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# Burn Area Detection and Burn Severity Assessment Using Sentinel 2 MSI Data: The Case of Karabağlar District, İzmir/Turkey

**Suhrabuddin Nasery** *1, **Kaan Kalkan** 2

[1]Eskişehir Technical University, Earth and Space Sciences Institute, Eskişehir, Turkey
[2]TÜBITAK Space Technologies Research Institute, Ankara, Turkey

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**ABSTRACT**

Forest fires are serious environmental problems for ecosystem which destroys huge amount of forests every year across the world. Detecting burned areas is not the only important task, it is also very important to distinguish severity degrees of soil suffered for post-fire land management and vegetation regeneration. Remote sensing presents accurate and efficient methods for mapping burned areas and assessing burn severity levels. In this study we detected forest burn areas and assessed burn severity levels using Remote Sensing techniques and Sentinel 2 satellite data products in Karabağlar, Menderes and Seferihisar districts of İzmir, Turkey. A recent big forest fire occurred on 18 August 2019 is assessed in this study, which burned down about 500 hectares of the forest. Burned areas are detected using Normalized Burn Ratio (NBR) and Soil Adjusted Vegetation Index (SAVI) indices and burn area severity analysis is performed using Differenced Normalized Burn Ratio (dNBR) and Differenced Soil Adjusted Vegetation Index (dSAVI) indices. The results of dNBR index show that a total of 6909.708-hectare area is burned during forest fire while 11184.502-hectare is unburned. Areas with different levels of burn severity were detected: 9.3 % Low, 11.1% Moderate-low, 8.5% Moderate-high and 9.3% High. Furthermore, based on the results of dSAVI analysis, 6699.554-hectare area is burned and 11394.656-hectare is unburned; the following different levels of burn severity were detected in the area: 9.4 % Low, 6.4% Moderate-low, 8.7% Moderate-high and 12.5% High.

## 1. INTRODUCTION

Fire emissions have very strong influence on composition of the atmosphere which directly affect the global climate, as well as human health and security (Pereira et al., 2018). Forest fires disturb the ecological functioning of various ecosystems as they partially or completely burn vegetation layers and affect post-fire soil and vegetation processes, for example soil erosion, debris flow, flooding and vegetation recovery (Nasi et al., 2002).

Forest fires can change the physical and chemical form of the earth organic substances. These changes are sometimes very serious which can destroy the organic material in the soil thus vegetations will not be able to regrowth in the soil (Sazayya et al., 2020). Forest typically regrow after forest fires; but some areas which are seriously damaged, will not regrow naturally in short time so it is needed to detect those areas and enrich the soil for growing forest and vegetations (Keeley, 2009; Sazayya et al., 2020).

It is very crucial to have accurate knowledge about the fire distribution pattern, particularly burn severity degree, to plan and execute post-fire land management and vegetation restoration activities (Quintano et al., 2017; Pereira et al., 2018). Burn severity assessment, specifically the term burn severity, is widely used to represent the loss of organic matter on the soil surface caused by a fire (Pereira et al., 2018; Sazayya et al., 2020).

Generally, field observations are very difficult and time consuming for detection of burned area severity degrees, fortunately remote sensing has the capability of detecting burned areas and its severity which is very effective, time and money saving

* **Corresponding Author**

*(suhrabuddin_nasery@yahoo.com) ORCID ID 0000-0001-5846-2476
(kalkaan@gmail.com) ORCID ID 0000-0002-2732-5425

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method. Remote sensing methods for estimating burn severity can be categorized into physical and empirical groups. Physical methods work based on the interactions between radiations and burned canopies (Chuvieco et al., 2019; Veraverbeke et al., 2011).

