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NDVI Analysis of Australian Bushfires with Cloud Computing

Bulut Tabanlı Hesaplama ile Avustralya Orman Yangınlarının NDVI Analizi

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Abstract

Our planet is constantly exposed to massive forest fires, which threaten the natural ecosystem. Determining damages of forest fires has been a subject of extensive research for many years. Remote sensing is one of the effective technologies used for monitoring forest fires. However, accessing and processing data are both costly and time consuming. Therefore, the use of cloud technologies for this purpose is beneficial for rapid response. Australia experienced a series of wildfires from June 2019 to February 2020. These fires are considered as one of the biggest disasters of our age. In our study, Landsat data was used to track the trend of fires across the entire timeline during forest fire events. The Google cloud platform Google Earth Engine was used to obtain the results. Landsat 8 images were processed for each month from June 2019 to March 2020. Landsat 5 images were used to eliminate the clouds. Thus, from June-2019 to March-2020, all images were processed and the damaged areas were determined by NDVI and vegetation analysis. The forest cover reference data of previous years were used for the NDVI threshold value in the study.

Keywords: *Remote sensing, Forest fire, Google Earth Engine*

Özet

Gezegenimiz sürekli olarak büyük orman yangınlarına maruz kalmakta ve bu da doğal ekosistemi tehdit etmektedir. Orman yangınlarının zararlarının belirlenmesi uzun yıllardır geniş bir araştırma konusu olmuştur. Uzaktan algılama, orman yangınlarını izlemek için etkili teknolojilerden biridir. Fakat veriye ulaşma, işleme hem maliyetli hem de zaman alıcı işlemlerdir. Bu yüzden bulut teknolojilerinin bu amaçla kullanımı hızlı müdahale için faydalı olmaktadır. Avustralya, Haziran 2019'dan Şubat 2020'ye kadar bir dizi orman yangını yaşamıştır. Bu yangın dizisi çağımızın en büyük felaketlerinden birisi olarak gösterilmektedir. Çalışmamızda, orman yangını olayları sırasında tüm zaman çizgisi boyunca yangının eğilimini izlemek için Landsat verileri kullanılmıştır. Sonuçları elde etmek için Google bulut platformu Google Earth Engine kullanılmıştır. Haziran 2019'dan Mart 2020'ye kadar olan görüntüler her ay için Landsat 8 TOA görüntüleri işlenmiştir. Bulutların elemine edilmesi için de Landsat 5 görüntülerinden faydalanılmıştır. Böylece, Haziran-2019'dan Mart-2020'ye kadar tüm görüntüler işlenerek NDVI ve bitki örtüsü analizi ile hasar gören bölgeler belirlenmiştir. Çalışmada NDVI eşik değeri için geçmiş yıllara ait orman örtüsü referans verisi kullanılmıştır.

Anahtar kelimeler: *Uzaktan algılama, Orman yangını, Google Earth Engine*

1. Introduction

Australia suffered a series of bushfires from June 2019 up to February 2020, and still continuing. Australia has been facing with such disasters starting from the first cases reported in the 17^{th} century. The recent fire caused the destruction of ca. 110,000 sq.km forest area with ca.6000 buildings, killing at least 34 people (Wikipedia, 2020). The forest cover of Australia includes various types of vegetation, including acacia, callitris, casuarina, eucalypt mallee, woodland, mangrove, melaleuca, rainforest and other native forests (Australian Government, 2019). Remote sensing is one of the efficient technologies used to monitor the wildfires.

