Güvendi: Conceptualization, Methodology, Data curation, Software, Writing-Original draft preparation. **Aziz Şişman:** Visualization Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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