Empirical methods benefit from statistical regression or machine learning to measure burn severity and are relatively easy to implement and interpret (De Santis and Chuvieco, 2009; Veraverbeke et al., 2011), for example spectral bands combinations and indexes, such as NBR, dNBR, relative differenced Normalized Burn Ratio RdNBR, Burn Area Index (BAI), Normalized Burn Ratio – Thermal (NBRT), SAVI and Burned Area Index for Sentinel-2 (BAIS2), NBR, dNBR and SAVI are widely used in the literatures for wildfires detection and measuring burn severity.

The primary aim of this study is mapping burned areas and burn severity assessment of a forest fire which was started in 18 august 2019 from Karabağlar district of İzmir and extended to two neighbor districts of Menderes and Seferihisar during three days and burned down about 500 hectares area (Url-1,2,3), using remote sensing-based methods and Sentinel 2 satellite data. The study focuses on fire severity classification and burn area detection through using dNBR, NBR, SAVI and dSAVI indices.

**Figure 1.** Area burned by forest fire occurred on 18/08/2019, Izmir/Turkey (Url-1)

### 1.1. Study Area

The study area is located in Karabağlar Menderes and Seferihisar districts of İzmir province and has 180.94 km$^2$ (18094.2 hectares) area. In Izmir, which is in the Mediterranean climate zone, summers are hot and dry and winters are warm and rainy. The steep extension of the mountains to the sea and the insertion of the plains up to the threshold of the Inner west Anatolia allows the spread of the maritime influences to the inner parts. However, differences in Physical Geography, such as altitude and distance from the Coast, also lead to climate differences that can be considered important in terms of rainfall, temperature and sunbathing. The average annual temperature in the province varies between 14-18 °C in coastal areas. July (27.3 °C) and August (27.6 °C) are the hottest months, while January (8.6 °C) and February (9.6 °C) months are the coldest (Url-4). According to statistics from Turkey's general directorate of forestry, Izmir has 1018259-hectare of forests and 1496478-hectare area dedicated for forestation purposes. Izmir experience many forest fires during summer which destroys significant amount of forests every year. During 2007 and 2016, Izmir had the third highest number of forest fires in Turkey with 1394 cases (Url-5,6). This year (until 28 June 2020), 16 forest fires cases were occurred in Izmir province (Url-7).


**Figure 2.** Location map of the study area, Izmir (Karabağlar, Menderes and Seferihisar district), Turkey

## 2. MATERIALS AND METHODS

### 2.1. Materials

Satellite images the study area have been downloaded from Copernicus Open Access Hub portal (https://scihub.copernicus.eu) which are acquired by sentinel 2B (S2B) satellite. Pre-fire and post-fire images of the study area were selected as close to fire occurrence day as possible; the image tile numbers, capturing date and cloud percentage of the scenes are given in table 1.

**Table 1.** Details of Sentinel 2 satellite images used in this study

| Satellite Image | Cloud Cover (%) | Capturing Date |
|---|---|---|
| S2B_MSIL2A_20190816T085559 | 0.468 | 16/08/2019 |
| S2B_MSIL2A_20190826T085559 | 0.199 | 26/08/2019 |

In addition, these images are Sentinel level 2A products which are both geometrically and radiometrically corrected; furthermore, they are bottom of atmosphere (BOT) products which are also atmospherically corrected (ESA, 2020). All

Sentinel 2A and 2B products are radiometrically corrected by Sentinel-2 Ground Segment and are available for users, level 0, 1A and 1B products which are without radiometric correction, are not available for users (Url-8).

## 2.2. Method

NBR and SAVI indices were selected for burned area detection and dNBR and dSAVI indices for determining fire severity degrees. Data analysis is performed in SNAP software environment and ArcGIS Pro is used for area calculation and plotting purposes.

The NBR is particularly sensitive to changes in living vegetation, moisture content and certain soil conditions in near infrared (NIR) and shortwave infrared (SWIR) bands that may occur after a fire (Miller and Thode, 2007), for this reason, NBR index is used for the detection of burnt green areas. NBR is expressed by mathematical formulas obtained using near infrared and shortwave infrared bands (Miller and Thode, 2007; Veraverbeke et al., 2011). The value range for NBR is in the interval between -1 to +1.

