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Google Earth Engine Based Approach for Finding Fire Locations and Burned Areas in Muğla, Turkey

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Abstract: Forests are considered as one of the main sources of biodiversity. Forest fires caused by various reasons pose a high risk in terms of biodiversity. Therefore, mapping of fire zones is of great importance in determining the damage caused by the fire, managing the fire process, and planning the interventions in the fire zone. Although remote sensing is a fast and cost-effective methodology for mapping fire zones, the implementation of the remote sensing methodologies is problematic in some respects. The web-based Google Earth Engine makes possible to access the satellite imagery and process the imagery easily. The research area of this study is Muğla, Turkey in where many forest fires broke out in 2021 summer. This study provides an implementation of normalized burn ratio which is widely used to highlight burned areas on Google Earth Engine platform. Both vector data and satellite images were used in the study. The vector data is in the shape file format and was uploaded to the Google Earth Engine platform as a table. The Sentinel-2 imagery was used to calculate normalized burn ratio. The satellite imagery was clipped using the table data. The difference pre-fire and post-fire images was calculated, and the classes were assigned to the pixels according to the normalized burn ratio ranges. The study indicates that finding the burned areas and constructing the burn severity levels can be realized in 1.32 minutes on Google Earth Engine platform.

Keywords: Burn Ratio, Forest Fire, Burn Severity, Remote Sensing

1. Introduction

Forests are considered as one of the primary sources of biodiversity. Forest fires caused by various reasons pose a high risk in terms of biodiversity. Mapping fire zones is of great importance in determining the damage caused by the fire, managing the fire process, and planning the interventions in the fire zone. Remote sensing is a fast and cost-effective methodology and can be used very effectively for mapping fire zones. However, the implementation of the remote sensing methodologies is problematic in some respects. Satellite images are enormous. Accessing data is not very simple. Processing, interpreting, and transforming data into information are time-consuming processes. Google Earth Engine (GEE) is a web-based geospatial processing service and platform that hosts satellite imagery. GEE makes the satellite imagery available for global-scale data mining. Forest and water coverage, land-use change can be analyzed, and the health of agricultural fields can be assessed with tools available on the GEE platform. It is possible to connect to the GEE services using the APIs provided by the platform. Complex geospatial analyses can be translated to GEE requests by client libraries for JavaScript and Python [1]. The GEE platform makes it easy to access high-performance computing resources for processing huge geospatial datasets. It is possible to produce systematic data products on the GEE platform. The developed algorithms can be embedded into the interactive applications on the GEE platform.

1.1. Studies with GEE Platform

In the literature, there are different academic studies on remote sensing carried out using GEE. Singh et al. generated a new index for detecting crop water stress condition to schedule the irrigation in real time. The real time analysis for crop water stress index in the study area has been realized using the GEE code editor platform. The authors indicated that GEE provides a very good platform for such research [2]. Dwivedi et al. developed an online web-based application to map and monitor flood in real time on GEE platform. The Authors indicated that the GEE platform provides an excellent environment for near real time satellite data monitoring [3]. Mutanga and Kumar indicated that the GEE platform had been used in several subjects, including vegetation monitoring, cropland mapping, ecosystem assessment, and gross primary productivity. The authors stated that the GEE platform is an excellent step in solving environmental problems affecting the earth since it has the power to handle huge data sets at various scales and building automated programs [4]. Kennedy et al. introduced the LandTrendr algorithm for the GEE platform. The authors indicated that the GEE platform simplifies pre-processing steps, allowing focus on the translation of the core temporal algorithm [5]. Mateo-García et al. presented a cloud detection and removal methodology implemented in the GEE platform. The authors stated that access to the complete satellite image archive is hard, and the required computational power is relatively high. However, these challenges can be overcome using the GEE platform [6]. Wang et al. indicated that by April 2018, 239 GEE-related studies had been published. These studies cover a wide spectrum of science domains, such as forest, rangeland, water, ecosystem, biodiversity, climate, temperature, wetland, soil, agriculture, land use, land cover, hazard, urban, health, and human activity. According to this paper, researchers studying forests took the lead in utilizing the GEE platform [7].

