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Monitoring the Regeneration Process of Areas Destroyed by Forest Fires Aided by Google Earth Engine

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Abstract

Aim of study: Our world is exposed to forest fires and threatens both natural and human environments. Remote sensing is one of the effective techniques to monitor forest fires. However, accessing and processing data on the field is challenging for researchers as it is costly and time-consuming.

Area of study: In this study, the Mersin-Gülnar fire that happened in 2008 in the Mersin region was investigated.

Materials and methods: Starting from 2000, data from the MODIS satellite images were used to monitor the forest's regeneration process along the forest fire's complete timeline. For this, analyzes were made over 471 Normalized Difference Vegetation Index (NDVI) MODIS satellite data from 2000 until 2020. The analyses were made in Google Earth Engine.

Main results: According to the data processed on the Google Earth Engine platform, the vegetation cover was damaged after the fire. As a result of the examined 471 MODIS images, it was observed that the recovery process of the study area after a forest fire takes an average of 10 years.

Highlights: Remote sensing methodologies and satellite datasets provide powerful functionality for assessing the damage caused by forest fires. This study is an example that the recovery period of forest fires is long, and it brings many difficulties together with other natural events.

Keywords: Google Earth Engine, Remote Sensing, Forest Fire, MODIS, NDVI.

Google Earth Engine ile Orman Yangınları Sonucu Tahrip Olan Alanların Yenilenme Sürecinin İzlenilmesi

Öz

Çalışmanın amacı: Dünyamız devamlı olarak orman yangınlarına maruz kalmakta ve canlıların hem doğal hem de beşeri ortamını tehdit etmektedir. Uzaktan algılama orman yangınlarının değişimini izlemek için etkili tekniklerden birisidir. Ancak, araştırmacılar için, veriye ulaşma, işleme hem maliyetli hem de zaman alıcı işlemlerdir.

Çalışma alanı: Bu çalışmada Mersin-Gülnar bölgesinde 2008 yılında olan orman yangını incelenmiştir.

Materyal ve yöntem: Çalışmada 2000 yılından başlanarak orman yangının tüm zaman çizgisi boyunca ormanın kendini yenileme sürecini izlemek için MODIS uydusunda Normalize Edilmiş Fark Bitki Örtüsü İndeksi (NDVI) veriler kullanılmıştır. Bunun için yangın alanının 2000 yılından başlanarak 2020 yılına kadar toplamda 471 MODIS uydu görüntüsü üzerinde analizler yapılmıştır. Sonuçları elde etmek için Google bulut platformu olan Google Earth Engine kullanılmıştır.

Temel *sonuçlar:* Google Earth Engine platformunda işlenen verilere göre, yangından sonra vejetasyon örtüsü zarar görmüştür. İncelenen 471 MODİS görüntüleri sonucunda, çalışma alanının orman yangınından sonrası iyileşme süreci ortalama olarak 10 yıl gibi geniş bir süreci kapsadığı gözlemlenmiştir.

Araştırma vurguları: Uzaktan algılama metodolojileri ve uydu veri kümeleri, orman yangınlarının neden olduğu zararları değerlendirmek için güçlü işlevler sağlamaktadır. Orman yangınlarının iyileşme sürecinin uzun olması maliyetli olmakla birlikte sebep olduğu diğer doğa olayları ile birlikte birçok zorluğu beraberinde getirmektedir.

Anahtar Kelimeler: Google Earth Engine, Uzaktan Algılama, Orman Yangını, MODIS, NDVI.

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Introduction

Forests are one of the most essential resources for living life. Forests are the basis of ecological balance and the most important shelter for natural life and living creatures. Forest fires destroy millions of hectares of land every year and cause economic damage and a loss of life. Besides, it causes damage such as the destruction of vegetation, damage to animal and plant habitats, and shrinkage of living spaces. Forest fires occur from both natural and human causes. Mapping the area damaged by forest fires is important for evaluating the economic losses and ecological effects caused by the fire, monitoring the land cover changes, and modeling the fire's atmospheric and climatic effects. Reliable and effective monitoring and analysis techniques should be applied to estimate fire's effect on the ecosystem (Li et al., 2003). Remote sensing data and technologies have been widely used for mapping and monitoring areas affected by fires (Matcı & Avdan, 2020; Matcı et al., 2020). Clemente et al. (2009) used 12 year remote sensing data such as Normalized Difference Vegetation Index (NDVI) for monitoring post-fire regeneration in Mediterranean ecosystems. Similar, Twele & Barbosa (2004) used Landsat imagery from 1997-2002 for vegetation regeneration monitoring in France after forest fires. Similarly, other studies have used different satellite sensors for the same purposes (Escuin et al., 2006; Henry & Hope, 1998). However, processing big amount of satellite data can be time-consuming.

