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Forest Fire Analysis with Sentinel-2 Satellite Imagery: The Case of Mati (Greece) in 2018

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Abstract

Due to the damage they cause to the environment, forest fires have an important place among the disasters that occur around the world. In recent years, forest fires have increased in frequency, size and intensity, especially in Mediterranean countries. Preventive measures should be taken and risk reduction should be implemented so that natural or man-made risks do not turn into a catastrophic disaster. After a disaster commences, the implementation of evacuation plans for the settlement, when necessary, is of great importance in this context. One of these forest fires started on July 23, 2018 in the popular holiday resort of Mati in Greece. Mati located within the borders of the Attica region and 29km east of Athens, was examined within the scope of this study. The forest fire that took place in the said regions affected a very large area and the fires caused the death of 103 people and the destruction of approximately 4,000 houses, including thousands of vehicles. In the study, data processing and evaluation using Sentinel-2 satellite images from the Copernicus program of the European Space Agency (ESA), SNAP software, an open source software developed by ESA and the ArcMap program were used for subsequent statistical calculations. As a result, it was determined how much the area was burned with the help of Sentinel-2 satellites and a study was carried out on the mapping of the affected areas. In addition, the relationship between disaster risk reduction activities has been examined.

Key words: Greece, Mati, Remote sensing, Burnt area mapping, Disaster management

1. Introduction

Disasters occurring today affect many living things and cause serious material and psychological loss. The concept of disaster has various definitions. According to the universal concept accepted by the United Nations, disaster refers to natural, technological and human-induced events that cause social, physical and economic losses for people, and affect communities by stopping or interrupting normal life and human activities [1]. Forest fires have an important place in natural disasters. Fires draw attention as a phenomenon that is frequent in the Mediterranean Basin especially, together with human causes, climate-related changes and changes in land use [2]. It is seen that there has been a great increase in the forest fire in this region and there has been an approximately twofold increase compared to the 1970s [3].

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Determination of burnt forest areas is made by using remote sensing and GIS techniques rather than terrestrial measurements. Remote sensing and GIS techniques are fast and economical methods when compared to terrestrial methods. In addition, they provide significant advantages in monitoring the course of fires, analysis studies and damage detection. Especially in the disaster management process, the operation of evacuation plans and the determining alternative transportation axes provide important advantages for those in charge of administering the disaster process. [4, 5].

As a result of the rapid developments in remote sensing technologies, it is more effective and faster to detect the areas destroyed after the forest fire with the diversification of satellite data [6]. Especially in recent years, great progress has been made in mapping forest fires, determining the impact areas of fires and the sum of the burned areas, and the use of remote sensing methods in mapping these areas [7].

Sentinel-2 satellites were developed by the European Space Agency under the Copernicus Program. In 2015 (Sentinel-2A) and 2017 (Sentinel-2B) the ESA placed its satellites in earth orbit [8]. The use of Sentinel-2 satellites has become widespread in many different application areas such as monitoring natural disasters, emergency management, determining changes in land use and monitoring marine biodiversity [9, 10].

We see that there are numerous studies related to forest fires. There are many studies in the literature on the detection, mapping and monitoring of burnt areas with the data obtained from sentinel imagery [11-18; 35-42].

In the study on the forest fire that occurred in Kahramanmaraş, Türkiye, in 2020, the burned areas were determined using different indices, and the relationship of satellite images with soil structure and morphometric features revealed important results in understanding the impact of forest fires, especially in the Mediterranean basin [19]. In a study conducted in 2016, the forest fire that occurred in Portugal was examined using Landsat and Sentinel data, and the results obtained were very close to the field data regarding the burned areas. It has been shown that Sentinel data gives more accurate results this is a result of the higher spatial resolution of Sentinel images [20]. In a study conducted in 2021, the forest fire that occurred in the holiday resort of Bodrum in the province of Muğla in Türkiye was examined. A fire severity map was produced with the dNBR index, according to NBR index differences. The author investigated the relationship between the forest fire and different slope values in order to determine the effect of the topographic structure of the land in the burned area on the fire [21]. In a study conducted in 2017, forest fires in Portugal and Spain were examined. As a result of the comparison made with the European Forest Fire Information System (EFFIS) information together with the proposed methodology, it was revealed that 10% better results were obtained in area estimation [22].

In the traditional disaster management processes, there was no planning or preventive action regarding mitigation or risk management before disasters occurred. Plans were generally created to cover the moment of the disaster and beyond. Today, disaster management systems (Integrated disaster management) constitute a two-stage process: crisis management and risk management. Intervention and improvement constitute the crisis management process. Risk reduction activities, on the other hand, include all preparations made before disasters. In particular, within the scope of the United Nations Sendai Disaster Risk Reduction Framework (2015-2030), it is one of the main objectives to identify existing risks on a local or global scale and to create resilient societies against disasters by reducing losses significantly through risk reduction studies. The concept of risk, on the other hand, includes all hazards, whether of natural origin or human origin. The preparatory phase (AFAD- Türkiye) is defined as "all kinds of activities carried out beforehand for disasters and emergencies in order to provide an effective response" within the framework of Law No. 5902 [23]. Today, it is seen that more importance is given to risk reduction and preparation studies in the integrated disaster management process compared to intervention and improvement studies, and research is carried out in this context. Training and awareness-raising activities on disasters that may occur in risk reduction studies, arranging exercises, and being organized in the institutional and social fields are of great importance. In particular, in parallel with technological developments, it includes all the work to ensure inventory management in disasters with software based on geographic information systems and to act on a common base and to carry out activities such as evacuation and placement correctly.