1.2. Determination Forest Fires and Burned Areas

Since the forest is one of the most widely studied topics in the GEE platform, this study also focused on determining of forest fires and burned areas using the GEE platform. Remote sensing is an efficient way to detect burned areas since the Earth observation satellites provide timely regional and global coverage of fire occurrence. Fire impacts on vegetation may vary depending on the type of fire, the behavior of fire, and the time between post-fire and image acquisition. Therefore, both post-fire and temporal changes in spectral behavior should be analyzed in order to understand the fire impacts. On the other hand, post-fire changes should be monitored in order to understand regeneration patterns. This review paper indicates that the near-infrared (NIR) and shortwave infrared (SWIR) spectral regions are sensitive to fire effects. The normalized vegetation index (NDVI) can be used to estimate three levels of burn severity. Since this index provides little sensitivity, particularly in tropical ecosystems, several different methodologies, such as the global environmental monitoring index (GEMI) and the burned area index (BAI), have been developed in the following years [8]. Elhag et al. used principal component analysis (PCA) on the before fire image, then they created a multi-temporal image from several bands of before and after images, including NDVI, to improve the quality of the results. Finally, they compared the results with data provided by the local forest service to evaluate their methodology's quality. According to the evaluation, the multi-temporal PCA outputs, including NDVI, improve accuracy [9]. Next, Polychronaki and Gitas developed a classification procedure for burned area mapping. The authors used Système pour l'Observation de la Terre (SPOT)-4 HRVIR images in this object-based classification environment. They used NIR, SWIR bands to detect the burned areas and the water bodies using normalized burn ratio (NBR). According to the results, they achieved very high classification accuracies [10].

1.3. Burned Area Maps, Burn Severity Maps

The fundamental requirement for modeling the impact of forest fires on the ecosystem are burned area maps and burn severity maps. Today one of the most critical information about the fires is the type of the fire, such as agricultural maintenance fires, land cover conversion fires, and wildland forest fires. To better understand fire effects at multiple spatial and temporal scales, the fire ecology and remote sensing communities should provide more collaborative work. The burned areas can be classified according to the burn severity. This classification helps researchers to understand the degree to which an ecosystem has changed [11].

1.3.1. Normalized Burn Ratio (NBR)

NBR is widely used in order to highlight burned areas in large fire zones [12]. NBR formulas combine the use of both NIR and SWIR wavelengths. According to the spectral response curves graphics (Figure 1), high reflectance in the NIR indicates healthy vegetation, whereas low reflectance indicates burned areas. When it comes to SWIR, low reflectance indicates healthy vegetation, whereas high reflectance indicates burned areas. NBR uses the ratio between NIR and SWIR bands, as in (1).

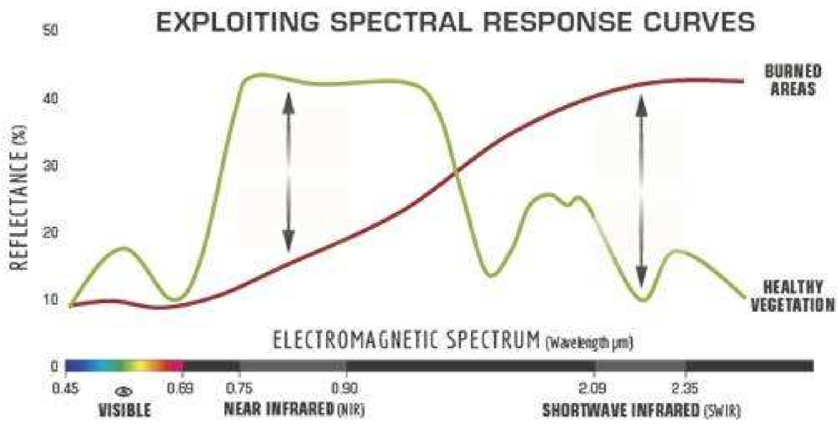

Figure 1. *Spectral response of healthy vegetation and burned areas (U.S. Forest Service).*