Google Earth Engine (GEE) is a significant data source in detecting and mapping web-based remotely sensed images of burnt areas caused by fire. GEE is a web-based interface where remotely sensed images are evaluated. GEE is also a cloud-based platform that facilitates access to both multi-temporal remote sensing big data and high-performance computing resources for processing these datasets. Another great benefit of working with GEE is its cloud computing power. Cloud computing platforms provide open access to data sets and analysis. The availability of large quantities of satellite images requires reducing constraints targeting data sharing among users, reproducibility of scientific results, and particular research problems (Sidhu et al., 2018).

Images obtained from image detection platforms such as GEE web-based Landsat, Sentinel, MODIS, ASTER are processed online with auxiliary scripts. Thanks to the developed cloud system, land use and cover change (Huang et al., 2017), time series analysis (Canty et al., 2020), night light images, etc. can be analyzed. Within the literature research scope, different studies have been examined to determine forest fires and to monitor burnt areas. Vlassova et al. (2014) investigated fire that occurred in the Extremadura region of Spain in 2009 and burned 3000 ha of forest. In the 27 months after the fire, 15 LANDSAT TM satellite images were taken and forest bloom was examined. Forest greenery was observed by calculating the NDVI for each image. Demir (Demir, 2020) used Landsat data to track the trend of fire across the entire timeline during forest fire events in Australia in GEE each month from June 2019 to March 2020. Thus, all images from June-2019 to March-2020 were processed and NDVI and vegetation analysis determined the damaged areas. Taking into consideration the advantages of GEE, in this study, we aim to monitor the rehabilitation period of the forest fires in the Mersin Gülnar region, Turkey, that occurred in 2008. Using remote sensing data within GEE, the study area's vegetation cover was examined during the 2000-2020 period. For this purpose, NDVI time series from MODIS were analyzed. The main objectives of the study are; (i) to investigate the rehabilitation time of the burnt area; (ii) to evaluate the GEE platform for post-fire application; and (iii) to evaluate MODIS data for post-fire time analyses.

Materials and Methods

Study Area

The study is located in the southwest of the Mersin province in the Mediterranean region of Turkey, in the Mersin-Gülnar region. Gülnar is located in the Mediterranean region and it is one of the coastal districts of Mersin (Figure 1). The district is 150 km from the city center, and it is on the Taseli Plateau. It is surrounded by Silifke in the east, Mut in the north, Ermenek in the northwest, Bozyazı-Anamur in the west, and Aydıncık district in the south. It is 950 meters above sea level, and its area is 1769 km^2. The climate in the coastal part of the district is a Mediterranean climate, and in the mountainous areas summers are cool and dry and winters are cold and rainy. Gülnar, like other districts, is mainly composed of forests. Forests cover a large part of the region. Forests are followed by agricultural lands, unused lands, and arid areas.