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

Burned area severity can be easily classified by dNBR index. The dNBR is obtained by subtracting pre-fire NBR and post-fire NBR indices (Miller and Thode, 2007).

$$\Delta\mathrm{NBR} = \mathrm{NBR}_{\mathrm{Pre-fire}} - \mathrm{NBR}_{\mathrm{Post-fire}} \tag{2}$$

Hypothetically, the values for dNBR are between -2 and +2 where the values for burnt areas ranging from 0.10 to 1.35 and the unburned areas from -0.10 to +0.10 in most areas, but the minimum and maximum values can be different based on the study area (Key and Benson, 2006).

**Table 2.** Burn severity levels obtained calculating dNBR, proposed by USGS (Key and Benson, 2000; Lutes et al., 2006)

| Severity Level | dNBR Range (not scaled) |
|---|---|
| Enhanced Regrowth, high (post-fire) | -0.500 to -0.251 |
| Enhanced Regrowth, low (post-fire) | -0.250 to -0.101 |
| Unburned | -0.100 to +0.99 |
| Low Severity | +0.100 to +0.269 |
| Moderate-low Severity | +0.270 to +0.439 |
| Miderate-high Severity | +0.440 to +0.659 |
| High Severity | +0.660 to +1.300 |

*(These value ranges are flexible; scene-pair dependent; shifts in thresholds +0.100 points are possible. dNBR less than about -0.550, or greater than about +1.350 may occur, but usually are not considered burned. Rather, they likely are anomalies caused by miss-registration, clouds, or other factors not related to real land cover differences)*

The SAVI index is identical to Normalized Difference Vegetation index (NDVI) and is used to correct NDVI for the influence of soil brightness or noise effects (soil color, soil moisture, soil variability across region, etc.) in areas with low vegetation cover (Xue and Su, 2017; Huete, 1988; EOS, 2019). This index was designed by Huete (1988) which can be expressed as follow:

$$\mathrm{SAVI} = \frac{(\mathrm{NIR-R})}{(\mathrm{NIR+R+L})} * (1 + L) \tag{3}$$

Where L is the soil adjustment factor.

The values for L factor vary based on the vegetation density of the land cover and is varied from 0 to 1; Huete suggests (L=0.25) for high vegetation density, (L=0.5) for intermediate vegetation density and (L=1) for low vegetation density (Huete, 1988).

Burned area severity assessment can be performed using the difference between pre fire and post fire SAVI index results, because the SAVI index is similar to NDVI. We can formulate the Differenced Soil Adjusted Vegetation index by subtracting pre fire and post fire SAVI for detecting burned areas and burn severity categories which can be expressed as follow:

$$\mathrm{dSAVI} = \mathrm{SAVI}_{\mathrm{Pre-fire}} - \mathrm{SAVI}_{\mathrm{Post-fire}} \tag{4}$$

Based on the review performed, this index is not used in any literature before, this index works similar to Differenced Normalized Difference Vegetation Index (dNDVI) which is widely used in vegetation cover change detection and assessment.

## 3. RESULTS

Based on the results of the analysis, dNBR value range was derived between -1.508 to +1.378, the value range was then classified into 7 classes in accordance with burn severity value range defined by USGS (Table 2); the resulted burn severity map is shown in figure 4. The results indicate that 9.3% of the study area is highly burned, also 8.5%, 11.1% and 9.3% of the area is covered by Moderate-high severity, Moderate-low severity and Low severity classes respectively (Figure 3).