$$NBR = (NIR-SWIR) / (NIR + SWIR) \quad (1)$$

1.3.2. Burn Severity

The difference between pre-fire and post-fire NBR is used to calculate the delta NBR (dNBR) as in (2). dNBR can be used to estimate the burn severity. Although there are different burn severity classifications in the literature, the most widely used is the one provided by the U.S. Geological Survey [13]. Figure 2 shows the burn severity levels of the U.S. Geological Survey. These levels can be used to interpret the burn severity.

$$dNBR = PrefireNBR - PostfireNBR \quad (2)$$

Severity Level	dNBR Range (scaled by 10^3)	dNBR Range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251	-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101	-0.250 to -0.101
Unburned	-100 to +99	-0.100 to +0.99
Low Severity	+100 to +269	+0.100 to +0.269
Moderate-low Severity	+270 to +439	+0.270 to +0.439
Miderate-high Severity	+440 to +659	+0.440 to +0.659
High Severity	+660 to +1300	+0.660 to +1.300

Figure 2. *Burn severity levels (U.S. Geological Survey).*

2. Study Area

2.1. Study Area

The research area was selected as the burned forest area in Muğla, Turkey, in 2021. Many forest fires broke out in different locations in Muğla, Turkey, in the summer of 2021. Hundreds of hectares of land were destroyed in the forest fires. This study aims to display the damage caused by forest fires on satellite images.

2.2. Data Sets Used

In this study, both vector data and satellite images were used. The political map of Muğla, Turkey, was obtained from the Ministry of National Defense General Directorate of Mapping [14]. The data set was downloaded in shapefile format. The data set includes all Turkey data. First, the data set was updated to cover the provincial borders of Muğla, as shown in Figure 3.

