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EVALUATING FOREST FIRE SUSCEPTIBILITY LEVELS IN ŞAHINKAYA CANYON (NORTHERN TÜRKİYE) USING AHP

Harun Reşit Bağcı[1], Cansu Kaya[2]*

[1]Ondokuz Mayıs University, Faculty of Humanities and Social Sciences, Department of Geography, Samsun, Türkiye; e-mail: harun.bagci@omu.edu.tr
[2]Ondokuz Mayıs University, Graduate School of Education, Department of Geography, Samsun, Türkiye; e-mail: cansukaya1201@gmail.com

Abstract: The aim of this study is to classify the forests in and around the Şahinkaya Canyon (Central Black Sea Region in Northern Türkiye) according to their levels of fire susceptibility, to identify priority areas in fire management, and to provide recommendations for the prevention and effective control of forest fires. To determine fire susceptibility levels, the Analytic Hierarchy Process (AHP), a multicriteria decision-making method, was employed, and the results were visualized in a Geographic Information Systems (GIS) environment. The parameters used, along with their impacts and weight values, were determined based on expert opinions, field surveys, and relevant literature. In this study, the effects of topography, forest resources and characteristics, and human activities on fire susceptibility were analyzed using nine parameters. The results indicate that fire susceptibility varies with forest structure and composition, topography, climatic factors, and anthropogenic influences. Of the study area, 34% falls within the high and very high fire susceptibility classes, while 38% is classified as low and very low. The remaining 28% represents moderate fire susceptibility, corresponding to transitional zones between low and high susceptibility. According to the fire inventory, 11 of the 17 recorded fires occurred in areas with high and very high fire susceptibility. This distribution indicates a spatial correspondence between observed fire occurrences and the susceptibility classes derived from the analysis. This study reveals the spatial distribution of forest fire susceptibility in and around the ecologically sensitive Şahinkaya Canyon, providing a data-based framework for the use of the findings in conservation and planning efforts.

Keywords: forest fire susceptibility; AHP; Şahinkaya Canyon

1. Introduction

Forests are essential for conserving biodiversity and maintaining environmental balance. As of 2020, forests cover 31% of the Earth's land surface, with 45% of global forests located in equatorial and subtropical regions and 43% in Northern Eurasia and North America (FAO, 2020). As of 2024, 30% of Türkiye's land area is covered by forests, and the country ranks 27th worldwide in terms of forest resources (General Directorate of Forestry [GDF], 2024a). The spatial distribution of forests in Türkiye is shaped by various factors, primarily

*Corresponding author, e-mail: harun.bagci@omu.edu.tr

precipitation and temperature conditions, as well as population, settlement patterns, and mining activities. The region with the highest proportion of forested areas is the Black Sea Region, which contains 24% of the country's total forest area (GDF, 2024a).

Both in Türkiye and globally, forest fires constitute the primary cause of forest degradation (Demir, 2023). These fires are environmental disasters that destroy natural habitats, vegetation, and forest ecosystems (Chowdhury & Hassan, 2015). Rising temperatures and warming-induced increases in fire weather conditions have significantly intensified the frequency and severity of forest fires across Mediterranean Europe (Turco et al., 2018). In Türkiye, large-scale forest fires such as those in Manavgat exemplify this trend and highlight the crucial role of human-induced factors (Ekberzade et al., 2025). Beyond the Mediterranean climate zone, significant increases in summer temperatures and emerging temperature-driven stress in the Black Sea region suggest that continued warming may alter forest ecosystem vulnerability, with potential implications for future fire susceptibility (Dogan Ciftci et al., 2024). Accordingly, considering Türkiye's diverse Mediterranean and Black Sea ecosystems, a reassessment of forest fire management strategies appears necessary.

In Türkiye, where the Mediterranean climate predominates, 97% of forest fires occur between June and October (Doğanay & Doğanay, 2011). To prevent such incidents and ensure effective response, Türkiye has established specialized and well-equipped firefighting units to enhance operational capacity. During high-risk periods, access to forested areas is restricted, and continuous monitoring is conducted using unmanned aerial vehicles (UAVs) and fire lookout towers (Erdönmez et al., 2023).

Between 1997 and 2022, a total of 56,968 forest fires occurred in Türkiye, affecting 3,639 km^2 of forested land. Of these fires, 91% were determined to be human-induced (47% negligence and accidents, 11% arson, and 33% unknown origin; GDF, 2023). Although forest fires are most common in the Mediterranean and Aegean regions (Baykal, 2023; FAO, 2020), they also occur in the Black Sea Region, where susceptibility analyses have become increasingly prevalent (Coşkun & Toprak, 2023; Dilekçi et al., 2021).

The study area, Şahinkaya Canyon and its surroundings, located in the Central Black Sea Region, is considered to be among the areas with second- and third-degree fire risk according to data from the GDF of Türkiye. This classification corresponds to forest management areas that experience six to ten fires annually (Özenen Kavlak et. al., 2020). The region's dense vegetation cover and anthropogenic pressures significantly contribute to its elevated fire risk (Akay & Şahin, 2019). Over the past decade, 947 forest fires have occurred within the jurisdiction of the Amasya Regional Directorate of Forestry (RDF), 844 of which were human-induced (Baltacı, 2021). Of these, 27 occurred within the jurisdictions of the Şahinkaya, Akçay, and Kuruçay Forest Management Directorates (FMDs) that encompass the study area; however, records with missing or erroneous coordinate information were excluded from the analyses, and the number of fires considered in the study was therefore limited to 17.