In addition, the Sendai Disaster Risk Reduction Framework (article/24) emphasizes the importance of developing spatial-based disaster risk maps, updating the obtained data periodically, presenting them to decision makers or the public in appropriate formats and disseminating them. Systems such as Geographical Information Systems and Remote Sensing should be used effectively in order to obtain data accurately and in real time, to process this data correctly and to assist decision makers [24]. It is predicted that the use of information technologies will be supportive in getting maximum efficiency from pre-disaster processes and being prepared for disaster risks. It can be predicted that the sharing of the obtained data will be one of the critical points in reducing the effects of disasters at local, national and international levels [25].

In this study, the forest fire in 2018 in the holiday town of Mati, in the Attica region in Greece, east of Athens, was examined. The forest fires began on July 23 and lasted less than 12 hours. The forest fire that took place in Mati affected a very large area and caused the death of 103 people and the destruction of 4,000 houses along with thousands of vehicles [26].

Images obtained from Sentinel-2 satellites were used to determine the burned areas and the relationship of the results obtained with the disaster risk management process was evaluated.

2. Materials and Method

2.1. Study Area

The Mati township (38°02′37″N 23°59′42″E) is located approximately 29 km east of the capital, Athens (Figure 1).

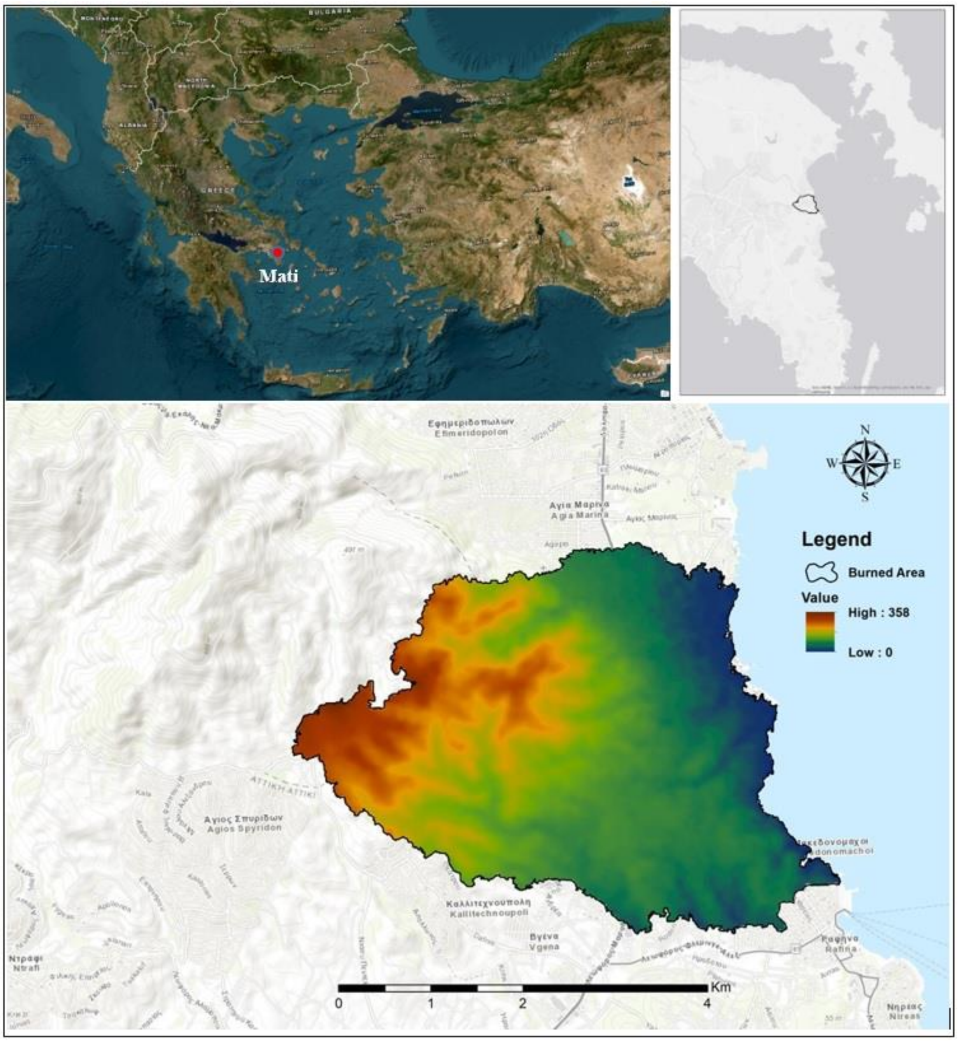

Figure 1. Study area

2.2. Data Set

The Sentinel-2 satellites are located at an altitude of 786 km from the Earth's surface. It has an orbital angle of 98.62° [27]. Sentinel-2 satellites use two satellites every 5 days for the land and coastal areas between the 56° south and 83° north latitudes. Sentinel-2 satellites, which provide free data with a 10 m, 20 m and 60 m spatial resolution depending on the wavelength, consist of 13 bands [28]. Orbital positions of the Sentinel-2 satellites are provided by a Global Navigation Satellite System (GNSS) receiver. Multispectral instruments work passively by collecting sunlight reflected from the earth's surface [29]. The bandwidth of Sentinel-2 satellites has become increasingly common in many different remote sensing applications and in detecting forest fire severity (NBR-burned area index) indexes [30].

In this study, Sentinel-2 satellite image data was used provided free of charge by the European Space Agency (ESA). Information on the satellite images used before and after the fire can be seen in Table 1 and the bands and spectral resolutions of Sentinel-2B satellite are presented in Table 2.

