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Burn severity evaluation in black pine forests with topographical factors using Sentinel-2 in Kastamonu, Turkiye

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FOREST MANAGEMENT

ABSTRACT

Background: Forest fires are one of the most important natural disasters all over the world in terms of the damage they cause to the ecosystem. Turkey is also exposed to wildfires damaging large areas of forests every year. Wildfires endanger the sustainability of forest resources and cause significant biological and ecological damage to the forests. It is crucial to estimate fire behaviour characteristics to take effective interventions in the fire events. Obtaining data based on terrestrial measurements is very expensive and very time-consuming to predict fire behaviour characteristics. The use of remote sensing technologies is therefore very useful since the satellite images will be faster, more sensitive, and economical to determine the burning severity and burning areas.

Results: In this study, the forest fire that occurred in the Kastamonu-Taşköprü district was analyzed with remote sensing techniques. The fire occurred in 2020 (06.09.2020). The fire satellite image was thus taken from the pre-fire period (26.08.2020) and post-fire period (13.10.2020). First of all, pre-fire and post-fire Sentinel-2 images of fire areas were used to determine the burned area using NBR (Normalized Burn Ratio) and dNBR (Differenced Normalized Burn Ratio) indices. Also, burned area rate and burn severity were evaluated depending on the altitude, aspect, and slope factors.

Conclusion: The total burned area was 1504.9 ha. The maps showed that the burned areas were covered by moderate- and high-severity classes. The forest fire was more severe in the altitude range from 1170 to 1370m, at 20-33% slope and northerly aspects in the burned area. The existence of extreme meteorological factors and the horizontal and vertical continuity of the forest fuels have been the main factors in the effect of the fire on large areas. Estimation of forest fire risk, taking into account extreme meteorological conditions and fuel properties, will have an important place in forest ecology and management.

Keywords: Forest fire; Sentinel-2; Burn severity; Topographic factors; Black pine forests

HIGHLIGHTS

The forest fire was more severe in the altitude ranges from 1170 to 1370 m, at 20-33% slope and northerly aspects in our study site.
Understanding how topographical factors influence burn severity will provide good knowledge of the fires in the Black Sea region and can guide decision-makers.

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INTRODUCTION

Forest ecosystems, which have a key role to ensure and maintain ecological balance, provide many social, ecological and economic services for human life. Forest fires are considered some of the most detrimental events that interrupt these services (Kucuk; Sevinc, 2023). Forest fires have serious damage to forest ecosystems since they lead to biodiversity loss, reduce global vegetation carbon sink, and threaten vegetation functionality, structure, and composition (Prestes et al., 2020). Globally, forest fires have destroyed a million hectares of forests each year. In recent years, climate (increasing temperatures and prolonged droughts) and land use changes have caused uncontrollable and extreme wildfires (Pausas, 1999; Bilgili et al., 2021a).

Forest fires cause serious environmental hazards particularly in the Mediterranean region because of temperature increases and extreme heat waves (Kucuk et al., 2015; Turco et al., 2017; Kucuk et al., 2018). In recent years, extreme temperatures and heat waves have caused serious wildfires in Portugal (2017), the USA (2018-2021), Greece (2019), Siberia (2020), Australia (2021), Canada (2021), and Turkiye (2021) (Bilgili et al., 2021a).

Turkiye's Mediterranean and Aegean regions are also very sensitive to forest fires due to their vegetation and climate. In 2021, 2.793 wildfires occurred in Turkiye, and approximately 139.503 ha of forest area was burnt (GDF, 2021). Although the Mediterranean regions of Turkiye are more sensitive to forest fires, the West Black Sea region of Turkiye has also become one of the important fire-prone regions in recent years (Küçük & Ünal, 2005; Küçük et al., 2017; Mitsopoulos et al., 2017; Kucuk et al., 2018; Yavuz et al. 2018; Kucuk et al., 2021). In 2020, a big forest fire occurred in the Western Black Sea region of Turkiye and burned almost 1300 ha of forest area in Kastamonu - Taşköprü Sub-District Forest Directorate.

Extreme forest fires are extraordinary fires that irretrievably destroy ecosystems (Bilgili et al., 2019; Bilgili et al. 2021a, Bilgili et al. 2021b). The extensive burned forest area is associated with the burn severity and fire size which are important fire regime characteristics (Carlucci et al. 2019; Chuvieco et al. 2008; Airey-Lauvaux et al. 2022). Burn severity correlates with high wind speed, high temperature, low relative humidity, and total available fuel load (Eskan et al. 2020; Bergonse et al. 2021). The fire reports of the Taşköprü Sub-District Forest Directorate severity indicate the extent of loss of vegetation and other biomass during a wildfire event, which is one of the main factors affecting the mortality of trees and causing a loss in biodiversity (Brandão et al. 2022; Sparks et al. 2023).