This situation emphasizes the region's vulnerability to forest fires and the importance of continuous monitoring and analysis. Studies assessing forest fire susceptibility commonly use Geographic Information Systems (GIS), Remote Sensing (RS), and Multi-Criteria Decision-Making (MCDM) methods (Baltacı & Yıldırım, 2021; Esen & Avcı, 2018; Ju et al., 2023; Özenen Kavlak et al., 2020). GIS and RS techniques enable the collection and analysis of spatial data on topography, vegetation, and climate factors influencing fire occurrence and spread, while MCDM methods integrate these data to generate susceptibility maps classifying areas by fire risk level (Esen & Avcı, 2018). These integrated approaches support the identification of fire-prone zones and the formulation of effective forest management and fire prevention strategies.

This study aims to identify forest areas with high fire susceptibility in and around Şahinkaya Canyon, including its designated Nature Park, within the jurisdictions of the Şahinkaya, Akçay, and Kuruçay FMDs (Amasya RDF). Increasing anthropogenic pressures from tourism and forestry underscore the need for conservation. The objectives are to assess fire susceptibility using the Analytic Hierarchy Process (AHP) method, compare past fire records with analysis results to identify high-risk areas, and raise awareness of fire causes, impacts, and prevention. Given its biodiversity, effective fire prevention is crucial for ecosystem integrity and the sustainability of ecotourism in the area.

2. Materials and methods

2.1. Study area

The study area encompasses approximately 453 km^2 around Şahinkaya Canyon (Figure 1). Şahinkaya Canyon is a narrow, elongated gorge formed by the erosive activity of the Kızılırmak River (Samsun Governorship, n.d). During the Pliocene epoch, as the Anatolian landmass underwent uplift, the river deepened its channel in the Vezirköprü region, forming Şahinkaya Canyon as an antecedent valley (Kuzucuoğlu et. al., 2019). Such topographical formations can increase susceptibility to forest fires (GDF, 2023).

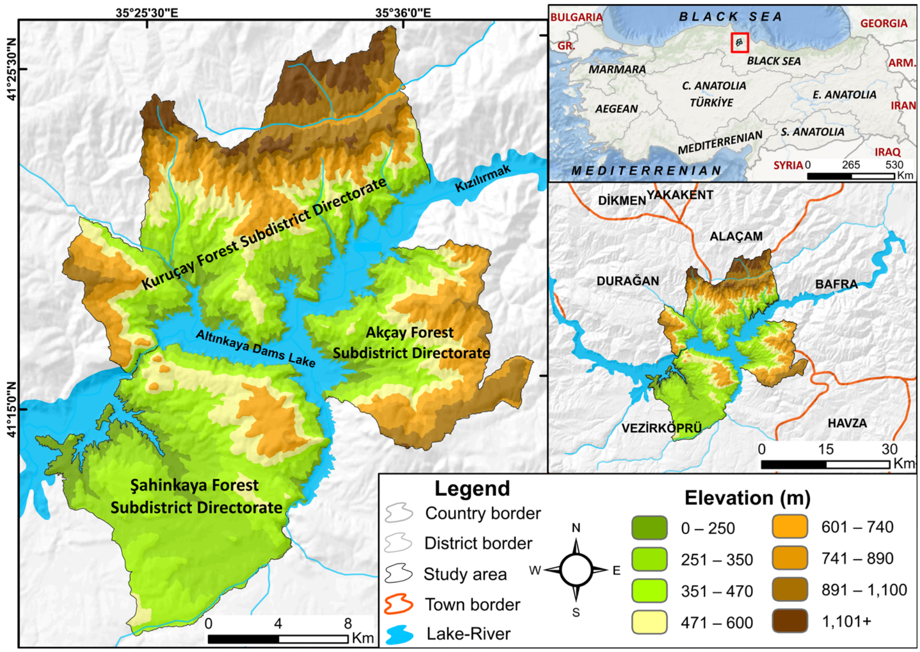

Figure 1. Study area.

Coniferous species, including *Pinus brutia*, *Pinus nigra*, *Pinus sylvestris*, and *Pinus pinea*, dominate the canyon and its surroundings, with some broadleaf species (*Fagus* and *Quercus*) also present, and *P. brutia* comprising the majority of the tree population (GDF, 2024b); the high flammability of conifers accelerates fire spread in areas where they are concentrated (Küçükosmanoğlu, 1986). Between 2014 and 2023, 27 forest fires were recorded in the Şahinkaya, Akçay, and Kuruçay Forest Sub-Districts (FSDs), with ignition points mapped for 17 fires. Most fires occurred in Akçay (88.9%), followed by Kuruçay (10.3%), and Şahinkaya (1.7%), affecting a total of 115.08 ha of forest. The causes of 88% of the fires remain unknown, while 4% were attributed to negligence, 4% to natural causes, and 4% to power transmission lines.

2.2. Data and methods

Within the methodological framework of the study, multiple types of data were utilized in the analysis process. While some datasets were generated through digitization procedures, secondary data were obtained from relevant institutions (Table 1).