Table 1. Dates of pre-/post-fire images employed in this study

Satellite	Filename of image	Date Viewed	Mod / Product
Sentinel-2 B	S2B_MSIL2A_20180705T091019_N0208_ R050_T34SGH_20180705T133603	05 July 2018	MSIL2A
Sentinel-2 B	S2B_MSIL2A_20180804T090549_N0208_ R050_T34SGH_20180804T142040	04 August 2018	MSIL2A

Table 2. Sentinel-2B MSI band settings

Acronym	Band	Central Wave-length (nm)	Spectral Width (nm)	Spatial resolution (m)
B1	Violet	443	20	60
B2	Blue	490	65	10
B3	Green	560	35	10
B4	Red	665	31	10
B5	Red-edge 1	705	15	20
B6	Red-edge 2	740	13	20
B7	Red-edge 3	783	19	20
B8	NIR	842	104	10
B8a	NIR narrow	865	21	20
B9	NIR	945	20	60
B10	NIR	1380	29	60
B11	SWIR	1610	94	20
B12	SWIR	2190	184	20

The processing of satellite data requires a GIS (Geographic Information System) environment. SNAP, Sentinel Application Platform (Sentinel-2 Toolbox) and ArcMap software were used for data processing and subsequent statistical calculations.

2.3. Method

The forest fire that started in the Mati vicinity on 23 July 2018 rapidly engulfed the area in a very short time leaving administrators helpless to do anything. In order to determine the NBR values before and after the fire, the dates before and after the forest fire were taken into account. In addition, dates with favourable weather conditions were chosen. The steps applied in the study are shown in Figure 2.

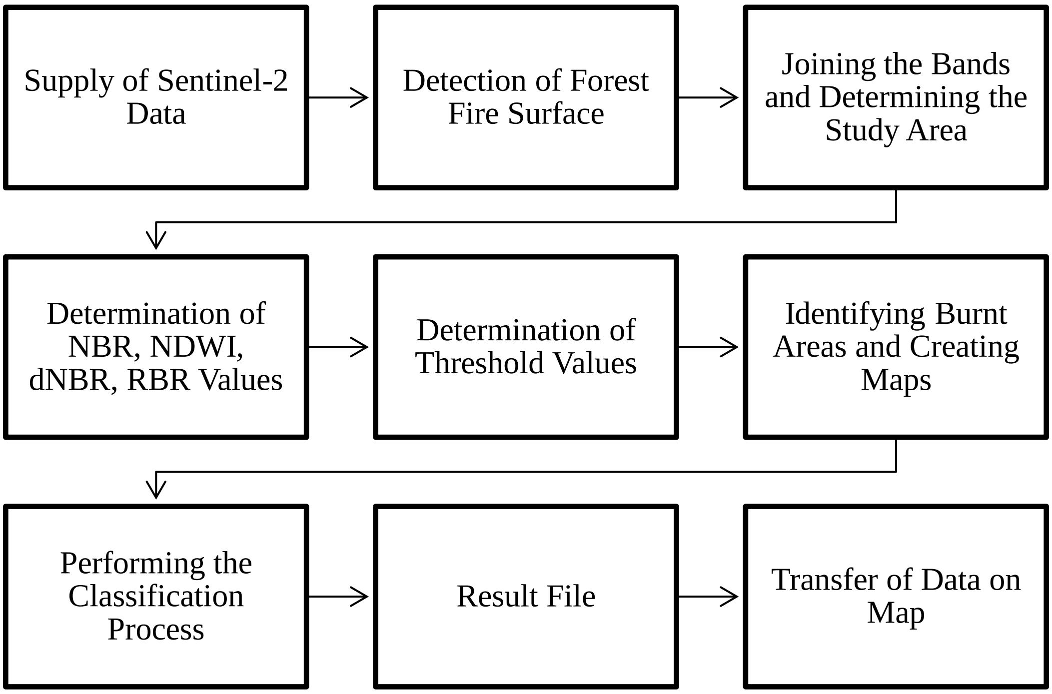

Figure 2. Data processing flow chart

As for the method applied in the study, the determination of the changes according to the index differences before and after the fire and mapping of the burned areas after the fire were carried out. First of all, a cloud mask was applied to the selected satellite images. The most commonly used metric for a burnt area and burn intensity mapping from satellite data is the Normalized Burned Area Ratio (NBR) (Equation 1). Burnt areas have relatively low reflectance in the near infrared band and high reflectance in the short wave infrared band. A high NBR value generally indicates healthy vegetation, while a low value indicates bare ground and recently burned areas. [31].

$$\mathbf{NBR} = (B8 - B12) / (B8 + B12) \tag{1}$$

Bodies of water may show a similar NBR difference in certain situations, so they need to be masked. For this purpose, a single composite mask consisting of water and clouds was created using Equation (2). The Normalized Difference Water Index **(NDWI)** was used to detect water bodies. The NDWI proposed by McFeeters was used to maximize the reflection of the water body in the green band and to minimize the reflection of the water body in the NIR (near-infrared) band.

$$\mathbf{NDWI} = (Green - NIR) / (Green + NIR) = (B3 - B8) / (B3 + B8) \tag{2}$$

The Difference Normalized Burn Ratio (dNBR), which is the difference between the pre-fire and post-fire NBR calculated by Equation (3), was used to identify recently burned areas and separate them from bare soil and other non-vegetated areas.

$$\mathbf{dNBR} = NBR_{pre\text{-}fire} - NBR_{post\text{-}fire} \tag{3}$$

Finally, the Relative Burn Ratio (RBR) was used to determine the burned areas by Equation (4). RBR means splitting dNBR to NBR before the fire. Adding 1001 to the denominator prevents the denominator from being zero [32].

$$\mathbf{RBR} = \{dNBR / (NBR_{pre\text{-}fire}+1.001)\} = \{(NBR_{pre\text{-}fire} - NBR_{post\text{-}fire}) / (NBR_{pre\text{-}fire}+1.001)\} \quad (4)$$

3. Results and Discussion

Newly burnt areas in the study area were created by combining bands near infrared (NIR) and short-wave infrared (SWIR) bands were used to detect burned areas, as shown in Figure 3.