The literature reports studies that use active or passive remote sensing datasets to identify the effects of the fires by reporting the total amount of the burned areas, forest types etc. Allison et al. (2016) presented a detailed review on optical and thermal remote sensing for wildfire detection and monitoring. They point the importance of the remote sensing with use of several types of sensors, such as Hyper-spectral cameras, image intensifiers and thermal cameras. Leblon (2001) summarized the studies that used remote sensing to monitor forest wildfire. His review is based on active and passive remote sensing methods, including NOAA-AVHRR NDVI images. Chuvieco and Congalton (1989) derived a forest fire hazard map using Landsat Thematic Mapper datasets. Sunar and Özkan (2001) analyzed the forest fire occurred in the Marmaris province of Muğla in July 1996 using Landsat Thematic Mapper dataset. Akther and Hassan (2011) evaluated several sensors for predicting the fire danger conditions over boreal forest regions of Alberta during the period 2006-2008 with use of surface temperature (TS), normalized multiband drought index (NMDI) and temperature vegetation wetness index (TVWI) measures.

The burned and fire-affected forest areas are identified with several measures, including the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), normalized burn ratio (NBR), integrated forest index (IFI) (Chen et al., 2011) etc. The enhanced vegetation index (EVI) is a measure that uses the atmospheric resistance coefficients, red bands, infrared bands and canopy background parameter to quantify vegetation greenness (USGS, 2020). This index was previously used to identify vegetation health (Amalo et al. 2018; Ambika and Mishra, 2019), environmental impacts (Xiao et al. 2003; Zhang et al. 2016) and also damage caused by forest fires (Caccamo et al. 2015; Chen et al. 2011; Wittenberg et al. 2007). Another measure, normalized burn ratio (NBR), is also highly mentioned and has been used in the previous literature to investigate damages caused by the forest fires.

Illera et al. (1996) analyzed temporal Normalized Difference Vegetation Index (NDVI) values derived from the Advanced Very High Resolution Radiometer (AVHRR) to assess the fire risk over forest areas. Matricardi et al. (2010) identified the impact of forest fires on natural forests from the southern Brazilian Amazon state of Mato Grosso by using a 13-year series of annual Landsat images. Zhu et al. (2012) analyzed Landsat 7 datasets to monitor the damages caused by the forest fires on a Savannah River site.

Detecting the vegetation from NDVI needs some thresholds and researchers apply different variants to achieve the most reliable results (Remmel and Perera, 2001). Escuin et al. (2008) utilized statistical analysis to determine the thresholds from the pixel values of the group of fires. Fernández et al. (1997) emphasized the importance of the study area and the used kernel sizes in the determination of the thresholds. Parto et al. (2020) proposed a series of thresholds to detect the level of fire damage based on MODIS dataset. Enhanced vegetation index is another measure, which is sensitive to the leaf area index (Chen et al. 2011).

Previous studies showed that damage detection mostly relied on NDVI changes and risk modeling was conducted with other indices. In this study, Landsat datasets acquired during the bushfire events is used to monitor the fire trends through a specific timeline. We use Google Earth Engine, a Google Cloud Computing Platform, to derive the results. Because Google Earth Engine provides quick access to its rich geospatial data catalog, and tools for algorithm implementations in JavaScript that saves the hardware and software costs for the users. The literature reported studies that used GEE for forest fire monitoring, including fire severity metrics (Daldegan et al. 2019; Parks et al. 2018) and assessment of fire damages (Liu et al. 2020; Long et al. 2019; Quintero et al. 2019). We calculate NDVI along the given timeline without any empirically selected thresholds. Our method estimates the threshold used to derive the vegetation areas by using the data collected from the field before the fire event. The objective of our study is to investigate the change in the vegetation cover using the NDVI values of Landsat 8 Top of Atmosphere dataset with the use of Google Earth Engine platform.

2. Materials and Methods

The study area is defined as the whole Australia. The used data are obtained from Google Earth Engine USGS Landsat 8 Collection 1 Tier 1 TOA Reflectance catalog. The NDVI values are calculated using the red and near-infrared bands. The images are directly loaded with JavaScript codes and analyzed accordingly. Normalized difference vegetation index is a common measure used to identify the vegetation cover and also their health. In this study, the change in the vegetation cover during the bushfire period is used to assess the effect of the fire. The images acquired from June 2019 to March 2020 (a total of 10 images) are processed accordingly for each month, and respective NDVI and vegetation land cover regions, which are mainly bushes, are detected. The methodology is shown in Figure 1.