Table 1. Data used in the study, their sources, and purposes of use

Data	Source
Slope, elevation, and aspect: these parameters were derived from a 10-meter resolution Digital Elevation Model (DEM) and used in the analysis.	General Directorate of Mapping (GDM) (2024)
Average temperature and relative humidity: distribution maps were generated using the Inverse Distance Weighting (IDW) interpolation method based on 10-year (2014–2023) average monthly meteorological observation data.	Turkish State Meteorological Service (TSMS) (2024)
Vegetation cover density and tree type: these data were obtained as secondary sources, classified, and incorporated into the analysis.	Ministry of Agriculture and Forestry, GDF (2024)
Land cover, distance to power transmission lines and roads: these features were digitized from satellite images.	Google Earth Pro (2024)

The AHP, a key MCDM method, was employed to determine forest fire susceptibility levels (Figure 2). Widely used in similar studies (Dilekçi et al., 2021; Özşahin, 2014), AHP is often integrated with GIS for spatial decision-making. It enables systematic comparison and quantitative weighting of environmental, topographic, and anthropogenic factors (Vaidya & Kumar, 2006), reducing subjectivity in expert evaluations and enhancing internal consistency (Ishizaka & Labib, 2011). Additionally, AHP supports the integration of parameters with different spatial scales, ensuring transparency and reproducibility in GIS-based analyses (Saaty, 2008; Vaidya & Kumar, 2006).

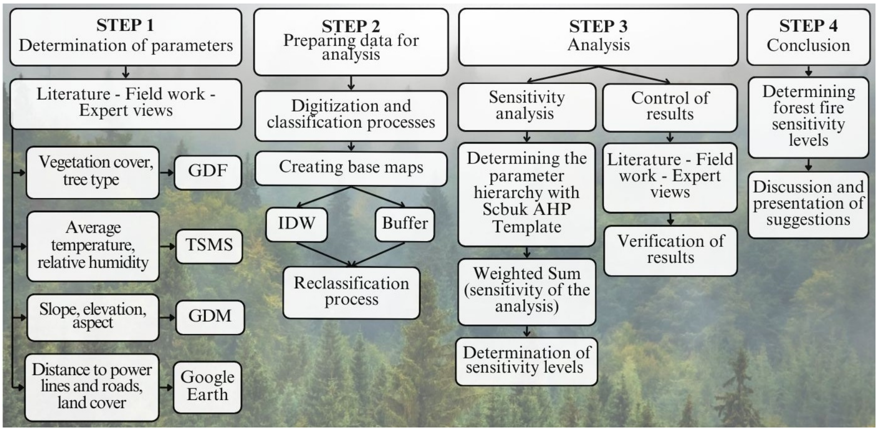

Figure 2. Research design.

The determination of the parameters to be used within the AHP constituted the first step of the study. In this step, parameters employed in similar studies were examined through a review of the relevant literature.

Forest fire risk parameters in the study area were assessed using field surveys and high-resolution Google Earth imagery. Parameter selection and hierarchy were informed by forestry and fire officials and Ondokuz Mayıs University (OMÜ) experts, and included vegetation canopy cover, stand type, relative humidity, land cover, average temperature, slope, aspect, elevation, and distances to power lines and roads (Demir, 2023; Dilekçi et al., 2021; Işık Pekkan et al., 2022; Özşahin, 2014). In AHP, weights, priorities, and consistency ratios (< 10%) were calculated using the "Scbuk AHP Template" (Saaty et al., 2003; Scbuk, n.d.; Table 2).

Table 2. Weights and consistency ratios of parameters and sub-criteria used in AHP

Parameters	Sub-parameters	Importance levels									Sub-parameter weights	Consistency ratio
		1	2	3	4	5	6	7	8	9		
Vegetation cover (%)	< 11	1	1/2	1/3	1/4						0.096	1%
	11–40	2	1	1/2	1/3						0.161	
	40.1–70	3	2	1	1/2						0.277	
	> 70.1	4	3	2	1						0.466	
Average temperature (°C)	8–9	1	1/2	1/3	1/4	1/5					0.062	2%
	9.1–10	2	1	1/2	1/3	1/4					0.099	
	10.1–12	3	2	1	1/2	1/3					0.161	
	12.1–14	4	3	2	1	1/2					0.262	
	> 14.1	5	4	3	2	1					0.416	
Aspect	Flat	1	3	4	4	1/4	1/4	1/4	1/2	1/3	0.070	7%
	North	1/3	1	1/2	1/2	1/6	1/6	1/6	1/3	1/3	0.025	
	Northwest	1/4	2	1	1	1/6	1/6	1/6	1/3	1/4	0.032	
	Northeast	1/4	2	1	1	1/5	1/5	1/5	1/3	1/4	0.034	
	South	4	6	6	5	1	1	1	4	3	0.238	
	Southwest	4	6	6	5	1	1	1	4	3	0.203	
	Southeast	4	6	6	5	1	1	1	1	1/3	0.161	
	East	2	3	3	3	1/4	1/4	1	1	1	0.101	
	West	3	4	4	4	1/3	1/3	3	1	1	0.135	

Table 2. Weights and consistency ratios of parameters and sub-criteria used in AHP (*continued*)