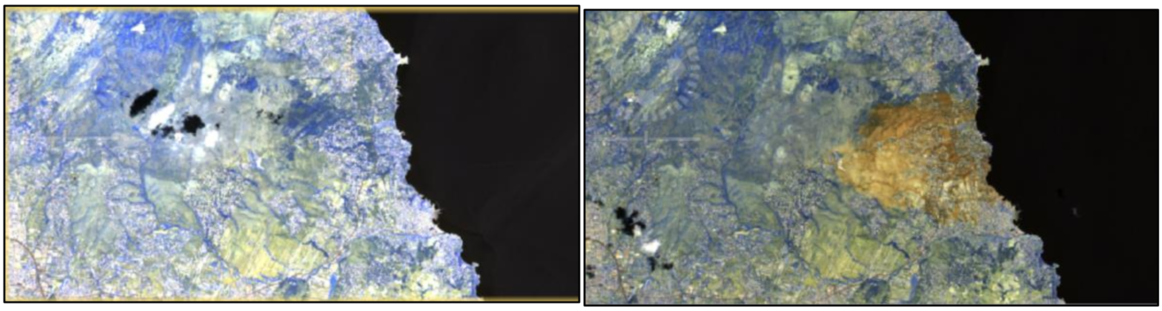

Figure 3. Fire area surface detection

After the fire, the index differences of the images before the fire and after were calculated by applying the NBR index from the satellite images in the study area. NBR and dNBR results are shown in Figure 4. Burnt areas are seen in black. The burned areas were calculated as 1511,89 hectares in total.

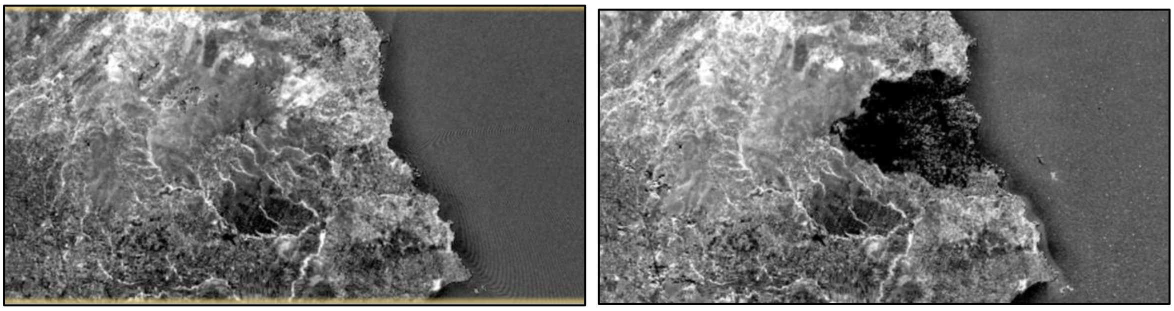

Figure 4. Comparison of NBR index and burnt areas

Afterwards, the map in Figure 5 was obtained by combining the images before and after the fire using the relative burning rate in order to detect only the burned areas.

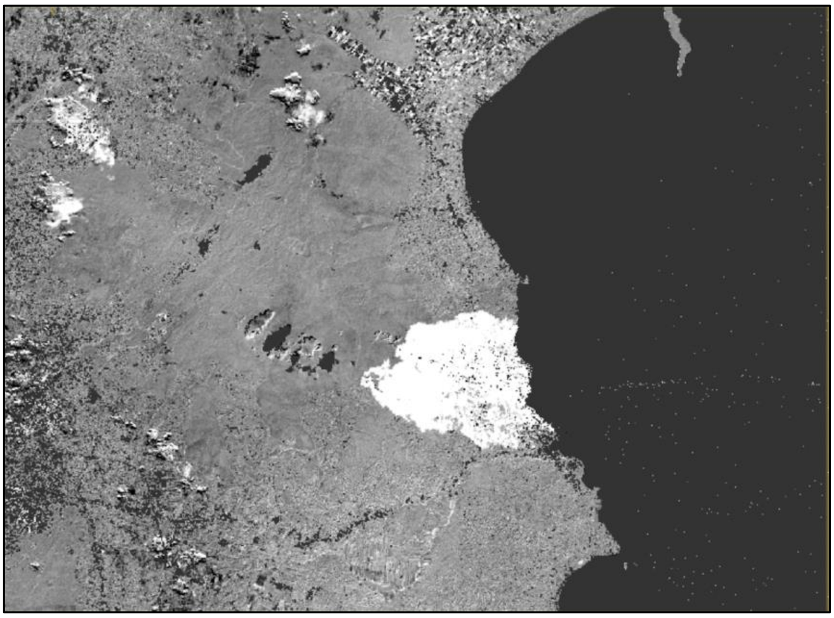

Figure 5. Illustration of burnt areas with RBR index

Only pixels with RBR greater than 0.10 were selected to determine the burnt area. This value of 0.10 corresponds to a low degree of burning intensity. Therefore, only areas classified as having low grade or higher burnt areas were selected. The classification method proposed by the USGS (U.S. Geological Survey) for interpretation of burnt areas is shown in Table 3 [33].