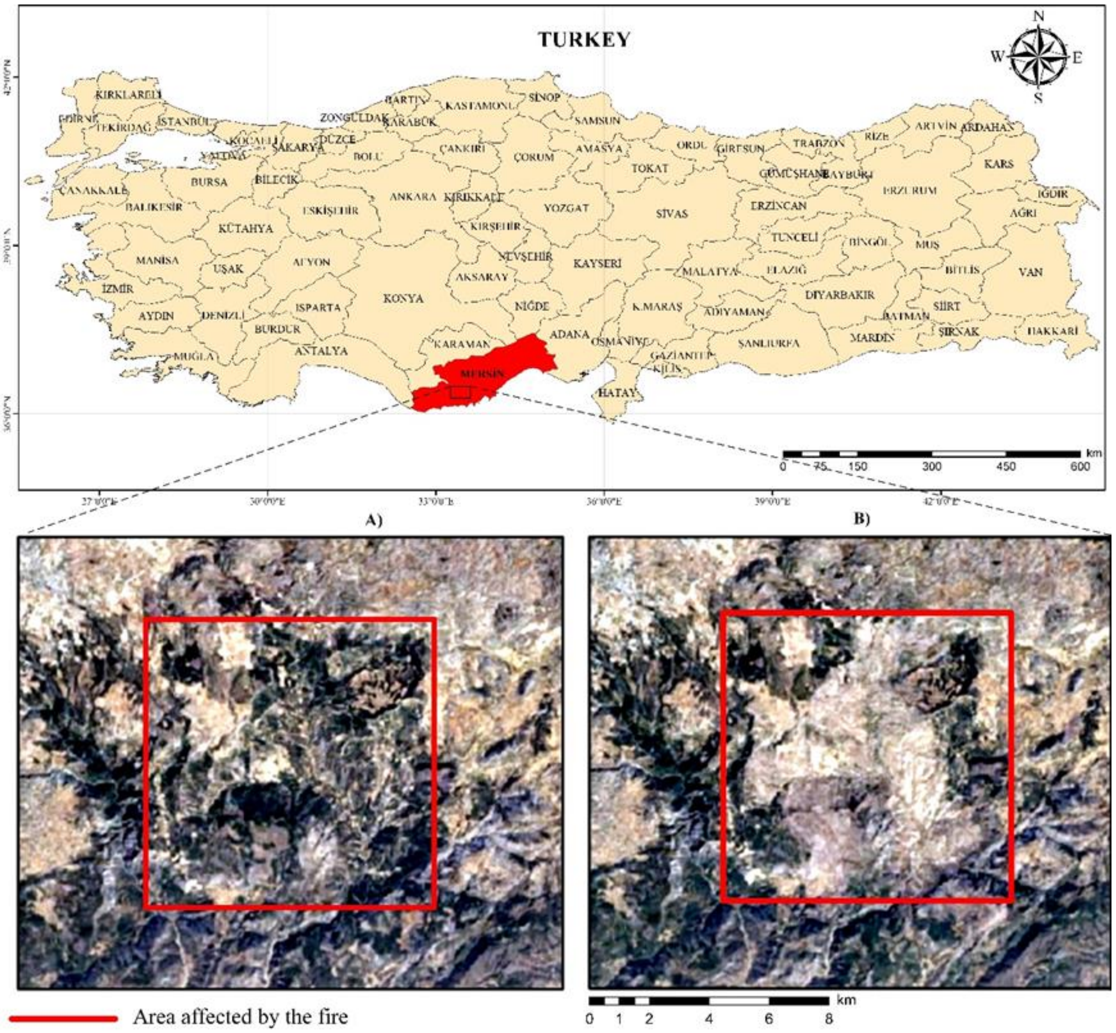

Figure 1. Study area; A) Satellite imagery before the fire (June 2008); B) Satellite imagery after the fire (September 2008).

The Mersin-Gülnar fire started in the village of Kavakoluğu as a result of the negligence of the citizen who burned the residues from the garden cleaning and when the favorable weather conditions for the fire occurred, the surrounding areas were threatened in a short time. The fire started around noon on 7th July, 2008, and it was taken under control after 42 hours. In the area determination after the fire, 5037 ha of land were found to be burned, and the total market value of the trees, the cost of afforestation, and the cost of extinguishing the fire was 22.085.375,34 TL. Also, the Mersin-Gülnar fire is the second biggest fire in our country in 2008. The fire zone consists of mostly young normal high forest and the dominant tree species in the fire area is Pinus brutia. Considering the weather conditions before and during the fire, the wind speed on the day of the fire is 65-70 km / s on average, the wind direction is north, the average relative humidity is 17%, and the highest temperature is 32° C. On the following day, the wind speed is on average 25-30 km / s, the dominant wind direction is north and the average relative humidity is 20% (Avcı & Boz, 2017).

Materials

In this study, the regeneration process of the area destroyed by fire was examined by using satellite images before and after the fire. For this, 471 MODIS MOD13Q1 V6 EVI (Enhanced Vegetation Index) satellite images were used. The data was selected over the fire area starting from 18.02.2000 until 31.10.2020 at intervals of 16 days. MOD13Q1 V6 data provides one vegetation index value per pixel. MOD13Q1 V6 data has two basic bands. The first is NDVI, and the second is EVI. The temporal resolution of these bands is 16 days, and their spatial resolution is 250 meters. In this way, it can produce 23 images throughout the year. The EVI values produced ranged from -2000 to 10000 values. In addition to its high temporal resolution, the MODIS satellite was preferred because it can provide uninterrupted images between the region's dates.