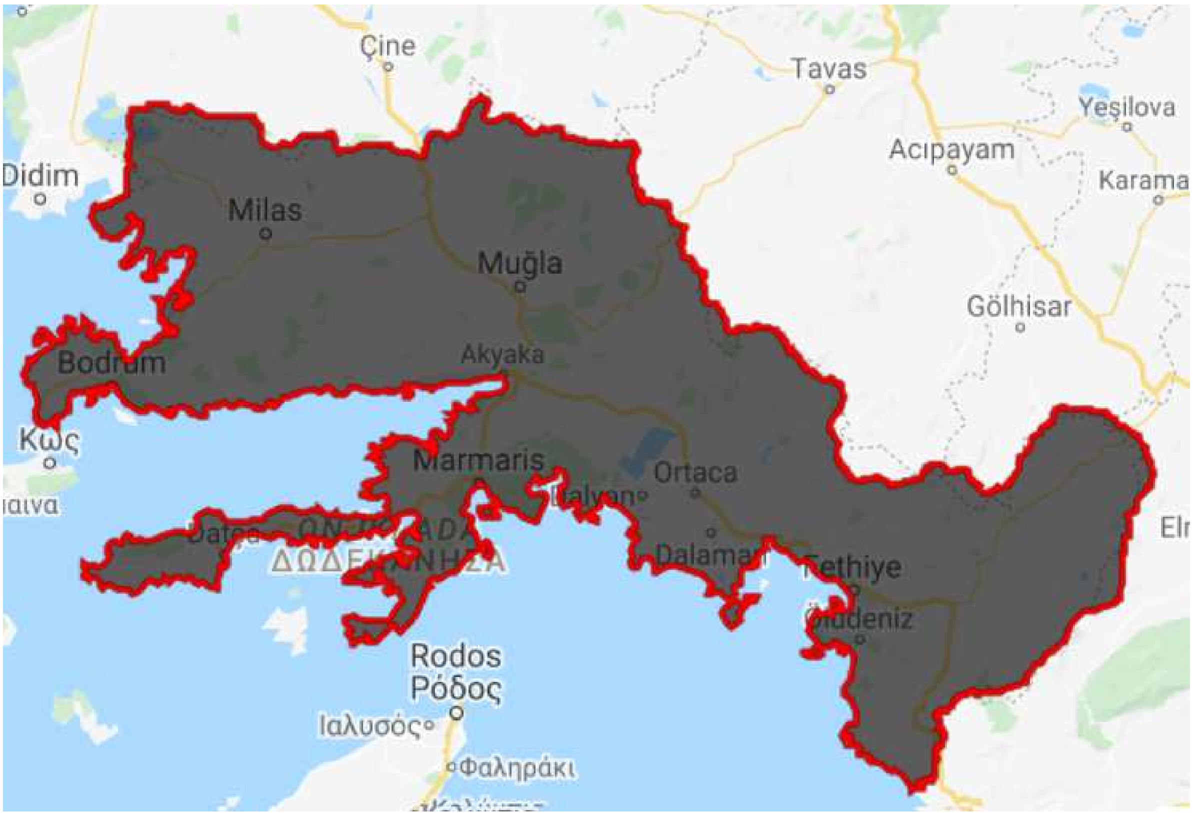

Figure 3. *The vector data of Muğla, Turkey.*

In this study, Sentinel-2 satellite imagery was used to calculate NBR. Two Sentinel-2 images from 2020 and 2021 were used. These images have been cropped according to the region of interest. Figure 4 shows the pre-fire and post-fire true-color images.

Figure 4. *Pre-fire and post-fire images of the region of interest.*

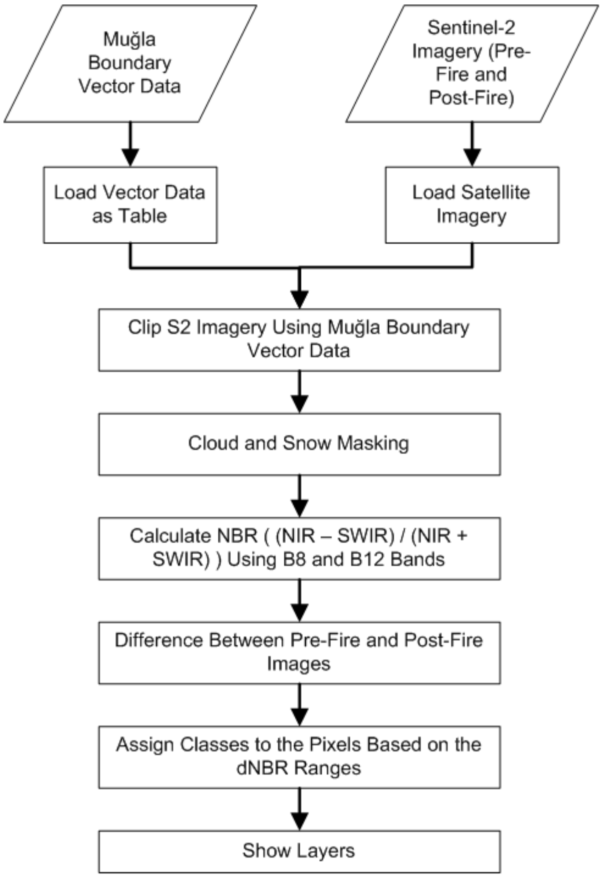

Figure 5. *Flow chart of the implementation.*

3. Methodology

Figure 5 gives the flow chart of the implementation.

First of all, the Muğla boundary vector data file has been uploaded to the Google Cloud Platform. Then, the shapefiles can be imported to the Google Earth Engine platform as table data. Since the boundary vector file is in shapefile format, the table data structure was used in this study. Once the data is uploaded to the platform, it can be accessed directly in the engine code editor. The boundary shapefile indicates the region of interest in this study. In the second step, Sentinel-2 imagery was searched for 2020 and 2021. The satellite imageries obtained were cropped using the region of interest. In the third step, the imagery was cleaned using cloud and snow masks using the functions provided by the GEE platform. After this step, the satellite images are ready to process. In the fourth step, NBR was calculated, and then the difference between pre-fire and post-fire images was calculated. These difference values correspond to dNBR ranges and can be classified using the burn severity level ranges. At the final step, the obtained layers can be shown in the GEE platform. Figure 6 shows the classified image.