It is useful to use remote sensing techniques to determine the effects of fires in forest areas and to be used in post-fire operational studies. Burn severity mapping is a widely used tool to make broad assessments during the first growth period following a fire and indicates how the functioning of the ecosystem is affected by burn severity after a fire (Key, 2006; Moressi et al. 2022). Burn severity classification in forests is generally determined by loss of canopy, tree mortality, and crown scorch (Keeley, 2009).

Understanding the drivers of burn severity for forested ecoregions is a key issue to lessen the impact of future burn severity patterns and also helps to assess effective site management after a fire regime. Burn severity maps may also develop future strategies for forest regeneration, forest recovery, and ecosystem services (Parks et al. 2018; Leverkus et al. 2018). The observations and early detection of forest fires have therefore played a significant role to minimize ecosystem destruction. In recent years, multispectral imaging sensors, air-floating devices, and satellite datasets have been frequently employed for early fire detection and monitoring of active fires (Kucuk et al. 2017; Gülci et al. 2021). Particularly, multi-spectral satellite images have become very widely used to classify burn severity, analyze the ecological effects of fires on ecosystems, show post-fire vegetation, create land management and post-fire damage maps, and forecast the potential severity (Yavuz et al. 2018; Sevinc et al. 2020; Sivrikaya; Küçük, 2022). Medium spatial resolution satellite images provide a landscape view of fire impacts on forests and estimate the extent of areas affected by forest fires.

Monitoring and analyzing the level of burn severity accurately is extremely crucial for forest management planning (i.e. the vegetation, soil, wildlife, post-fire rehabilitation, regeneration, and afforestation works) (Parks et al. 2014). It is extremely important to determine the destruction situation depending on the severity of the fire and to classify and map it, instead of carrying out the same forestry activity in the entire fire area. Burn severity maps thus can be useful tools to determine where natural regeneration should be carried out and to identify areas requiring rapid response after a fire, show erosion potential, and protect against rockfall and avalanches, especially in areas with high-severity burns (Busico et al. 2019; Parajuli et al. 2020; Li et al. 2022; Morante-Carballo et al. 2022; Qarallah et al. 2022)

In this study, the forest fire of 2020 in the Western Black Sea of Turkiye was analyzed. In the study site, the pre-and post-fire situation was determined for Kastamonu-Taşköprü Forestry Management Directorate using Sentinel-2 images. In this study, burn severity maps were produced using topographical factors (altitude, aspect and slope) to show how the fire affected the forest areas. The result of this study will have an important function to develop a post-fire management plan to utilize strategies for suppressing wildfires in the future. Understanding the burn severity of forest fires can provide better knowledge of burned areas and therefore cost-efficient techniques can be developed.

MATERIAL AND METHODS

Study site

The study was conducted in Taşköprü which is located in the Western Black Sea of Turkiye, in Kastamonu (41°18'-41°25'N, 34°08'-34°17'E) (Figure 1).