Methods

The study area in this paper, the Mersin-Gülnar fire zone, was monitored to investigate the regeneration process of the damaged forest areas. Various remote sensing techniques are used for damage assessment after the fire. In this study, rather than damage assessment, the time needed for regenerating of the affected areas was investigated. Thus, a large number of satellite images are required. Therefore, GEE cloud platform was used. In this way, the analyzed images were automatically taken from the cloud platform. Considering that the data set has 471 images, this method has provided the study a great convenience in the data acquisition process compared to conventional methods. Since monitoring the NDVI values of the pre-fire zone will act as a guide after the fire, our image analysis was carried out from 2000 until the end of 2020. Considering the satellite platforms, the MODIS satellite, which provides uninterrupted images in these date intervals and whose temporal resolution is sufficient for the application, was chosen. After a visual inspection, statistical analyses were performed in order to investigate the correlation between the healing of the burnt area and the time passes. The flowchart of the used methodology is given in Figure 2.

GEE is a cloud computing platform designed to store and process large data sets for analysis and final decision making. After the Landsat series was released for free in 2008, Google archived all data sets and connected them to the cloud computing engine for open source use. The current data archive includes Geographic Information Systems (GIS) based vector datasets, social, demographic, weather, digital elevation models, and climate data layers, as well as those from other satellites (Mutanga & Kumar, 2019).

The GEE platform provides the opportunity to analyze thousands of computer users simultaneously from the data warehouse located in Google's data centers.

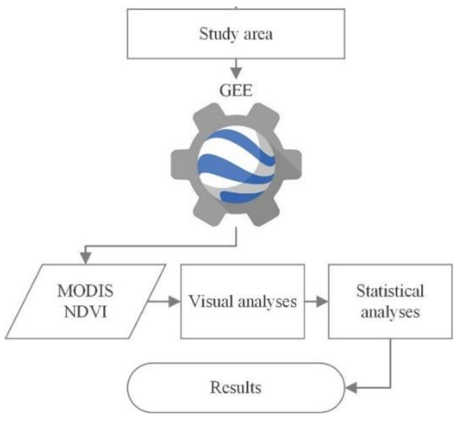

Figure 2. Flowchart of the used methodology

The purpose of the platform is to advance operational approaches to existing scientific studies and strengthen public institutions and civil society's ability to better understand, manage and report the state, and enable this platform to serve the work of scientists and independent researchers. In the last few years, many studies have been conducted using the GEE platform. Although there are some studies related to fire forest and time-series analyses (Demir, 2020; Kaplan, 2020; Long et al., 2019; Parks et al, 2018), to our knowledge, this is the first study investigating the burnt areas rehabilitation time in GEE. Like other studies, in this study, we analyze the NDVI values for the study's main aim. The NDVI is an index calculated from satellite data bands. It gives an approximation of the vitality and density of vegetation in a pixel-based on different intensities of reflected sunlight from the visible (VIS) (0.4-0.7 µm) and near-infrared (NIR) (0.7-1.1 µm) spectrum. While satellite sensors mostly absorb light from the red spectrum (0.63-0.69 µm) using chlorophyll to produce glucose from carbon dioxide and water in the process of photosynthesis, cell walls strongly reflect light from the NIR spectrum. If more light is reflected in the NIR than VIS wavelengths, the pixel is likely to be vegetation with healthy leaves because the plants have already absorbed the light from the red spectrum (VIS). NDVI can also be used as an indicator of photosynthetic activity/capacity. NDVI monitoring can be used to detect vegetation changes. Low NDVI values mean unhealthy, while high NDVI values mean healthy vegetation cover.

The NDVI values from the 471 MODIS images were then used for visual and statistical analyses.

Results

To follow the renewal process of the area damaged in the fire area over the years, analyses were performed on MOD13Q1 V6 NDVI images between 2000 and 2020. As a result of the analyzes, NDVI maps were created every two years between 2004 and 2020. In the maps' visual observations, the maps between 2004 and 2006 are taken as reference as the normal NDVI value of the region (Figure 3). The visual analyses showed that the regeneration of the study area's vegetation cover is noticeable after 2014.