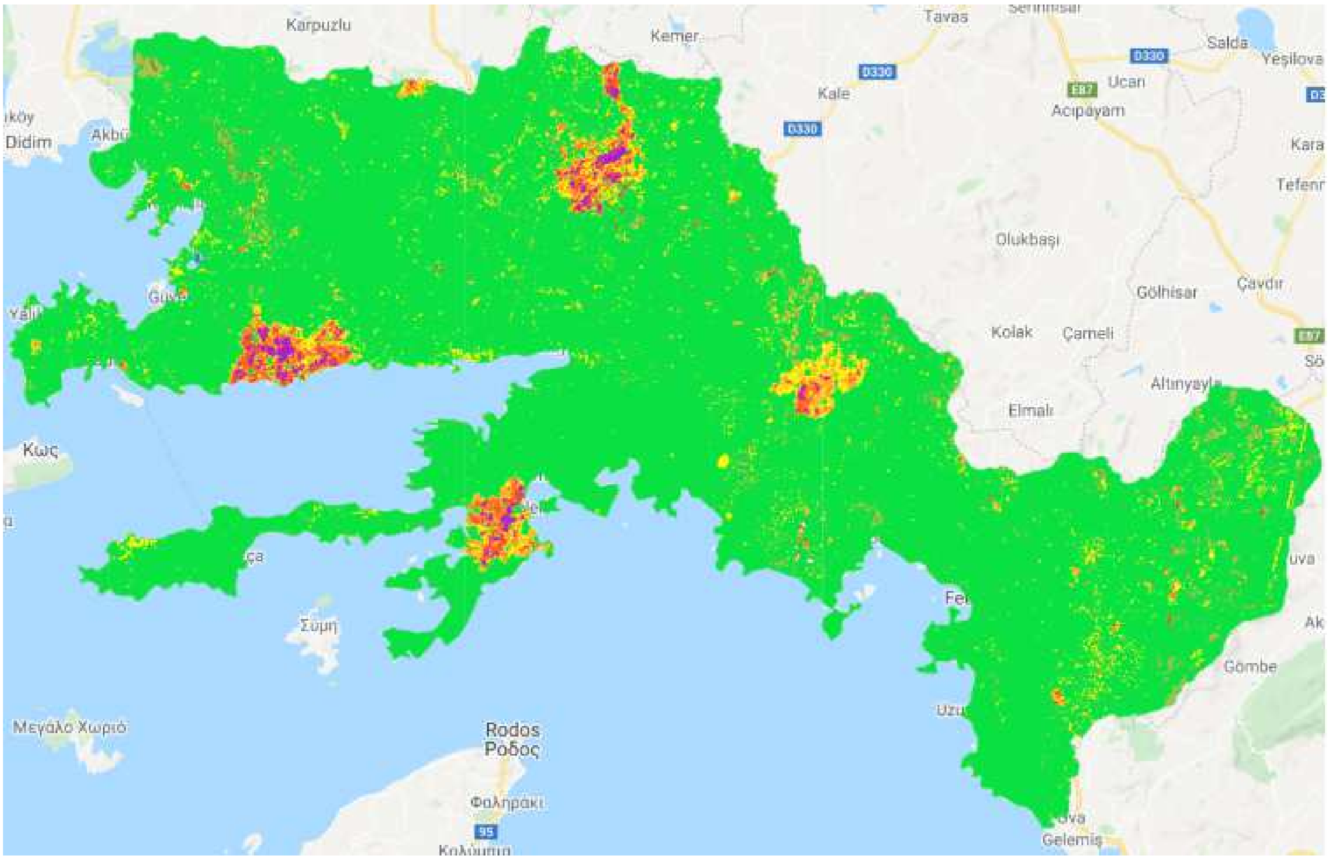

Figure 6. *Classified image according to the burn severity levels.*

4. Results and Discussion

In this study, it is aimed to reveal how the Muğla / Turkey region, which has experienced severe fires recently, was affected by the forest fires by using satellite imagery on the GEE platform. Sentinel-2 imagery was used to achieve this, and the satellite images were cropped using the region of interest. NBR was calculated, and the pixels were classified according to the burn severity levels. Table 1 shows the total area of the different level classes.