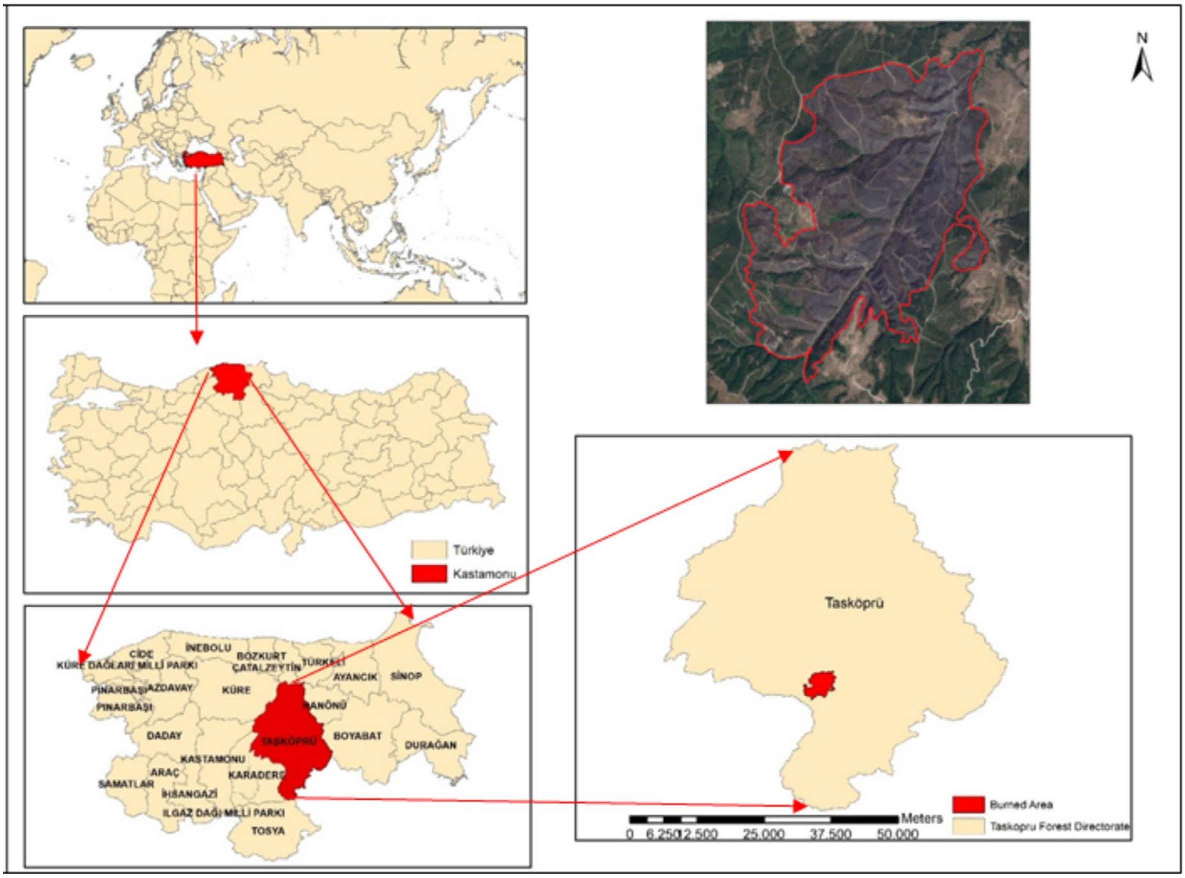


Figure 1. Geographical location of the study site and google earth satellite image of the burnt area.

The study site was primarily chosen because a big forest fire occurred in 2020 and approximately 1300 ha of forest burned based on reports of the Taşköprü Sub-District Forest Directorate. The altitude of the forest-burned sites ranged from 970 m to 1570 m. In the study site, the annual mean temperature is 9.7 °C, and the mean annual precipitation is 413.2 mm (Figure 2). In the study area, pure natural black pine (Pinus nigra L.) stands dominated and covered almost 5472.6 ha forest area.

Remote sensing data

In the study site, the burn severity was quantified using high-resolution satellite images. Sentinel-2A satellite images (all of them atmospherically, radiometrically, and geometrically corrected) were downloaded free of charge by the United States Geological Survey (USGS) website for pre-fire and post-fire dates. Sentinel-2A data provide an estimation of accurate and rapid mapping of fire-damaged areas and burn severity in different scales (local, regional and global) (Mallinis et al., 2018; Navarro et al., 2017; Garcia-Llamas et al., 2019; Lang et al. 2019; Roteta et al., 2019). The images were as close as possible to the fire without the presence of clouds. There are 13 different spectral bands in the Sentinel-2 satellite system (Table 1). It records a view of approximately 290 km by scanning in the visible region (RGB), near-infrared (NIR), and short-wave infrared (SWIR) ranges. We mapped burn severity patterns using the Sentinel-2A dataset acquired on the pre-fire 26th of August and post-fire 13th of September 2020.

Methods

The Sentinel-2A satellite images were used to build up the burned area and burn severity maps. Firstly the maps were created and then the topographic variables (altitude, aspect, slope) that affect severity were analyzed. Research on burn severity has increased considerably in recent years. Key and Benson (2006) proposed a composite burn index (CBI), which is a ground-based plot survey measure method. CBI has continued to be used as the standard index in assessment of forest fire severity by the forestry services in the west of the USA. Lopez-Garcia et al. (1991) proposed nbr as an alternative to the Normalized Difference Vegetation Index (NDVI) because the NBR index is more sensitive to changes in chlorophyll and vegetation water content, and have concluded that this index is the most valuable remote sensing method for assessing fire severity (Roy et al., 2006; Carvalheice et al., 2010). Recently, many researchers have used dNBR to assess burn severity, which is later related to different aspects of vegetation evolution.