The NDVI MODIS satellite images are integrated into GEE as a separate product, and its values range from -2000 to +10000. The data analyses showed that the average NDVI values ın the study area before the fıre is 4,643.89. Thus, NDVI values between 4,500 and 4,800 are considered normal due to the differences in seasonal events (Yıldız et al., 2016) (Figure 4-A).

When we examine the year when the fire occurred, 2008, the NDVI values until the date of the fire show the same values as the previous years, but as can be seen in the graph, after the 177th day, the NDVI values decrease to an average of 2,487 for the study area (Figure 4-B).

To see the effect of fire and its regeneration process from a broader perspective, the average NDVI values by years were examined.

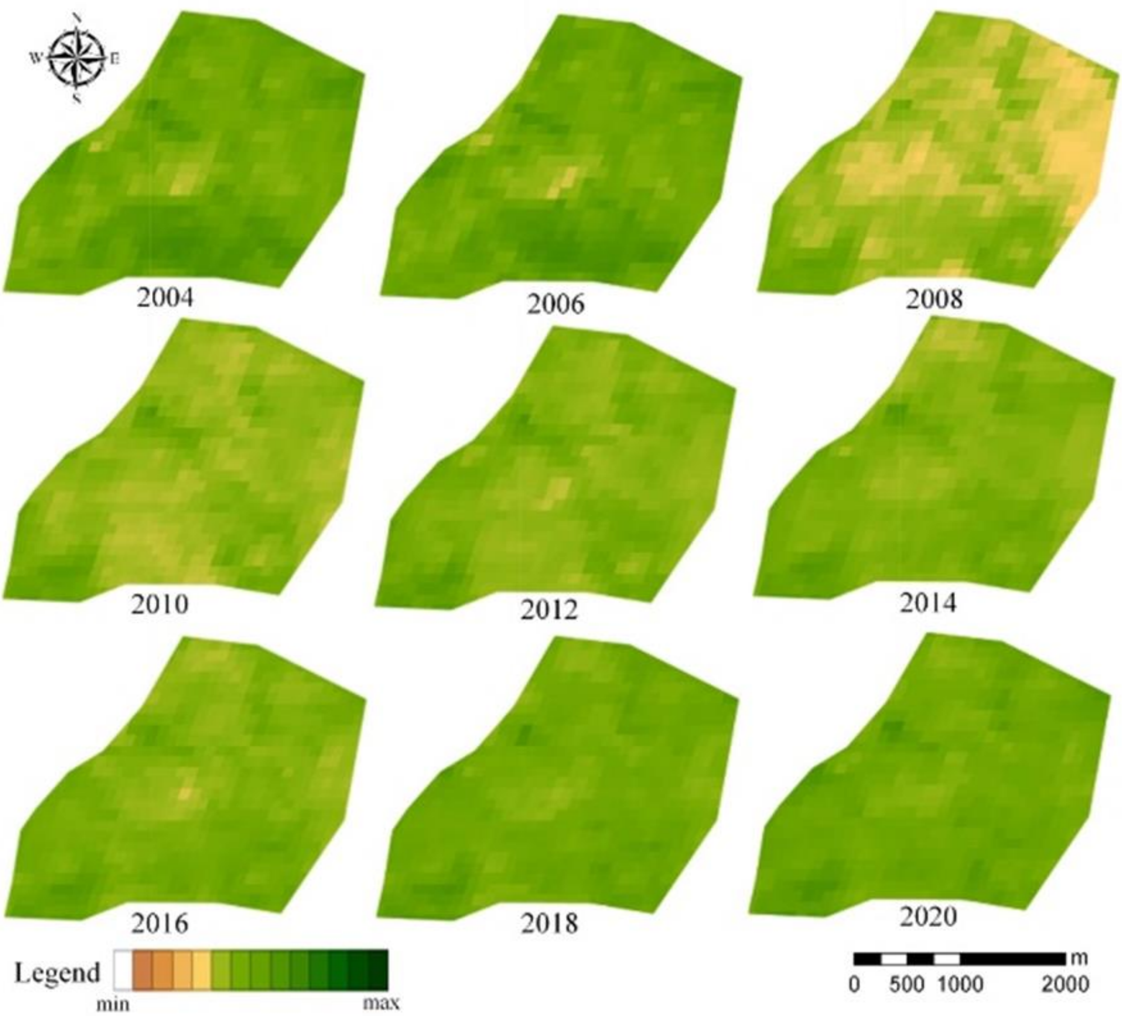

Figure 3. NDVI Maps pre and post fire

The lowest average NDVI value has been noticed in 2009. This is because the fire took place in July 2008. In other words, the normal course of NDVI values in the period until July 2008 causes the NDVI year average to be higher than 2009. When the NDVI values are examined and evaluated over the years in the study area, it is seen that the closest NDVI value was calculated as 4,643 before the fire was 4,541 NDVI in 2018 (Figure 4-C).