Parameters	Sub-parameters	Importance levels									Sub-parameter weights	Consistency ratio
		1	2	3	4	5	6	7	8	9		
Relative humidity (%)	66–68	1	2	3							0.539	1%
	68.1–70	1/2	1	2							0.297	
	> 70.1	1/3	1/2	1							0.164	
Distance to power transmission lines and roads (m)	0–50	1	2	3	4	5					0.416	2%
	51–100	1/2	1	2	3	4					0.262	
	101–200	1/3	1/2	1	2	3					0.161	
	201–300	1/4	1/3	1/2	1	2					0.099	
	> 301	1/5	1/4	1/3	1/2	1					0.062	
Land cover	Recreational area	1	3	5	7	9					0.505	8%
	Forest	1/3	1	3	5	7					0.262	
	Agriculture	1/5	1/3	1	3	4					0.128	
	Settlement	1/7	1/5	1/3	1	3					0.069	
	Grassland	1/9	1/7	1/5	1/3	1					0.036	
Tree type	*P. brutia*	1	3	4	4	5	5	7			0.375	6%
	P. brutia + *P. nigra*	1/3	1	3	3	4	4	6			0.231	
	P. nigra	1/4	1/3	1	2	3	3	5			0.142	
	Quercus cerris	1/4	1/3	1/2	1	2	2	4			0.099	
	Mixed species	1/5	1/4	1/3	1/2	1	1	3			0.063	
	Leafy	1/5	1/4	1/3	1/2	1	1	2			0.058	
	Degraded forest	1/7	1/6	1/5	1/4	1/3	1/2	1			0.032	
Slope (%)	0–5	1	1/2	1/3	1/4	1/5					0.062	2%
	5.1–10	2	1	1/2	1/3	1/4					0.099	
	10.1–20	3	2	1	1/2	1/3					0.161	
	20.1–30	4	3	2	1	1/2					0.262	
	> 30.1	5	4	3	2	1					0.416	
Elevation (m)	0–250	1	1/2	1/3	1/4	1/5					0.416	2%
	251–500	2	1	1/2	1/3	1/4					0.262	
	501–750	3	2	1	1/2	1/3					0.161	
	751–1,000	4	3	2	1	1/2					0.099	
	> 1,000	5	4	3	2	1					0.062	

Based on the findings, forest fire susceptibility levels in the study area were identified, and the results were validated using field observations and high-resolution, up-to-date satellite imagery visualized through the Google Earth platform. These images were used to compare the thematic maps produced from the analysis with land cover, forest boundaries, settlements, roads, and open areas, ensuring spatial consistency and supporting the accuracy of the results. To concretize the susceptibility levels, representative sample areas were selected from each class and comparatively evaluated in terms of the parameters used in the analysis.

3. Results

3.1. Forest fires in the study areas

Within the scope of the study, base maps were generated to illustrate the spatial distribution of environmental and anthropogenic factors influencing fire occurrence. Figure 3 presents the layers of the parameters used in the AHP analysis, forming the fundamental basis of the analytical process. This visualization enabled both spatial and analytical comparison of the criteria considered in determining fire susceptibility.

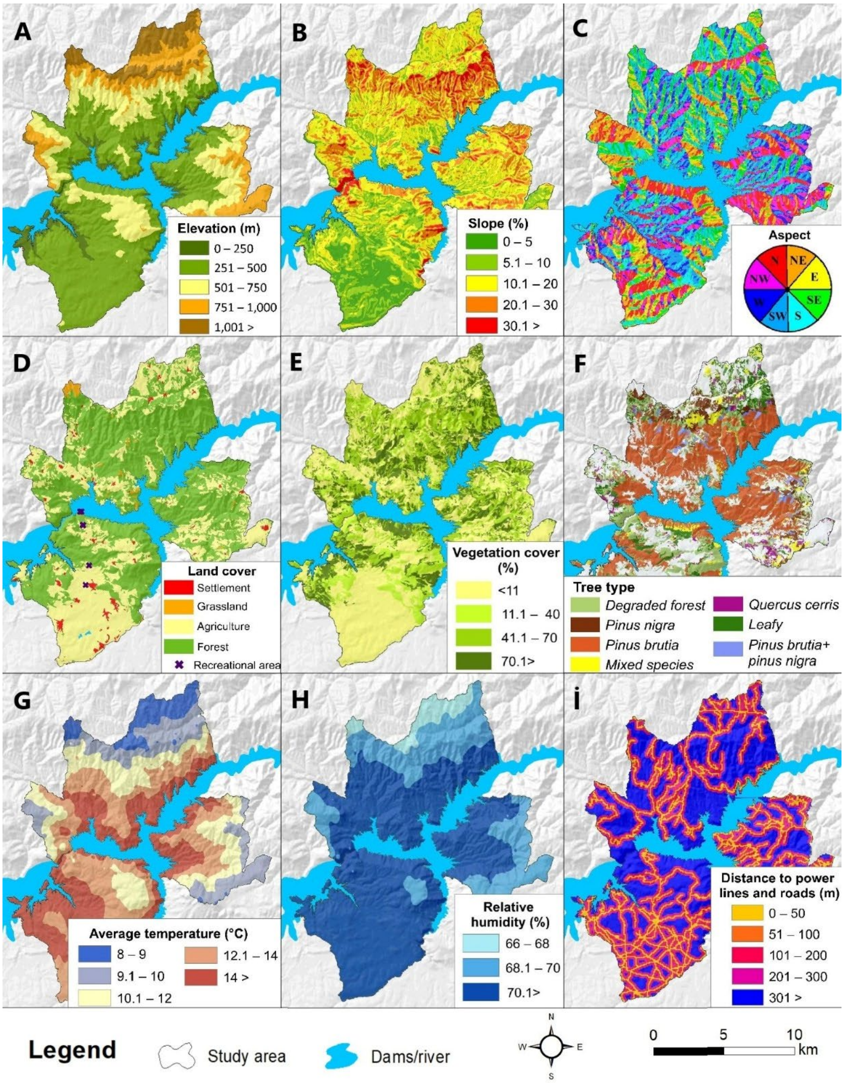

Figure 3. Maps of the parameters used in the AHP analysis.