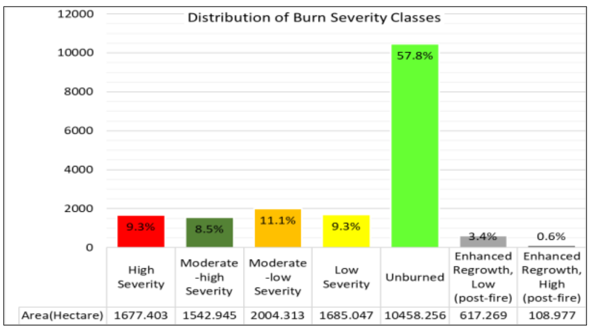


**Figure 3.** Distribution of burn severity classes derived from dNBR index

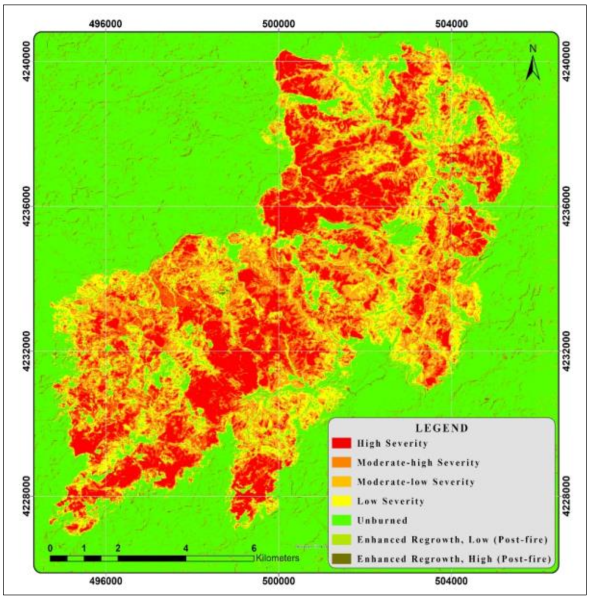


**Figure 4.** dNBR resulted burn severity map, showing the distribution of severity classes across the study area

The dSAVI data range was derived between -0.523 to +0.747 and the results were thresholded into 5 classes considering its histogram and burn severity classes, the resulted burn severity map is shown in figure 5.

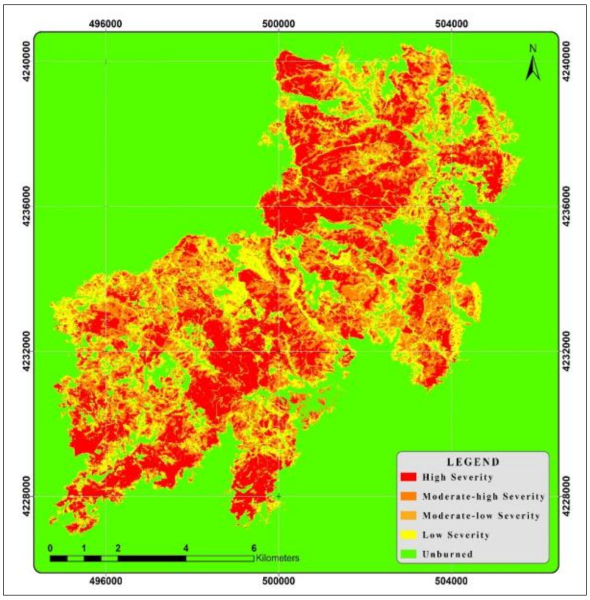


**Figure 5.** dSAVI resulted burn severity map, showing the distribution of severity classes across the study area

Based on the results of dSAVI, 12.5% of the study area is highly burned, 8.7%, 6.4%, 9.4% and 63.0% of the area is covered by Moderate-high severity, Moderate-low severity, Low severity and Unburned classes respectively (Figure 6).