In order to see the fire damage more clearly on the NDVI chart, the average NDVI values in July were examined and the lowest NDVI value was noticed in 2008, the year when the fire occurred (Figure 4-D).

Considering the improvement rate in NDVI values of the study area over the years, it is seen that it has improved with a high correlation rate over the years (R = 0.92). The NDVI value, which was 2.619 in July 2009, increased to 4.051 in July 2020 and approached the pre-fire NDVI values within 11 years (Figure 4-E).

Discussion

Turkey is continuously dealing with challenges when it comes to fires for various reasons. As in other parts of the World, these forest fires cause serious loss of life and property and disrupt the ecological balance in Turkey.

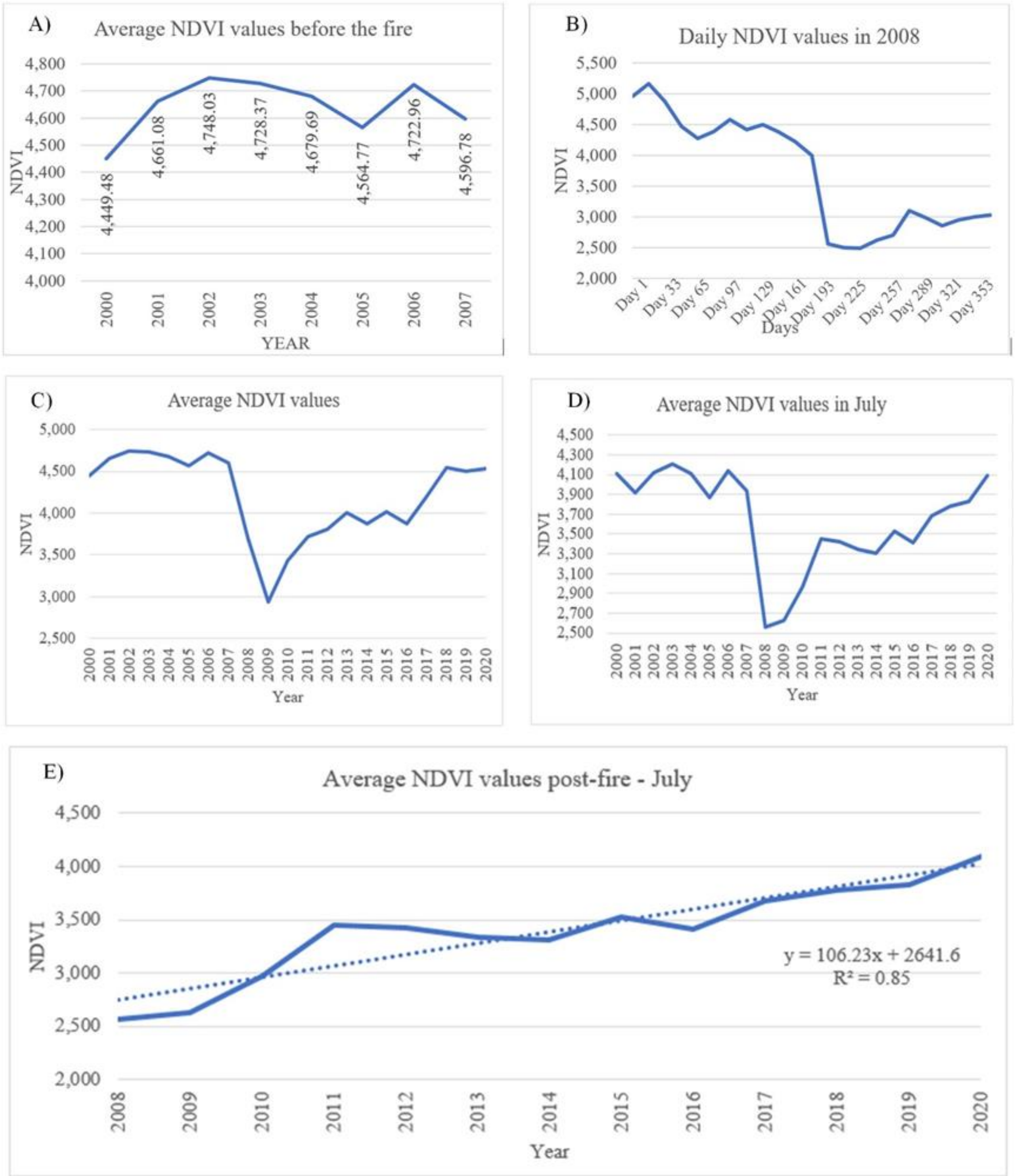

Figure 4. NDVI analyses: A) Pre-fire average NDVI values; B) Daily NDVI values in 2008; C) Average NDVI values 2000 - 2020; D) Average NDVI values in July, 2000 - 2020; E) Post-fire average NDVI values, July, 2008 - 2020.

As it is known, forests are called the lungs of our planet and forest regions' destruction causes multiple interrelated natural events. For example, erosions are the number one natural phenomenon caused by a lack of forest. Likewise, it can be said that the lack of forests indirectly causes the drought caused by the lack of rainfall. We can point to global warming and drought caused by lack of rainfall as one of the most important climate change factors, which has global effects. For this reason, remote sensing methodologies and satellite datasets provide powerful functions for evaluating the damage caused by forest fires. Two important factors for efficient monitoring are the availability of datasets and software packages. The methodology used in this study is based on open access data sets and GEE, an open-access cloud-based remote sensing data analysis platform. Without the aid of GEE, in order to perform the analyses in this study, a significant amount of time would have been needed as we used 471 MODIS images within GEE. For instance, several authors used remote sensing imagery from different sensors to monitor the regeneration of the areas affected by fires (Ireland & Petropoulos, 2015; Meng et al, 2015). Twele & Barbosa (2004) used eleven Landsat images and similar to this study, showed that the area recovered faster in the first years after the fire. Riaño et al. (2002) used AVIRIS images for twenty-year monitoring of two fires. Similar to this study, Viana-Soto et al. (2017) used NDVI values to estimate the regeneration period of burnt areas. Their study evaluated two different forest types, which can be considered for future studies using GEE. From this