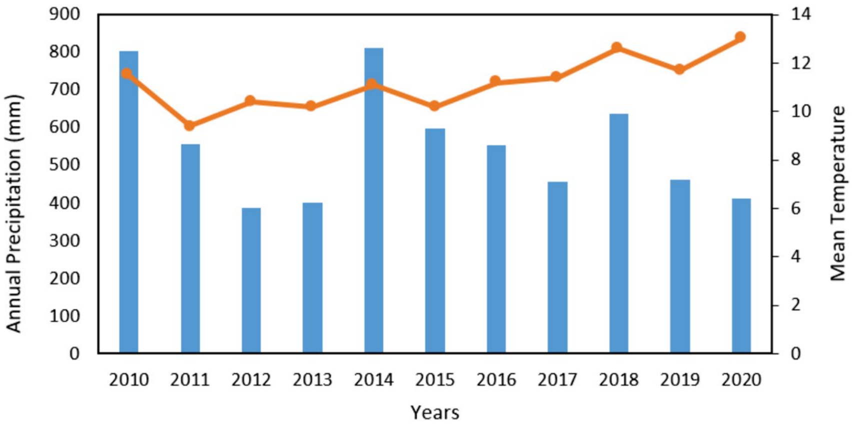


Figure 2. The annual precipitation and mean temperature variations between 2010-2020 in the study site.

Table 1. Sentinel-2 bands with their corresponding central wavelengths and spatial resolution (USGS).

Band Number	Name	Central Wavelength (nm)	Spatial Resolution (m)
1	Coastal Aerosol	443	60
2	Blue	490	10
3	Green	560	10
4	Red	665	10
5	Vegetation Red Edge	705	20
6	Vegetation Red Edge	740	20
7	Vegetation Red Edge	783	20
8	NIR	842	10
8a	NIR narrow	865	20
9	Water vapor	945	60
10	SWIR- Cirrus	1375	60
11	SWIR 1	1610	20
12	SWIR 2	2190	20

Preprocessing of Remote Sensing Data

Each satellite image provides multi-spectral bands in visible and infrared wavelengths ranging from blue to the short wave infrared SWIR 2. To find out which bands best discriminate between unburned and burned areas, Sentinel-2A band reflectances were compared. Thus the appropriate bands for discriminating between burned and unburned areas that contain information in the NIR and SWIR spectrum were used. Data analyses were conducted in ArcGIS and used for area calculation.

The Normalized Burn Ratio (NBR) and the Differenced Normalized Burn Ratio (dNBR) mapping

In this study, the NBR metric was selected for burned area detection and the dNBR index then was used to quantify burn severity degrees (Table 2). Previous studies have used many burn severity indices which are the standardized NBR difference (dNBR), the standardized difference of NDVI (dNDVI), and the relative version of dNBR (RdNBR) (Chu; Guo, 2014). Normalized Burn Ratio (NBR) is a generally used algorithm to show total burn scar area for the pre-and post-fire season (García; Caselles, 1991; Escuin et al., 2008; Key; Benson, 2006). However, Delta Normalized Burn Ratio (dNBR) and Relativized Burn Ratio (RdNBR) are also the most commonly used satellite image-based indices for determining burn severity (Key; Benson, 2006; Miller; Thode, 2007; Parks et al., 2014).

In this study, we generated NBR and dNBR burn severity metrics. The dNBR index is very convenient to determine burn surfaces and burn severity levels (Llorens et al., 2021) (Table 3). NBR was used to identify burn severity and computed for each image (pre-fire and post-fire) using the 20 m resolution Sentinel-2 bands. It was calculated by the ratio between the 8A (NIR) and 12 (SWIR) values (Navarro et al., 2017; Key; Benson, 2006). To determine the severity of the damage in the vegetation, the NBR index was applied to the Sentinel-2 satellite images. The pre-and post-forest fires images were then subtracted from each other. In the study site, the results of NBR were applied to the dataset before the forest fire, then the NBR was applied to the dataset of the region after the forest fire. The theoretical range of NBR is −1.0–1.0, and it is negatively correlated with burn severity. The analysis was implemented using the Raster Calculator of ArcGIS software. The algorithm for NBR and dNBR is given in equations [1] and [2].

$$NBR = \frac{NIR - SWIR}{NIR + SWIR} \quad (1)$$

$$dNBR = NBR_{prefire} - NBR_{postfire} \quad (2)$$

Table 2. Definition of burn severity classes based on the Ministe`re des Fore^ts, de la Faune et des Parcs (MFFP, Bouvher et al., 2016).