The factors contributing to fire occurrence in the study area were examined under four main categories. These include forest resources and stand structure, climatic factors, anthropogenic factors, and topographic factors.

3.1.1. Forest resources and stand structure

Forest canopy density and stand structure play a decisive role in the ignition and spread of forest fires. In dense forests, the abundance of combustible materials can cause fires to spread rapidly and uncontrollably, whereas in areas with sparse vegetation, fire progression tends to slow down (Demir, 2023). The forest cover of the study area was quantitatively assessed using high-resolution, up-to-date satellite imagery on the Google Earth platform, revealing that forests cover approximately 50% of the total area. Due to agricultural activities and settlements, the proportion of forested land in the Şahinkaya FSD is 27%, while it increases to 63% in Akçay and 68% in Kuruçay. Data from the FSDs for 2024 also indicate that vegetation canopy density varies across districts (Figure 3D–3E and Figure 4).

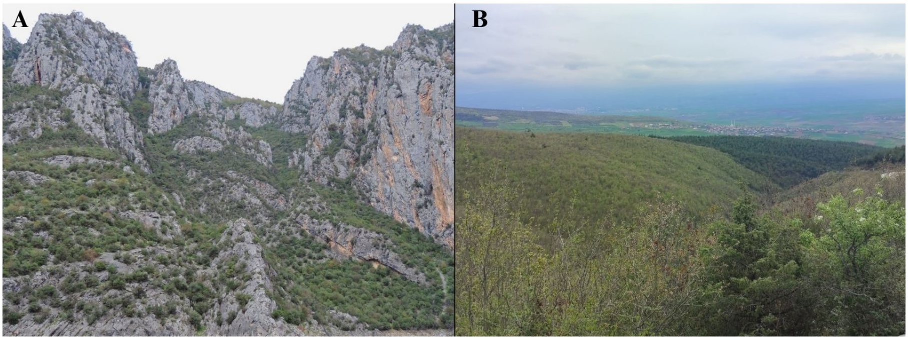

Figure 4. Different closure rates in the study area.
Note. Panel A: closure rate 11–40%. Panel B: closure rate 71–100%.

Figure 4 illustrates the spatial variation in forest canopy density within the study area, highlighting the contrast between densely forested and sparsely vegetated zones. This visual representation is crucial for understanding how vegetation density influences fire susceptibility, as areas with higher canopy cover generally correspond to zones with greater fuel continuity and higher ignition potential.

The Akçay and Kuruçay FSDs exhibit higher susceptibility to forest fires compared to Şahinkaya, primarily due to the prevalence of dense, *P. brutia*-dominated, and resinous forest stands in these sub-districts. Forest density and species composition are key factors influencing forest fires. Fires tend to spread more rapidly in homogeneous and dense coniferous stands due to higher fuel continuity and flammability, whereas structurally diverse and mixed forests may reduce fire spread and intensity (Agee & Skinner, 2005; Fernandes, 2009; Stephens et al., 2014). In contrast, species such as *Fagus orientalis*, *Quercus* spp., and *Carpinus betulus* can slow fire progression thanks to their higher water content and lower flammability (Karabulut et al., 2013).

Although the study area contains various stand types, the most common coniferous species are *P. brutia* and *P. nigra*. In particular, *P. brutia* constitutes 66% of all stands (GDF, 2024b; Figure 3F). Due to its resinous structure, *P. brutia* is highly flammable and can cause fires to spread rapidly (Küçükosmanoğlu, 1993). Its dominance in the study area increases overall fire susceptibility. According to local FSD fire inventories, of the 17 fires with known ignition points in the past 10 years, eight occurred in areas dominated by *P. brutia* and five in areas dominated by *P. nigra*.

3.1.2. Climatic factors

Temperature, relative humidity, and wind speed are key climatic parameters influencing forest fires (Sinha et al., 2023). High temperatures and low humidity dry vegetation and forest litter, increasing flammability and fire spread (Çanakçıoğlu, 1993; Westerling et al., 2006). Wind also strongly affects the speed and direction of fire spread. Based on the data from nearby meteorological stations, the region's annual average temperature ranges between 8 and 14 °C, while relative humidity exceeds 70%. July and August, characterized by the highest temperatures and lowest humidity, coincide with the peak fire occurrences (Figure 3G–3H, Figure 5).