Table 1. *The total area of the different level classes.*

Level Class	Area (Hectares)	Percentage
Enhanced Regrowth, High	6657.3	0.74
Enhanced Regrowth, Low	29463.3	3.27
Unburned	759934.62	84.44
Low Severity	65092.68	7.23
Moderate-low Severity	17145.99	1.91
Moderate-high Severity	12701.34	1.41
High Severity	9005.85	1
NA	0.09	0

The method used in this study is a method known in the literature for a long time. This study aims to implement the method on the GEE platform and measure the platform's performance. The execution of the script took about 1.32 minutes. The profiler recorded 66 operations. The first ten operations are shown in Table 2.

Table 2. *The profiler results.*

Compute	Peak Memory	Description
37.943	6.8M	Algorithm Image Collection. mosaic
13.598	7.4M	(plumbing)
7.489	634k	Algorithm (user-defined function)
6.125	12M	Algorithm Image. and computing pixels
3.338	364k	Loading assets: COPERNICUS
2.875	1,000k	Encoding pixels to image
1.073	1.1M	Table query
1.006	1.0M	Reprojection precalculation
0.904	20k	Listing collection
0.79	3.2M	Algorithm Image. updateMask

The highest peak memory (12 megabytes) was needed for computing pixels in the image algorithm, which took less than 7 seconds. The second highest peak memory (7,4 megabytes) was used on plumbing. Finally, the most time-consuming operation was the image mosaic algorithm. Considering the huge size of the satellite images and the costs of the algorithms working on satellite imagery, the completion of all these processes in 1.32 minutes shows that the performance of the GEE platform is at a very high level.

Other studies on remote sensing using the GEE platform also confirm the high performance of the platform. Kennedy et al. implemented the LandTrendr algorithm on the GEE platform. They achieved a high performance compared to other platforms [5]. The authors included six study areas across the U.S. in the study. They concluded that processing and handling imagery for these study areas would take several weeks of person time. When using the GEE platform, these basic operations take almost no time. New study areas can be easily added to the study by adding a few lines of code. While it takes three days to execute the algorithm on a region using traditional methodologies, only 20-40 minutes are required for each region with the GEE platform.

Data management and powerful visualization functions in remote sensing studies are the most challenging operations [15]. These processes, which are of great importance, cause very high time costs. GEE platform offers ready-to-use options, which is essential for non-expert users of satellite imagery.

The GEE platform is also frequently used in studies on the classification of land use/land cover. For example, Pan et al. implemented machine learning algorithms to classify land use/land cover on the GEE platform. According to the authors, the GEE platform makes satellite imagery computing an efficient, flexible, and fast process [16].

5. Conclusion

This study concluded that determining burned areas in near-real-time is possible using the GEE platform. Determination of burned areas and constructing burn area levels provides essential information to the governments to manage the fires, protect ecological balance, and re-green the burned areas.

Using satellite imagery is a very efficient methodology to detect the burned areas and construct the burned severity levels. On the other hand, access to satellite imagery and processing the satellite imagery are very time-consuming processes. The GEE platform is an excellent platform that provides satellite imagery and the required functions to process the imagery.

This study shows that the GEE platform can easily and quickly access large-scale satellite images and produce results by processing the data in a short time.

In further research, it might be possible to include additional parameters, such as wind which affects the fire. In addition, additional parameters can be included in the study to predict the damage to the ecological system in the burned area.

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