Class Definition	Class Definition
Unburned	Fire has not spread to the ground or the crown.
Low	The surface fire that burned all or part of ground vegetation (moss, shrubs, seedlings, etc.) or the organic matter (slash, litter, etc.). In forested stands, less than 50% of tree crowns are affected (brown or charred).
Moderate	Surface fire or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and crowns of more than 50% of these affected trees are brown.
High	Continuous or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and for more than 50% of these affected trees, fire consumed the leaves and blackened the stems.

Hypothetically, the dNBR values vary between -2 and +2 where the values for burnt areas range from -0.10 to +0.10 in unburned areas. The range of fire severity within the study area was then determined, and fire severity was categorized into three grades; namely, low, moderate, and high. (Table 2 and Table 3). However, minimum and maximum values show differences depending on the study site (Key; Benson, 2006; Nasery; Kalkan, 2020). The equation for dNBR is given in equation 2 (Lutes et al., 2006; Amos et al., 2019). The discrimination of burn severity levels was carried out by establishing threshold values over the dNBR index.

Table 3. Differenced Normalized Burn Ratio (dNBR) thresholds proposed by the United States Geological Survey (USGS, 2016).

dNBR value	Burn severity
-0.1 < dNBR < 0.1	Unburned
0.1< dNBR < 0.27	Low severity
0.27 < dNBR < / 0.44	Moderate low severity
0.44< dNBR < 0.66	Moderate high severity
>0.66	High severity

Topographical Data

The wildfire spread rate is the result of a complex interaction between topography, fuel, and vegetation. topographic, physiographic, and fuel conditions strongly affect burn severity when weather conditions are not extreme (Estes et al. 2017). In this study, the relationship between burn severity and the topography factors (altitude, aspect and slope). Burn severity maps were also overlaid on the aspect, altitude and slope maps using ArcGIS 10.5. A digital elevation model (DEM) was extracted from the altitude curves. Altitude, aspect, and slope maps were generated from the DEM, The resulting values of altitude for every pixel were categorized into four classes:970-1170 m, 1170-1370 m, and 1370-1570 m. The resulting values of the aspect for every pixel were categorized into two classes: shady and sunny aspect. The resulting values of slope for every pixel were categorized into two classes 0-20%, 20-33%, 33-50%, and >50%.

RESULTS AND DISCUSSION

The NBR index analyses showed that the NBR data range was derived between -0.98 (no vegetation/bare soil) to +0.88 (healthy) for the pre-fire period. However, the NBR data range was derived between -1 to +0.998 for the post-fire period (Figure 3).

Based on dNBR index values, results were separated into 5 classes and the burn severity map was shown in Figure 4. The study site was covered by unburned, low, moderate-low, moderate-high, and high classes. The high dNBR value indicated severe damage and the low dNBR value indicated a high rate of vegetation. Nasery and Kalkan (2020) have also studied burn area detection and burn severity assessment using Sentinel-2 MSI data in İzmir, Turkiye. Their study site was also covered by 5 burn severity classes (unburned, low severity, moderate low severity, moderate high severity, and high severity). Their results of the dNBR index have shown that a total of the 6909.708-hectare area is burned during forest fire while 11184.502-hectare is unburned. However, different levels of burn severity were detected 9.3 % low, 11.1% moderate-low, 8.5% moderate-high and 9.3% high.

Although Taşköprü Sub-District Forest Directorate reported that almost 1300 ha of forest was burned, the results of our study showed that a total of 1504.9 ha of forest land was burned. 9.9% (149.8 ha) of the study site was unburned, 17.8% (269.1 hav) of the study site was covered by low severity class, 19.2% (289.2 ha) of the study site was covered by moderate low severity class, 23.3% (351.2 ha) of the study site was covered by moderate high severity class, and 29.6% (445.5 ha) of the study site was covered by high severity class depending on the dNBR index (Table 4). In this study, dNBR index results showed that half of the burned area was covered by moderate high severity and high severity classes.