Table 3. Burned severity classification

Severity Level		dNBR-RBR (not scaled)
Unburned		< 0.1
Low Severity		0.1 - 0.26
Moderate Severity		0.27 - 0.43
High Severity		0.44 - 0.65
Very High Severity		> 0.66

A map showing the severity of the burned areas was obtained by using the classification method specified in Table 3. The effect of the forest fire on the town of Mati and the extent affected by the fire are shown on the map in Figure 6. There is a total of 1,511.89 hectares of burned areas, of which unburned areas are 194.97 hectares (12.89%), areas with low burned intensity are 377.41 hectares (24.96%), areas with moderate burned intensity are 482.27 hectares, (31.90%), areas with high burned intensity were determined as 443.14 hectares (29.31%) and areas with very high (severe) burned intensity were determined as 14.12 hectares (0.94%) (Table 4).

Table 4. Calculates of burned areas

Area	Level	Field (ha)	Percentage (%)
Mati	Unbourned	194.97	12.90
	Low Severity	377.41	24.96
	Moderate Severity	482.27	31.90
	High Severity	443.14	29.31
	Very High Severity	14.10	0.93
	Total	**1511.89**	**100**

In the report presented by the Emergency Response Coordination Centre (ERCC), the results obtained in the study (1316,92 ha) with the burned areas (1275,9 ha) in the town of Mati show 96.88% compatibility [34].

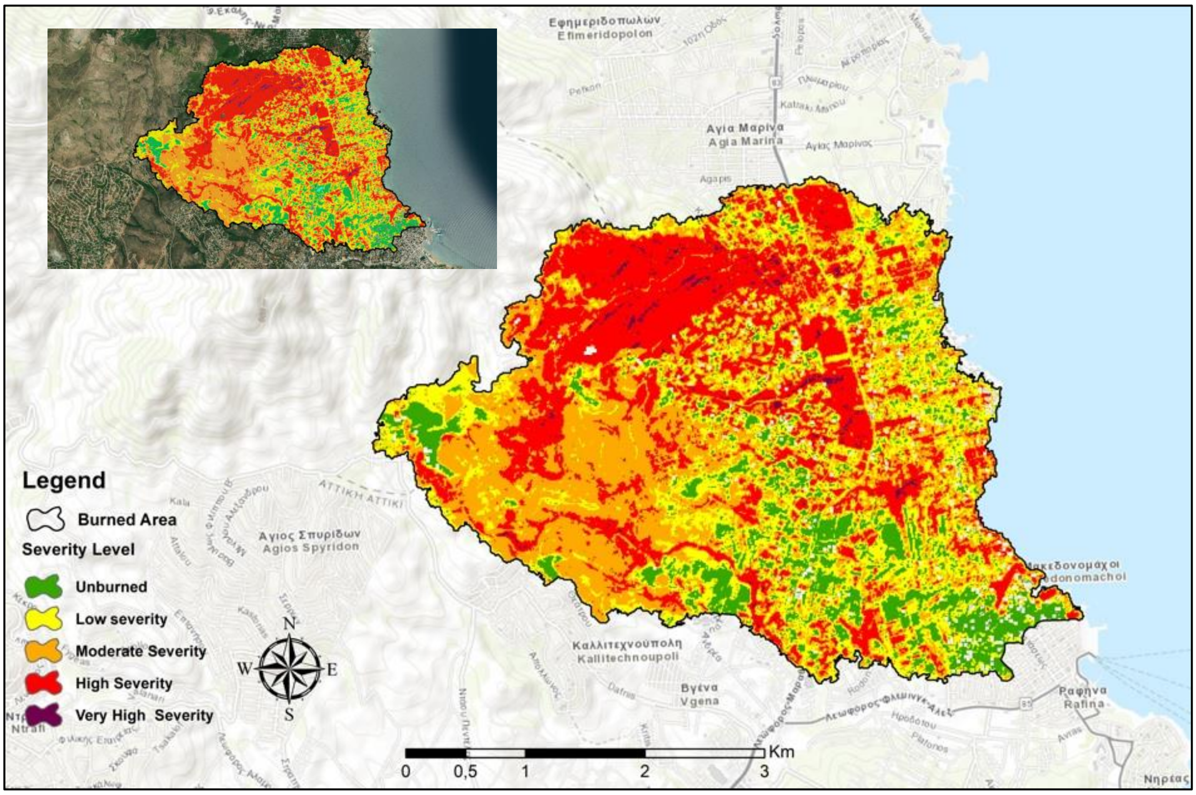

Figure 6. Burn severity map on Mati town

When previous studies were examined, it was seen that dNBR and RBR indices were used in many studies and gave successful results [19, 21, 35-42]. In their study, Arisanty et al. determined forest oil areas used dNBR and RBR indices used Sentinel-2 images. The results showed that the general accuracy values varied between %91.5 and %92.9. Simone et al, in their study in 2020, carried out a study on the classification of burned areas with the RBR index and determined the overall accuracy value as %83 and the kappa value as %71. Uttaruk et al, in their study in Thailand, revealed forest fires in forest fires that occurred between 2017-2020 using Sentinel-2 images and NBR, NDWI, RBR indexes. Authors concluded that the overall accuracy value they obtained was between %76.67 and %93.33 and the statistical value of kappa was between 0.53 and 0.87. Moressi et al, in their study, examined 10 forest fires in Italy in 2017 used Sentinel-2 images. As a result of the study an accuracy value between %76.9 and %83.7 and a kappa value varying between 0.61 and 0.72 were obtained. Dindaroğlu et al, in their study, examined the forest fire that occurred in Kahramanmaraş, Türkiye with Sentinel-2 satellite images. Used different indices, they calculated the overall accuracy value as %83 and the kappa value as 0.70. Yılmaz et al, studied the forest fire that occurred in Muğla (Bodrum), Turkey in 2021. As a result, authors obtained an overall accuracy value of %89.07 and a kappa value of 0.716. When the mapping studies of burnt areas are examined it is seen that the general accuracy values vary between %76 and %96, and the statistical values of kappa vary between 0.53 and 0.93.