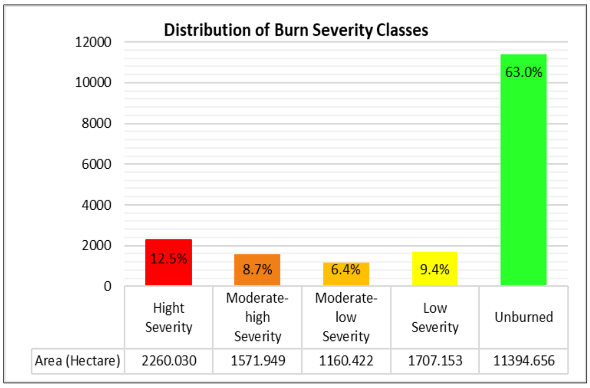


**Figure 6.** Distribution of burn severity classes derived from dSAVI index

## 4. DISCUSSION AND CONCLUSION

Wildfires change the physical and chemical properties of soil and vegetation. Significant changes in spectral reflections can be observed as a result of reduced moisture in vegetation, covering the surface with ashes and a sudden increase in surface temperature (Lanorte et al., 2012). This study demonstrates that burned area detection and burn severity assessment can be successfully executed using remote sensing indices and sentinel 2 satellite imageries. The NBR, dNBR, SAVI and dSAVI indices used in this study had very good performance (Figure 5) which shows the suitability of the indices used.

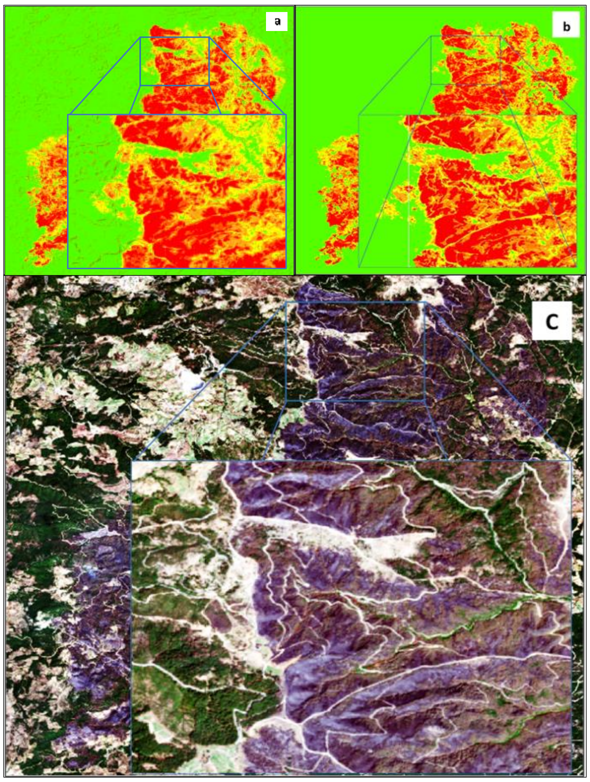


**Figure 7.** (a) burned areas detected by NBR and dNBR indices, (b) burned areas detected by SAVI and dSAVI indices, (c)RGB composite of the burned area

The NBR and dNBR indices had very good performance in detection of burned areas and burns severity analysis in many studies (Veraverbeke et al., 2011; Key and Benson, 2006; Miller and Thode, 2007). Recently, Roy et al. (2006) have questioned the efficiency of the NBR index assessing forest fires in South Africa, Australia, Russia and South America; they have used Landsat and MODIS satellite data in their study.

The results obtained in this study are the opposite of the results obtained by Roy et al. (2006), the fires they have assessed are likely to be understory surface fires which were not visible due to very dense canopy. In addition, the optimality analysis performed by them would have included burned and unburned pixels in their calculations. The results of the analysis show that NBR index is more sensitive to pre and post fire spectral changes in the scene than SAVI index. The dNBR index had better performance in discriminating between different severity levels than dSAVI, especially in high severity class.

The study revealed that from the total 18094.21 hectares of the study areas, 6909.708-6699.554 hectare is burned. According to the statistics announced by authorities and news agencies, the burned area is repeatedly reported 500 hectares after the fire was extinguished (Url-1,2,6), which have an extreme difference with the results obtained in this study. The results indicate that only High severity class detected by dNBR and dSAVI covers 1677.403-hectare and 2260.030-hectare area respectively, which is about three to four times bigger than it was reported in media.

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