In this study, the effects of topographic variables such as aspect, altitude and slope on the burn severity were determined . The burned area which was covered by the high severity class (445.5 ha) was located in a 239.8 ha shaded aspect and 205.7 ha sunny aspect. The moderate high severity class area of the study site was located in a 201.8 ha shaded aspect and 149.3 ha sunny aspect; the moderate low severity class of the study site was located in a 170.6 ha shaded aspect and 118.5 ha sunny aspect; the low severity class area of the study site was located in 176.7 ha shaded aspect and 88.3 ha sunny aspect and the unburned class area of the study site was located in 110.7 ha shaded aspect and 39.1 ha sunny aspect. Previous studies suggested that the aspect which is one of the important topographic factors plays a significant role in wildfire occurrence. Studies have shown that south aspects have the greatest potential risks on the probability of wildfire occurrence (Jo et al., 2000; Graham et al., 2004). In contrast to earlier findings, our results indicated that most forest fires occurred in shady aspects of our study site (Figure 5). The previous findings also agreed with our results (Rollins et al., 2002; Bigler et a., 2005). Wu et al. (2013) studied the effect of topographical factors on burn severity. Their results showed that fires were more common in north aspects than in south aspects. In their study, it was suggested that higher burn severity in northern aspects could be due to denser and tight gap dynamics and multi-layered canopies of forest trees. In our study site, the burn severity was higher in the northern aspect because northern aspects could have more surface fuel types which were covered by the understory shrub layers of *Cistus laurifolius*. The burn severity in the northern aspect can be also related to the *in-situ* factors since soil moisture, wind, the type of tree, and tree age may correspond to wildfire occurrence in the northern aspects of our study site. Therefore north aspects may tend to burn with more burn severity. Duran (2014) studied the effect of aspect on the fire occurrence in the Mediterranean Region of Turkiye. He reported that fires were more common in the northern (23%) and western (21%) aspects of his study site. Our study was well agreed with the previous study by Duran (2014). Fires, however, have a dynamic nature thus the effect of the aspect may vary depending on the behavior of the fire (Yılmaz et al., 2021).

Our study also determined how altitude affected the burn severity. The altitude of the study site ranged from 970 to 1570 m. 29.6% (445.5 ha) of the burned area was covered by high severity class which was located at 214.35 ha in the altitude range from 970 to 1170m, 230.82 ha in the altitude range from 1170 to 1370 m, and 0.40 ha in the altitude range from 1370 to 1570 m. 23.3% (351.2 ha) of the burned area was covered by moderate high severity class which was located at 175.1 ha in the altitude range from 970 to 1170 m, 174.9 ha in the altitude range from 1170 to 1370 m, and 1.2 ha in the altitude range from 1370 to 1570 m. 19.2% (289.2 ha) of the burned area was covered by moderate low severity class which was located at 124.5 ha in the altitude range from 970 to 1170 m, 160.7 ha in the altitude range from 1170 to 1370 m, and 13.9 ha in the altitude range from 1370 to 1570 m. 17.8 % (269.1 ha) of the burned area was covered by low severity class which was located at 66.9 ha in the altitude range from 970 to 1170 m, 188.9 ha in the altitude range from 1170 to 1370 m, and 9.2 ha in the altitude range from 1370 to 1570 m. Gonzalez et al. (2006) studied the fire occurrence model for forest stands in Catalonia (north-east Spain). Their study found that the higher the altitude the lower the occurrence of wildfire. Lee et al. (2018) investigated the influence of topographical factors on burn severity. Their study found that it is more with the energy created by dense vegetation at lower altitudes. Weatherspoon and Skinner (1996) reported that higher elevation was associated with lower burn severity because of specific microclimate (higher humidity) and lower temperatures. Our results are quite consistent with that of these studies (Lee et al. 2009; Vilar et al. 2010) since we also indicated that the highest burn severity was found in the burned area with an altitude range from 1170 to 1370 m (Figure 5). In our study site, it could be predicted that the burned area was higher in the altitude range from 970 to 1370 m because a forest fire started in the valley and the ground had the highest soil temperatures and denser understory shrub layers. Therefore, forest fires were affected more likely by the lower altitudes than the higher altitudes.