Here, the accuracy to be achieved was analysed for the forest fire occurred in the Mati region. To do it, the study area is divided into two classes as burned and unburned areas. In order to estimate the accuracy of the classification process, a total of 298 points was randomly assigned in the study area by using ArcMap Software, Create Random Points (Figure 7). The discarded points and the classification result values and actual values were compared. As a result of the comparison, the kappa value ($\varkappa$) was 0.7176, and the overall classification accuracy was %93.29. The producer's accuracy of the burnt areas was 0.9762 and the user's accuracy was 0.9463.

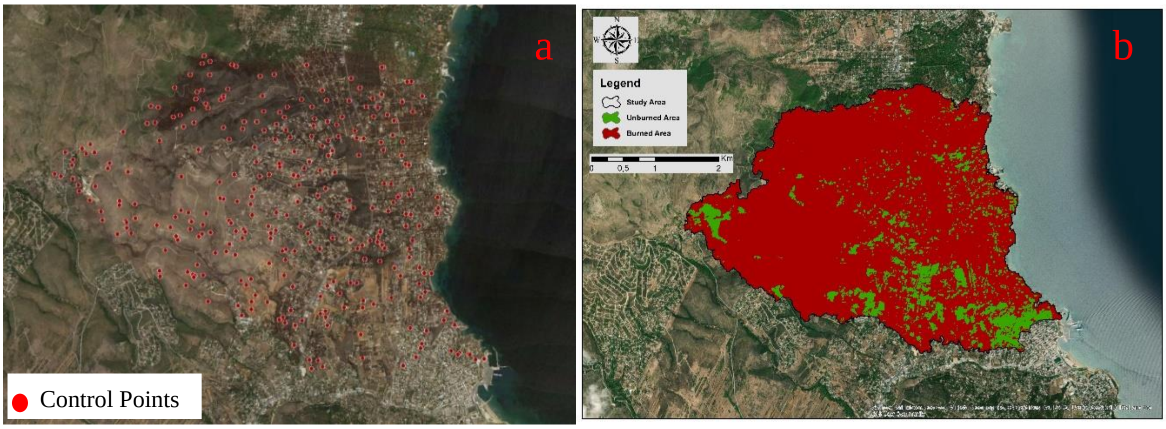

Figure 7. Classification process: a. real image and checkpoints b. Image obtained by classification

4. Conclusions

This study, shows the fire area that was most affected by using the July and August satellite images for Mati in Greece in 2018. The most affected areas were the northern and central part of the town. The interpretation of the comprehensive images was generally used by means of extensive information system.

In addition, mapping of the burned areas as a result of forest fire was carried out. The RBR index was used in the study. The total area affected by the fire was calculated as 1511.89 hectares. In the classification process made as a result of the forest fire that occurred in July 2018, it was seen that the producer's accuracy was 97.62% and the user's accuracy was 94.63%.

In the vicinity of Mati where the fire occurred, it was observed that there were great difficulties in evacuating the town especially during the disaster response process, and alternative evacuation routes were insufficient. Authorities reported that illegal settlements were one of the main reasons fort he failure to evacuate. The failure of the town's evacuation plan caused great problems in the northern part of the town close to the forest area and caused the death of many people. In order to prevent fires in the residential areas where the risk of fire is high, especially in the northern and middle parts of Mati town and close to forested areas, it is necessary to create fire buffer areas, prohibit the areas for settlement and monitor the regularly. In this way, it will be possible to implement the evacuation and resettlement plans more effectively.

In the disaster management process, risk reduction is much more important than the response. In the scope of this process, it is essential to raise public awareness about disasters and to provide training on disasters at consistent intervals. In addition, sea search and rescue activities should be given importance, especially in case of fires in coastal towns, and drills should be held at regular intervals.

In order for the integrated disaster management to be successful, all the stakeholders responsible for this process should fulfil their responsibilities in coordination.

As in the example of the study area, disasters (earthquakes, fires, floods, forest fires) that have occurred or will occur with rapid and unplanned construction will disrupt risk reduction and crisis management activities. It is clear that minimizing the effects of disasters and applying risk prevention correctly will be effective in minimizing the loss of life property caused by large forest fires that may occur in Greece and all over the world. Multidisciplinary approaches in scientific studies would provide a basis for new studies to understand the processes and provide a broad assessment, and this approach should be implemented and on-going.

Conflict of Interest

No conflict of interest has been declared by the authors.

Author Contribution

Both authors contributed in the design, data collection, data analysis and writing of the present study.