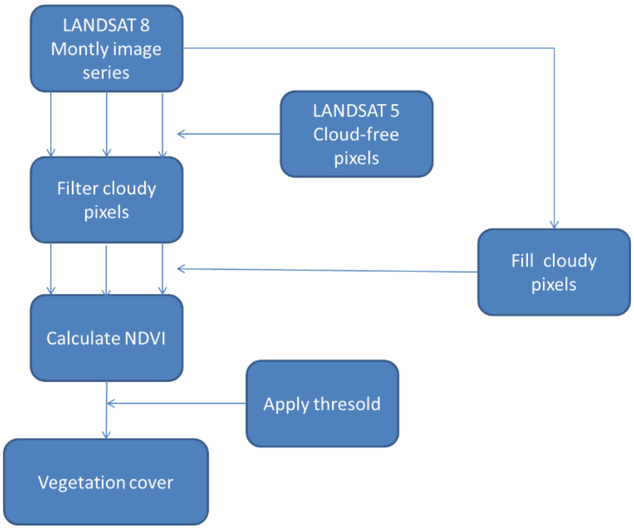


Figure 1. Method workflow

The method starts by loading images from Google Earth Engine Landsat 8 Catalog. The cloudy pixels are filtered out using Landsat 5 images acquired in 2012. For the elimination of the pixels with clouds, the cloud-free Landsat 5 datasets were used. The difference value between Landsat 5 and Landsat 8 images was calculated. The difference value which is larger than a certain threshold in the blue band gave the pixels which contain the clouds (Karpov, 2017). The cloudy pixels are filled with three different methods, including mosaicking, calculation of the mean and calculation of the median values of all images within the analyzed month. Vegetation cover is sensitive to NDVI values. Index values above zero indicates any type of vegetation. The aim of this study is to identify the changes in main forest cover, not any other low vegetation like grass. A reference dataset provided from the Australian Government is used to estimate the threshold value. This dataset includes all information about the forest types in Australia. This dataset is in grid format and shown in Figure 2.

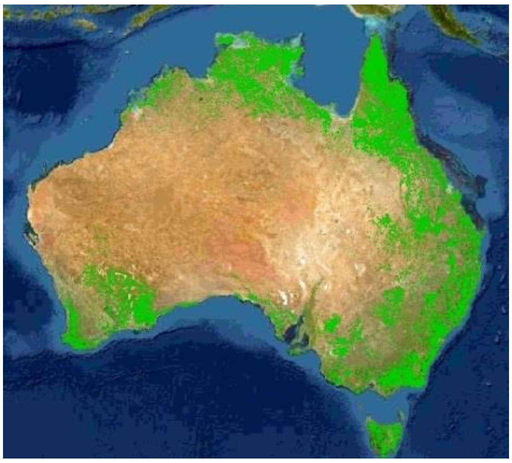
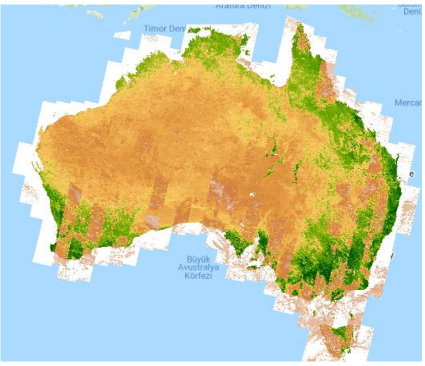


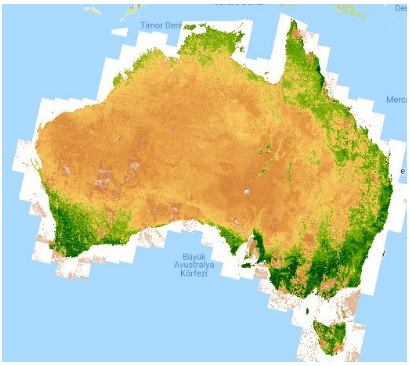
Figure 2. The forest cover of Australia in 2018 (Australian Government, 2019)