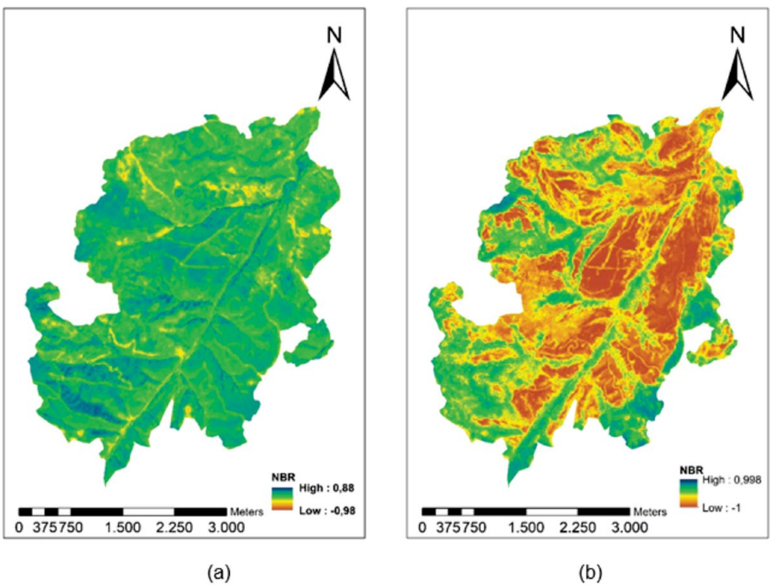


Figure 3: NBR index application for pre-fire (a) and post-fire (b) periods.

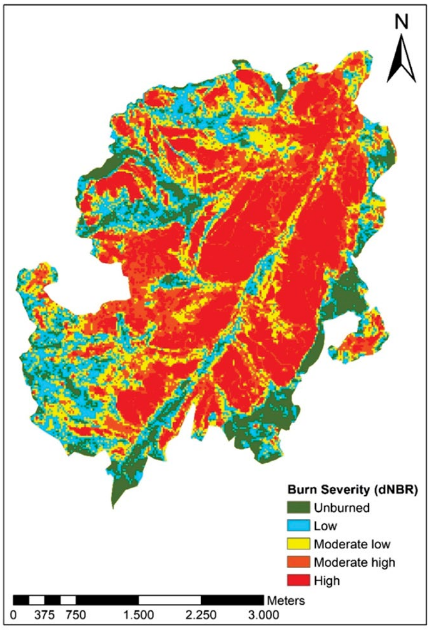
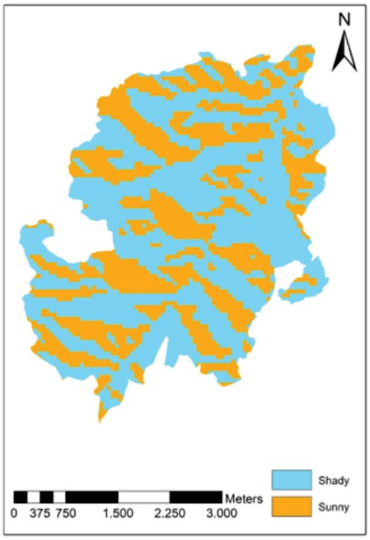


Figure 4: Burn severity map derived from dNBR index across the study site (Unburned = Fire has not spread to the ground or the crown, Low = The surface fire that burned all or part of ground vegetation (moss, shrubs, seedlings, etc.) or the organic matter (slash, litter, etc.). In forested stands, less than 50% of tree crowns are affected (brown or charred, Moderate = Surface fire or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and crowns of more than 50% of these affected trees are brown, High = Continuous or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and for more than 50% of these affected trees, fire consumed the leaves and blackened the stems).

In this study, the slope range of the burned area was identified. The slope range of burned area was separated into 4 classes which are 0-20%, 20-33%, 33-50%, and >50% (Figure 6). 29.6% of the burned area was covered by high severity class which was located at 152 ha in the 0-20% slope group, 194.2 ha in the 20-33% slope group, 88.9 ha in the 33-50%, 12.3 ha in the >50% slope group. 23.3% of the burned area was covered by moderate high severity class which was located at 128.4 ha in the 0-20 % slope group, 137.8 ha in the 20-33% slope group, 69.4 ha in the 33-50% and 16.7 ha in the > 50% slope group. 19.2% of the burned area was covered by moderate low severity class which was located at 98.1 ha in the 0-20% slope group, 110.3 ha in the 20-33% slope group, 61.5 ha in the 33-50% slope group, 20.2 ha in the >50% slope group. 17.8 % of the burned area was covered by low severity class which was located at 84.8 ha in the 0-20%, 103.2 ha in the 20-33% slope group, 59.5 ha in the 33-50% slope group, 17.1 ha in the >50% slope group. The unburned area however was located at 42.9 ha in the 0-20% slope group, 58.8 ha in the 20-33% slope group, 37.6 ha in the 33-50% slope group, and 10.6 ha in the >50% slope group (Figure 5). The slope is one of the important topographic factors in the probability and spread of fire. Fire moves up the slope in the form of a fan depending on the strong wind. In forest areas, as the degree of slope increases, burn severity increases (Çanakçıoğlu, 1985; Ireland; Petropoulos, 2015; Rahmani & Benmassoud, 2019). Fang et al. (2015) pointed out that there was a strong association of severe burning with steep slopes in the boreal forest of the Great Xing'an Mountains, China. In our study, partly agreed with the study of Fang et. al (2015) because the greatest proportion of the burned area was found in the 20-33% slope group (Figure 6).