References

[1] UNDHA (United Nations Department of Humanitarian Affairs). 1992. Internationally agreed glossary of basic terms related to disaster management. Geneva: UNDHA.
[2] A. Teodoro and A. Amaral, "A statistical and spatial analysis of Portuguese forest fires in summer 2016 considering Landsat 8 and Sentinel 2A data", *Environments,* vol. 6, no.3, pp. 36, 2019, doi: https://doi.org/10.1023/A:1009752403216
[3] M. C. Rulli and R. Rosso, "Hydrologic response of upland catchments to wildfires", *Advances in Water Resources*, vol. 30, no. 10, pp. 2072-2086, 2017, doi: https://doi.org/10.1016/j.advwatres.2006.10.012
[4] İ. H. Saylan and R. Çömert, "Sentinel-2A ürünlerinin yanmış orman alanlarının haritalanmasındaki başarının araştırılması", *Türkiye Uzaktan Algılama Dergisi*, vol. 1, no. 1, pp. 8-15, Dec. 2019.
[5] M. Yavuz and B. Sağlam, "Uzaktan Algılama ve Coğrafi Bilgi Sistemlerinin Orman Yangınlarında Kullanılması", Ulusal Akdeniz Orman ve Çevre Sempozyumu, KSÜ Mühendislik Bil. Der., vol. special, pp. 235-242, 2012.
[6] A. Sabuncu and H. Özener, "Uzaktan Algılama Teknikleri ile Yanmış Alanların Tespiti: İzmir Seferihisar Orman Yangını Örneği", *Doğal Afetler ve Çevre Dergisi*, vol. 5, no. 2, pp. 317-326, Tem. 2019, doi:10.21324/dacd.511688
[7] A. da P. Pacheco, J. A. da S. Junior, A. M. Ruiz-Armenteros, and R. F. F. Henriques, "Assessment of k-Nearest Neighbor and Random Forest Classifiers for Mapping Forest Fire Areas in Central Portugal Using Landsat-8, Sentinel-2, and Terra Imagery", *Remote Sensing*, vol. 13, no. 7, p. 1345, Apr. 2021, doi: 10.3390/rs13071345.
[8] https://sentinel.esa.int/web/sentinel/missions (Erişim Tarihi: 2022). (Accessed on 12 November 2022).
[9] Z. Malenovský, H. Rott, J. Cihlar, M. E. Schaepman, G. García-Santos, R. Fernandes, and M. Berger, "Sentinels for science: Potential of Sentinel-1,-2, and-3 missions for scientific observations of ocean, cryosphere, and land", *Remote Sensing of environment*, vol.120, pp. 91-101, May 2012, doi: https://doi.org/10.1016/j.rse.2011.09.026

[10] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/mission-objectives (Accessed on 12 November 2022).
[11] S. Xulu, N. Mbatha, and K. Peerbhay, "Burned Area Mapping over the Southern Cape Forestry Region, South Africa Using Sentinel Data within GEE Cloud Platform", *ISPRS International Journal of Geo-Information*, vol. 10, no. 8, p. 511, Jul. 2021, doi: 10.3390/ijgi10080511.
[12] A. Verhegghen et al., "The Potential of Sentinel Satellites for Burnt Area Mapping and Monitoring in the Congo Basin Forests", *Remote Sensing*, vol. 8, no. 12, p. 986, Nov. 2016, doi: 10.3390/rs8120986.
[13] D. Stavrakoudis, T. Katagis, C. Minakou and I. Z. Gitas, (2019, June) "Towards a fully automatic processing chain for operationally mapping burned areas countrywide exploiting Sentinel-2 imagery", In Seventh International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2019), International Society for Optics and Photonics, vol. 11174, p. 1117405, June.2019, doi: https://doi.org/10.1117/12.2535816.
[14] L. Pádua, N. Guimarães, T. Adão, A. Sousa, E. Peres, and J. J. Sousa, "Effectiveness of Sentinel-2 in Multi-Temporal Post-Fire Monitoring When Compared with UAV Imagery", *ISPRS International Journal of Geo-Information*, vol. 9, no. 4, p. 225, Apr. 2020, doi: 10.3390/ijgi9040225.
[15] N. Puletti, F. Chianucci and C. Castaldi "Use of Sentinel-2 for forest classification in Mediterranean environments", *Ann. Silvic. Res*, vol. 42, no. 1, pp. 32-38, 2018, doi: :10.1016/j.rse.2011.09.026
[16] F. Filipponi, "Exploitation of Sentinel-2 Time Series to Map Burned Areas at the National Level: A Case Study on the 2017 Italy Wildfires", *Remote Sensing*, vol. 11, no. 6, p. 622, Mar. 2019, doi: 10.3390/rs11060622.
[17] H. Youn and J. Jeong, "Detection of forest fire and NBR mis-classified pixel using multi-temporal Sentinel-2A images", *Korean Journal of Remote Sensing*, vol. 35, no. 6_2, pp.1107-1115, 2019, doi: https://doi.org/10.7780/kjrs.2019.35.6.2.7
[18] E. Roteta, A. Bastarrika, M. Padilla, T. Storm and E. J. R. S. O. Chuvieco, "Development of a Sentinel-2 burned area algorithm: Generation of a small fire database for sub-Saharan Africa", *Remote sensing of environment*, vol. 222, pp.1-17, 2019, doi: https://doi.org/10.1016/j.rse.2018.12.011
[19] T. Dindaroglu, E. Babur, T. Yakupoglu, J. Rodrigo-Comino and A. Cerda, A. "Evaluation of geomorphometric characteristics and soil properties after a wildfire using Sentinel-2 MSI imagery for future fire-safe forest", *Fire Safety Journal*, vol.122, pp.103318, June 2021, doi: https://doi.org/10.1016/j.firesaf.2021.103318
[20] A. Teodoro and A. Amaral, "A Statistical and Spatial Analysis of Portuguese Forest Fires in Summer 2016 Considering Landsat 8 and Sentinel 2A Data", *Environments*, vol. 6, no. 3, p. 36, Mar. 2019, doi: 10.3390/environments6030036.
[21] O. S. Yılmaz, D. E. Akyüz, M. A. Akgül, M. Aksel, M. Dikici, Y. Oral, H. Aksoy and F. B. Şanlı, "Uzaktan Algılama ve Coğrafi Bilgi Sistemleri ile Orman Yangını Şiddeti Haritalarının Üretilmesi ve Eğimlere Göre Analizi: Bodrum; Orman Yangını Örneği", TMMOB Afet Sempozyumu, Ankara, pp.865-874, Apr. 2022.
[22] R. Llorens, J. A. Sobrino, C. Fernández, J. M. Fernández-Alonso and J. A. Vega, "A methodology to estimate forest fires burned areas and burn severity degrees using Sentinel-2 data", Application to the October 2017 fires in the Iberian Peninsula, *International Journal of Applied Earth Observation and Geoinformation*, vol. 95, no.102243, March 2021, doi: https://doi.org/10.1016/j.jag.2020.102243