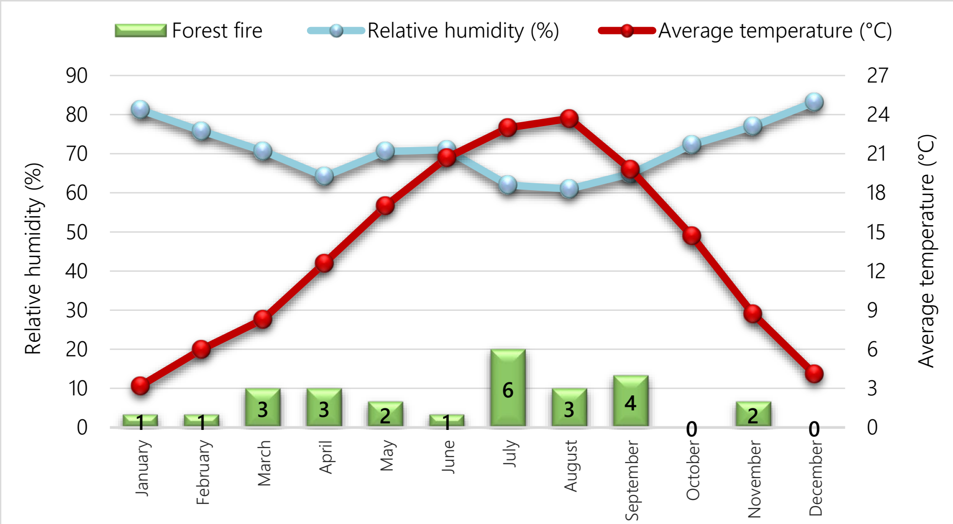

Figure 5. The average temperature, average relative humidity, and monthly distribution of the number of forest fires in the study area.

Daily maximum temperature and minimum relative humidity values can also be decisive factors in forest fires (Krueger et al., 2016). In the study area, maximum temperatures can reach up to 40 °C during July and August. According to the fire incident record forms, a temperature of 38.2 °C was recorded in Vezirköprü on June 30, 2013. In the same months, relative humidity levels can drop to as low as 20% (TSMS, 2025). These conditions create an environment highly conducive to the ignition and spread of fires (Westerling & Bryant, 2008). According to the fire records of the Kuruçay FSD's, during a fire that burned one ha of forest on August 15, 2019, the daily maximum temperature reached 43 °C, while relative humidity dropped to 13%. In 2014, which was the year with the highest number of fires in the study area, five events resulted in a total of 102 ha of damage, and it is considered that wind may have influenced this process. Wind can increase evaporation and reduce relative humidity, thereby facilitating ignition, and it may also affect the rate of fire spread once a fire has started (Potter, 2012; Rossa, 2017). Records from the study area indicate that on June 28, 2014 wind speed reached 81 km/h (Kuruçay FSD).

3.1.3. Anthropogenic factors

According to the data from the GDF (2024a), 91% of forest fires in Türkiye in 2022 were caused by human activities, indicating that human influence plays a major role in the occurrence of forest fires. The primary contributing factors include negligence and carelessness, stubble burning, arson, transportation infrastructure, and malfunctions in energy transmission lines. Şahinkaya Canyon and its surroundings, which include Nature Parks, stand out for their natural beauty and recreational value. The area attracts a high number of visitors, especially during the summer months, for activities such as boat tours, hiking, and picnicking, which increase human presence and consequently elevate the region's fire susceptibility (Figure 6).

Figure 6. Tourism activities in the Şahinkaya Canyon Nature Park—one of the causes of fire susceptibility.

During this period, rising temperatures and favorable humidity conditions for fire, combined with increased human presence, elevate the risk of forest fires. The fire inventory of the FSD's supports the link between human activity and forest fires. According to the records, the fires that occurred in Şahinkaya Canyon National Park on September 29, 2020 and July 22, 2021 coincided with the days of the highest visitor density. Picnics and campfires, along with glass, plastic, and paper waste left by visitors, can lead to the outbreak of surface fires.

3.1.4. Topographic factors

The initiation and spread of forest fires are governed by a complex network of factors (Tezcan & Eren, 2024). Due to the significant influence of topographic conditions such as slope, elevation, and aspect on forest fires (Ocak et al., 2024), many studies analyzing forest fires also incorporate topographic evaluations (Dilekçi et al., 2021; Işık Pekkan et al., 2022; Özşahin, 2014). In this study as well, the effects of slope, elevation, and aspect were assessed to determine forest fire susceptibility levels.

On steep slopes, thinning of soil cover and difficulties with vegetation anchorage lead to sparse vegetation, which tends to reduce fire susceptibility in these areas. On the other hand, during fires, fallen trees and branches can roll downslope, increasing the speed of fire spread. In this context, slope can both reduce fire susceptibility by limiting vegetation and simultaneously increase the rate of spread by facilitating the movement of burning materials (Gai et al., 2011). In the study area, which includes a canyon, slope values reach up to 88% (Figure 7).

Figure 7. Slopes of Şahinkaya Canyon.

Canyons, with their narrow and deep structures, create a "chimney effect" that accelerates fire spread by channeling hot air and flames upward (GDF, 2023). Firefighting in these areas is difficult and often requires aerial support. Although the slopes of Şahinkaya Canyon show high fire susceptibility, the Kızılırmak River and nearby reservoir lakes provide accessible water sources. In this study, consistent with the literature (Coşkun & Toprak, 2023), the weight of the slope parameter in the analysis was increased proportionally with slope steepness (Table 1). Elevation also affects fire behavior. While higher elevations generally have lower temperatures and thus lower fire risk (Gai et al., 2011), reduced humidity at higher altitudes can increase fire spread (Hacısalihoğlu, 2018). The study area has an average elevation of 500 m a.s.l., with an elevation difference of up to 1,220 m. According to records of the GDF, fires have occurred within the elevation range of 50–1,032 m a.s.l., with the highest fire frequency observed between 200–400 m a.s.l. Therefore, the highest influence values in the analysis were assigned to the 0–500 m a.s.l. elevation range.