Table 4: Distribution of burn severity level, burned area, and the ratio of burned area classes derived from the dNBR index across the study site.

Burn severity level	Burned area (ha)	Burned area (%)
Unburned (Fire has not spread to the ground or the crown)	149.8	9.9
Low severity (The surface fire that burned all or part of ground vegetation (moss, shrubs, seedlings, etc.) or the organic matter (slash, litter, etc.). In forested stands, less than 50% of tree crowns are affected (brown or charred))	269.1	17.8
Moderate low severity (Surface fire or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and crowns of more than 50% of these affected trees are brown)	289.2	19.2
Moderate high severity (Surface fire or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and crowns of more than 50% of these affected trees are brown)	351.2	23.3
High severity (Continuous or intermittent crown fire. At least 50% of tree crowns were partly or entirely affected by fire (brown or charred) and for more than 50% of these affected trees, fire consumed the leaves and blackened the stems)	445.5	29.6
Total	1504.9	100



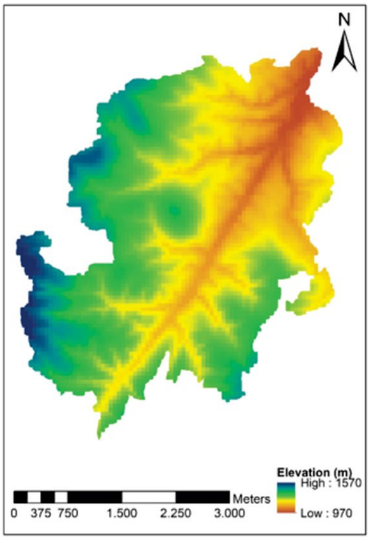


Figure 5: Showing the aspect (shady and sunny) and elevation (m) map across the study site.

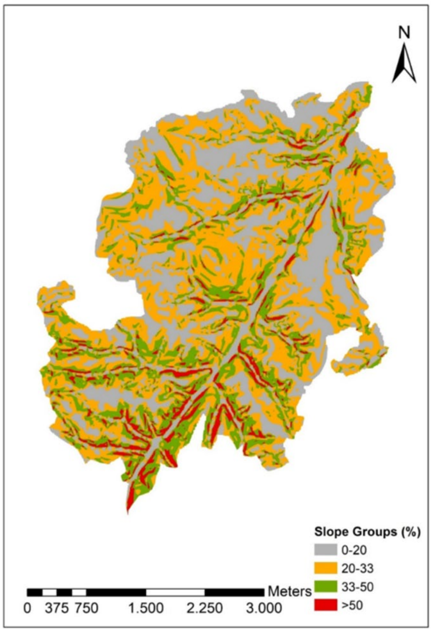


Figure 6: Showing the slope map across the study site.

Özşahin (2014) also studied the effect of topographic factors on the probability of fire using GIS techniques. He found that altitude, slope, aspect, distance to water, distance to road lines, land use, and vegetation were the main factors that trigger the forest fire risk. In his study, vegetation was the most effective factor that increased the fire risk and topographic factors and land use were also significantly effective in fire risk.

CONCLUSION

Wildfires are a serious disturbance effect in all forest vegetation zones and have dominant risks to forestry, tree growth, and development. Turkiye is one of the important countries due to the risk of forest fire. Turkiye is located in the Mediterranean region where the number of annual forest fires is very high. Recently, however, the Western Black Sea Region of Turkiye has also become a new risky wildfire area. We developed NBR and dNBR burn severity metrics to classify wildfire events depending on the critical factors (i.e. slope, altitude, and aspect) of the fire event. This study indicated that wildfires devastated 1504.9 hectares of the forests in Taşköprü in 2020. We found the burned areas were covered by moderate- and high-severity classes. Altitude, slope, and aspect also had a serious effect on the wildfire severity since the wildfire was more severe in the altitude range from 1170 to 1370 m, at 20-33% slope and northerly aspects in our study site. The results of this study could provide good knowledge on the fires in the Black Sea region and can guide decision-makers in case of a second forest fire that may occur in the same region. The study will have very important results for estimating the burn severity and developing local variables against the fire risk that may occur in more than one region with different weather, climate, and topographic conditions. The results of this study thus will create fire effects history database in a specific fire event and also under a better gide to future wildfire governance.

AUTHORSHIP CONTRIBUTION

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