[23] 5902 Sayılı Afet ve Acil Durum Yönetimi Başkanlığının Teşkilat ve Görevleri Hakkında Kanun. https://www.mevzuat.gov.tr/mevzuatmetin/1.5.5902.pdf (Accessed on 11 November 2022).
[24] https://uclgmewa.org/uploads/file/748e86d91ae4409e9188794ddb6c004d/Sendai_TR.pdf (Accessed on 18 November 2022).
[25] İ. Macit , "Bütünleşik Afet Yönetiminde Sendai Çerçeve Eylem Planının Beklenen Etkisi", *Doğal Afetler ve Çevre Dergisi*, vol. 5, no. 1, pp. 175-186, Jan. 2019, doi:10.21324/dacd.421564
[26] H. Smith, "*In my nightmares I'm always in the sea a year on from the Greek fires*", The Guardian, 2019. https://www.wikiwand.com/en/2018_Attica_wildfires (Accessed on 14 November 2022).
[27] https://sentinel.esa.int/web/sentinel/missions/sentinel-2/satellite-description/orbit (Accessed on 12 November 2022).
[28] Suhet, (2013) Sentinel-2 User Handbook 1: 9, https://sentinel.esa.int/ documents/247904/685211/ sentinel-2_user_handbook (Accessed on 10 November 2022).
[29] https://sentinel.esa.int/web/sentinel/missions/sentinel-2/satellite-description(Accessed on 12 November 2022)
[30] R. Gibson, T. Danaher, W. Hehir and L. Collins, "A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest", *Remote Sensing of Environment*, Vol. 240, no.111702, Apr. 2020, doi: https://doi.org/10.1016/j.rse.2020.111702
[31] D. P. Roy, L. Boschetti and S. G. Trigg, "Remote sensing of fire severity: assessing the performance of the normalized burn ratio", *IEEE Geoscience and Remote Sensing Letters*, vol.3, no.1, pp. 112-116, Jan. 2006, doi: 10.1109/LGRS.2005.858485
[32] S. Parks, G. Dillon, and C. Miller, "A New Metric for Quantifying Burn Severity: The Relativized Burn Ratio," *Remote Sensing*, vol. 6, no. 3, pp. 1827–1844, Feb. 2014, doi: 10.3390/rs6031827.
[33] A. Sabuncu ve H. Özener , "Uzaktan Algılama Teknikleri ile Yanmış Alanların Tespiti: İzmir Seferihisar Orman Yangını Örneği", *Doğal Afetler ve Çevre Dergisi*, c. 5, sayı. 2, ss. 317-326, Tem. 2019, doi:10.21324/dacd.511688
[34] European Union Emergency Response Coordination Centre (ERCC). DG ECHO Daily Map, Greece Forest Fires Situation 26/07/2018. https://reliefweb.int/sites/reliefweb.int/files/resources/ECDM_20180726_Greece_ Forest-Fires.pdf, (Accessed on 20 November 2022).
[35] D. Arisanty, M. Feindhi Ramadhan, P. Angriani, M. Muhaimin, A. Nur Saputra, K. Puji Hastuti and D. Rosadi, "Utilizing sentinel-2 data for mapping burned areas in banjarbaru wetlands, South Kalimantan province", *International Journal of Forestry Research*, vol. 2022, Oct. 2022, doi: https://doi.org/10.1155/2022/7936392
[36] B. Kurnaz, C. Bayik and S. Abdikan, "Forest fire area detection by using Landsat-8 and Sentinel-2 satellite images: A case study in Mugla, Turkey", May 2020, doi: https://doi.org/10.21203/rs.3.rs-26787/v1
[37] W. De Simone, M. Di Musciano, V. Di Cecco, G. Ferella and A. R. Frattaroli, "The potentiality of Sentinel-2 to assess the effect of fire events on Mediterranean mountain vegetation", *Plant Sociology*, vol. 57, no.11, Apr. 2020, doi: doi.org/10.3897/pls2020571/02
[38] Y. Uttaruk, T. Rotjanakusol and T. Laosuwan, "Burned Area Evaluation Method for Wildfires in Wildlife Sanctuaries Based on Data from Sentinel-2 Satellite", *Polish Journal of Environmental Studies*, vol. 31, no.6, pp. 1-11, 2022, doi: DOI: 10.15244/pjoes/152835

[39] F. Ngadze, K. S. Mpakairi, B. Kavhu, H. Ndaimani and M. S. Maremba, "Exploring the utility of Sentinel-2 MSI and Landsat 8 OLI in burned area mapping for a heterogenous savannah landscape", *PLoS One*, vol. 15, no. 5, 2020, doi: https://doi.org/10.1371/journal.pone.0232962

[40] D. Morresi, R. Marzano, E. Lingua, R. Motta, and M. Garbarino, "Mapping burn severity in the western Italian Alps through phenologically coherent reflectance composites derived from Sentinel-2 imagery", *Remote Sensing of Environment*, vol. 269, no.112800, Feb. 2022, doi: https://doi.org/10.1016/j.rse.2021.112800

[41] S. Gülci , K. Yüksel , S. Gümüş and M. Wing , "Mapping Wildfires Using Sentinel 2 MSI and Landsat 8 Imagery: Spatial Data Generation for Forestry", *European Journal of Forest Engineering*, vol. 7, no. 2, pp. 57-66, Dec. 2021, doi:10.33904/ejfe.1031090

[42] S. Abdikan et al., "Burned Area Detection Using Multi-Sensor SAR, Optical, and Thermal Data in Mediterranean Pine Forest", Forests, vol. 13, no. 2, p. 347, Feb. 2022, doi: 10.3390/f13020347.