South- and southwest-facing slopes receive more solar radiation, raising temperatures, reducing humidity, and lowering fuel moisture, thus increasing fire susceptibility (Çanakçıoğlu, 1993). In Türkiye, north-facing slopes may support denser vegetation due to higher moisture conditions, leading to increased fuel accumulation, which can enhance fire intensity during prolonged drought periods (Ebel, 2012). In contrast, southern and southeastern aspects are generally more fire-prone because of drier conditions (Doğanay & Doğanay, 2011). In the study area, 11 of 17 fires originated on south- and west-facing slopes, which were accordingly assigned the highest influence values.

3.2. Forest fire susceptibility levels of Şahinkaya Canyon and surroundings

In this study, an AHP-based forest fire susceptibility analysis was conducted by weighting the relevant criteria and generating a susceptibility map. Based on the resulting susceptibility values, the study area was subsequently classified into five fire susceptibility levels (Figure 8).

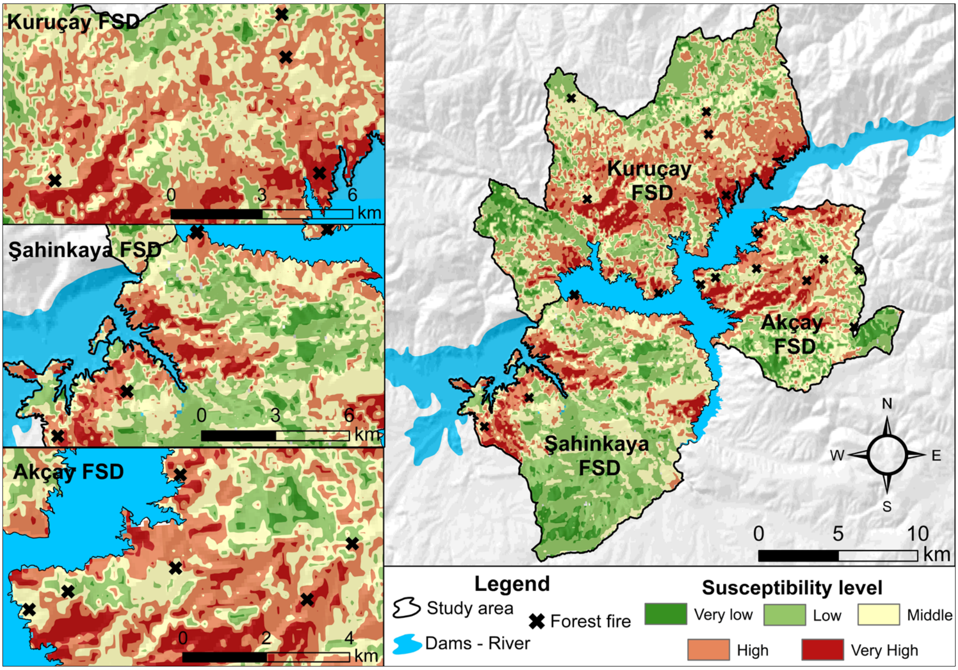

Figure 8. Forest fire susceptibility classes and distribution in Şahinkaya Canyon and surroundings.

The total of 34% of the study area (15.01 thousand ha) falls within the high and very high fire sensitivity classes, of which 10% is classified as very high and 24% as high sensitivity (Figure 9). Consistent with the fire inventory, these areas are predominantly located within the boundaries of the Kuruçay and Akçay Forest Enterprise Chiefdoms; the proportion of forest cover is 68% in Kuruçay, 63% in Akçay, and a lower value of 27% in Şahinkaya. In particular, a marked increase in fire sensitivity has been observed within and around the canyon, which is attributed to the high forest density resulting from increased humidity and the widespread presence of resinous, coniferous tree species that are easily ignitable and capable of sustaining prolonged combustion (Figure 9).

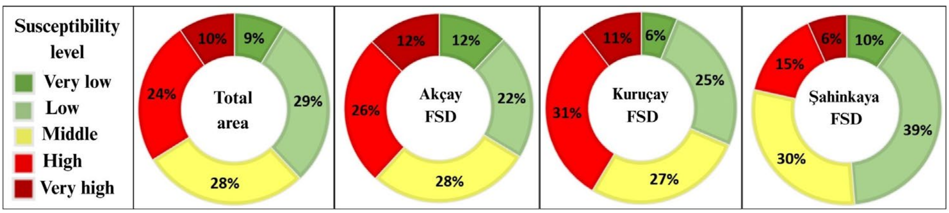

Figure 9. Areal distribution of susceptibility levels by FSD directorates.

Approximately 9% of the study area has very low and 29% has low fire susceptibility, totaling 38% (16.77 thousand ha) (Figure 9). These areas are mainly located in the Şahinkaya FSD, farther from the canyon and with limited forest cover. Fire susceptibility increases near the canyon, influenced by both forest presence and tourist use; recreational sites with samovar and barbecue themes were observed on the canyon slopes. This factor was incorporated into the analysis through the parameters distance to power transmission lines and roads and land cover. Areas with very high and high susceptibility constitute 42% of the Kuruçay FSD, 38% of the Akçay FSD, and 21% of the Şahinkaya FSD, reflecting differences in forest density. Low-susceptibility zones generally have less than 11% forest density and consist mostly of agricultural lands or pastures.

4. Discussion

Of the 17 forest fires recorded in the study area, 11 occurred in areas with very high and high susceptibility, three in areas with moderate susceptibility, and three in areas with low susceptibility (Figure 10), showing consistency between historical records and the analysis results. Most fires occurred in dense forests dominated by *P. brutia*, while fewer incidents were observed in agricultural lands, pastures, and sparsely vegetated areas. High-susceptibility zones near agricultural lands and settlements increase both the risk of fire spreading into farmland and the likelihood of human-induced ignition. Moderate-susceptibility areas are generally located near settlements and pastures, whereas low-susceptibility areas are typically found in regions with limited human influence and sparse forest cover.