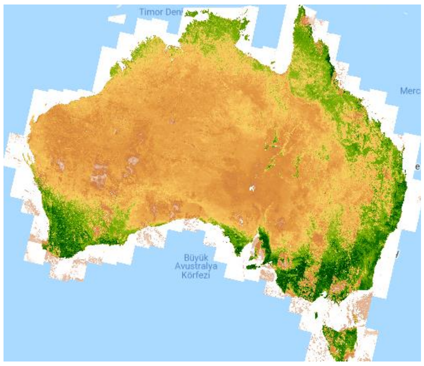
According to the Australian Government Report, the forests covered an area of 134,037,200 ha in 2018. Here, we calculate the NDVI of the June 2018, and estimated the threshold value to identify the vegetation cover. The threshold value of 0.150884999 is found to give the most accurate value (i.e. 134,037,436 ha) for the total forest covered area of June 2018. Then, we use this selected threshold to monitor and calculate the vegetation coverage throughout the selected timeline, from June 2019 to February 2020.

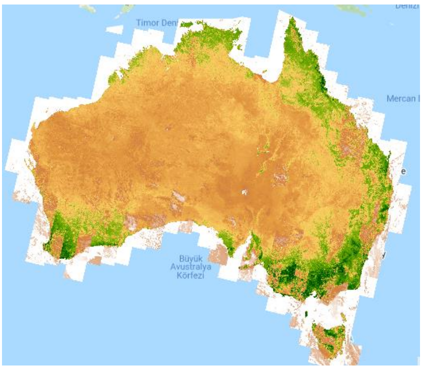
3. Results

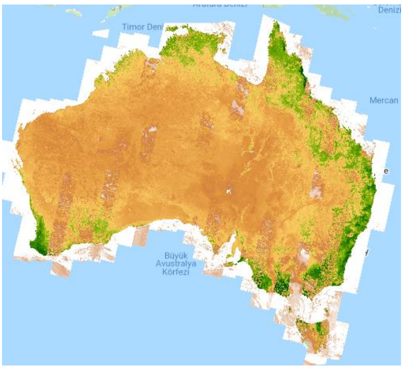
The change in the forest area is monitored through the NDVI values calculated from June 2019 to February 2020. The calculated NDVI images are shown in Figure 3. In this figure, the green color represents the vegetation cover.

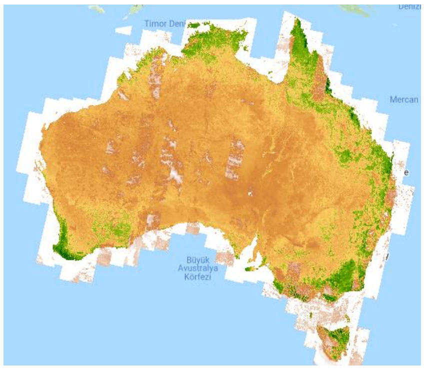

June 2019


July 2019


August 2019


September 2019


October 2019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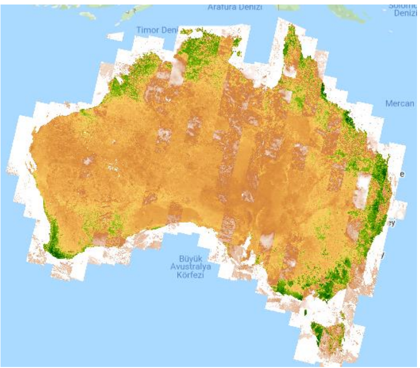
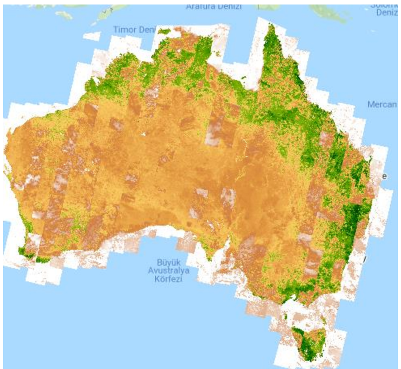