point of view, GEE has proven to be very practical in analyzing a huge amount of data, in the given case, for monitoring regenerating of burnt areas. Future work could focus on determining the damage caused by forest fires on a global scale. In this study, the post-fire regeneration process of Mersin-Gülnar region, which was affected by the forest fire, was monitored with MODIS satellite data. It has been observed that the recovery process of the study area after the forest fire covers a wide period of more than 10 years. For this reason, although the long recovery period of forest fires is costly, it brings many difficulties together with other natural events. Therefore, it is important to take all kinds of precautions to prevent forest fires and to raise awareness and raise awareness about forest fires for people using forest areas. Although according to the results there is a significantly high correlation between the average NDVI value and the years, it should be mentioned that the regeneration process is usually sped up by the authorities with afforestation. The findings in this study can also be useful for detecting burnt areas in unreachable locations and determining the time of the fire for unknown or undetected fires. For future studies, we also recommend investigating other fires and different forest types using the same or improved methodology.

Conclusion

In the presented study, the regeneration of burnet areas was investigated using remote sensing satellite imagery from the satellite MODIS within the GEE platform. For that purpose, we used 471 satellite images and analyzed the NDVI values pre- and post-fire. As a case study, the fire that occurred in the Mersin province in 2008 was investigated. The fire damaged more than 5000 ha of forest, and it was one of Turkey's biggest fires that year. The results showed that, although the vegetation cover in the study area is still not fully recovered, the NDVI values appeared to be close to the one before the fire after 11 years. In comparison with conventional remote sensing techniques, this study has proven that the use of GEE can be significant in both time and cost preserving. For future studies, we recommend investigating other fires using data integrated into GEE.

Ethics Committee Approval

N/A

Peer-review

Externally peer-reviewed.

Author Contributions

Conceptualization: A.G., K.B., F.B., G.K., Investigation: A.G., K.B., F.B.; Material and Methodology: A.G., K.B., F.B.; Supervision: G.K.; Visualization: A.G., K.B., F.B., G.K.; Writing-Original Draft: A.G., K.B., F.B.; Writing-review & Editing: G.K.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare.

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