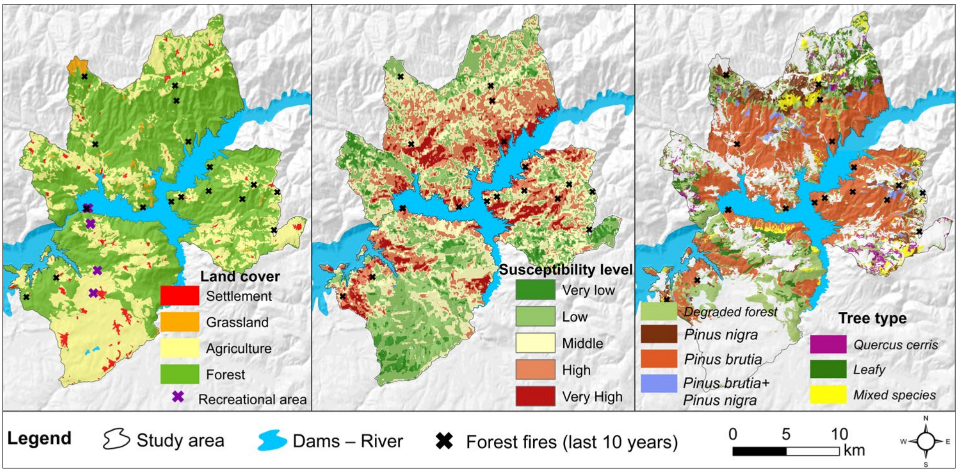

Figure 10. Land cover, fire susceptibility levels, and forest stand and recorded forest fire distribution maps for the 2014–2024 study period.

These patterns align with previous studies in the Black Sea and other regions, showing that proximity to settlements, roads, and agricultural lands increases fire susceptibility (Akay & Şahin, 2019; Coşkun & Toprak, 2023; Dilekçi et al., 2021; Erdin & Çağlar, 2021; Sivrikaya & Küçük, 2022). Integrating AHP with spatial data enhances the reliability of fire susceptibility assessments by systematically weighting environmental and anthropogenic factors (Ahmad et al., 2025; Khan et al., 2024).

The heterogeneous forest structure in the study area also strongly affects fire susceptibility. *Pinus brutia*, the most widespread species, is concentrated around the canyon (Figure 10) and is highly flammable due to its resinous structure (Boydak, 2004; Eron, 1987).

Mixed *P. brutia*–*P. nigra* stands are also considered fire-prone (Fyllas et al., 2008), and most of the previous fires in the area originated in these stands. Studies in Türkiye have shown that steep and dry terrains dominated by *P. brutia* exhibit the highest fire susceptibility (Ersoy et al., 2025; Sari, 2021), which is consistent with the high-susceptibility zones identified in the Akçay and Kuruçay FSDs (Figure 10). In contrast, degraded forests dominated by *Q. cerris* experienced very few fires.

This study has several limitations, including incomplete fire coordinates, the subjective nature of AHP weighting, and the spatial and temporal constraints of the input datasets. An assessment of the *Forest Fire Fighting Action Plan* prepared by the Republic of Türkiye, Ministry of Agriculture and Forestry (2023) indicates limited institutional capacity in the study area: Kuruçay has nine water tankers and a helicopter landing/operation point, Akçay has four tankers and one initial response vehicle, whereas Şahinkaya has no firefighting units; moreover, existing lookout towers do not cover the study area. Despite these constraints, the findings can inform forest management and fire prevention, particularly in high-susceptibility areas near settlements and agricultural lands, and improve understanding of the spatial distribution of fire risk.

5. Conclusion

Approximately 34% of the study area falls within high and very high forest fire susceptibility classes, concentrated mainly in the Kuruçay and Akçay FSDs, where the widespread presence of fire-prone *P. brutia*, sensitive forest structures, and rugged topography facilitates fire spread. Historical records indicate that 65% of the 17 documented fires occurred in these areas, confirming the reliability of the susceptibility assessment in guiding management strategies. Slope values ranging from 60% to 88% around the canyon further enhance fire propagation, while recreational activities and the use of open fires increase the risk of human-induced ignitions. Medium- and low-susceptibility areas, which constitute the remainder of the study area, are largely dominated by *Q. cerris* or have been converted to agricultural and pasture lands and can be managed through preventive observation, sustainable land-use planning, and periodic vegetation monitoring. Priority measures in high-susceptibility zones include systematic monitoring, establishment of firebreaks, increased patrolling during the June–October fire season, and regulation of human activities. Strengthening community awareness and response capacity further supports effective fire management. The findings provide a practical framework for prioritizing interventions and contribute to a clearer understanding of the spatial distribution of fire susceptibility in heterogeneous forest landscapes. Nevertheless, these results also highlight the need for future studies employing higher-resolution data, longer time series, and alternative analytical approaches to further improve fire susceptibility assessments. Furthermore, future studies integrating higher-resolution RS data, long-term fire and climate datasets, and diverse analytical and modeling approaches are expected to enhance the accuracy and generalizability of forest fire susceptibility analyses by enabling a more robust representation of temporal variability.

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