December 2019


January 2020

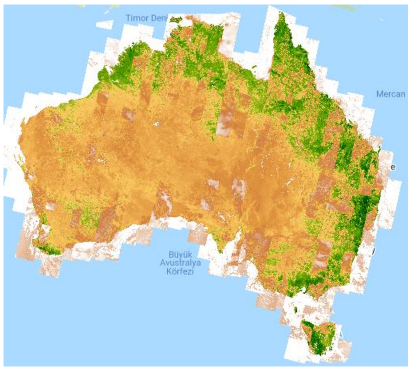

February 2020

Figure 3. The NDVI images for the timeline between June 2019 and February 2020, green: vegetation cover

After applying the selected threshold, the areas covered by forests are calculated and shown in Table 1. The graph of the change in forested areas is shown in Figure 4.

Table 1. Total forest areas estimated from NDVI Analysis (1000 ha)

Month/Method	Mosaicing	Use of Mean	Use of Median
June 2019	171301	146042	156419
July 2019	182697	167964	175030
August 2019	198711	179303	187481
September 2019	195057	195314	202000
October 2019	187259	177212	186352
November 2019	170370	152604	166417
December 2019	148678	137358	149730
January 2020	114755	92216	104631
February 2020	162376	186341	202826

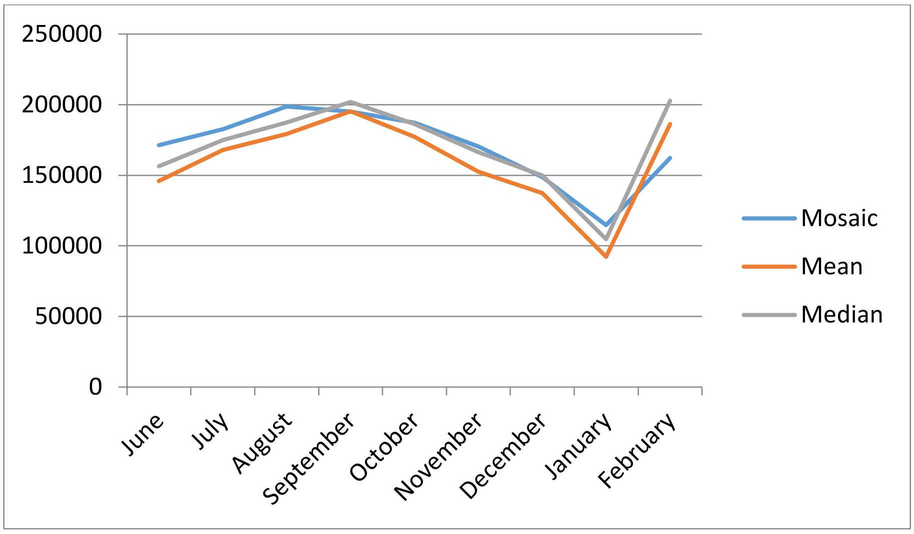


Figure 4. Total areas of estimated high vegetation cover (1000 ha) from three different criteria

As shown in Figures 3 and 4, the forestry cover changed dramatically from June to January and the highest peak observed on December 2019. he results show that new vegetation regions are increased from January to February 2020, which is needed to be confirmed with ground-truth validation since it is not discussed in this paper.

4. Discussion

Vegetation cover change studies have already a large portion in the previous remote sensing literature. The state-of-art is already significant, and provides large scale information about the outcomes of the wildfires over forestry. This study investigates the advantages of the Google's Cloud Computing Earth Observation Platform in producing the results in a short span of time with high performance.

The use of GEE allows for

- downloading any satellite image dataset
- processing data without the need of an external software
- the visualization of the data online, and sharing the results with third-parties.

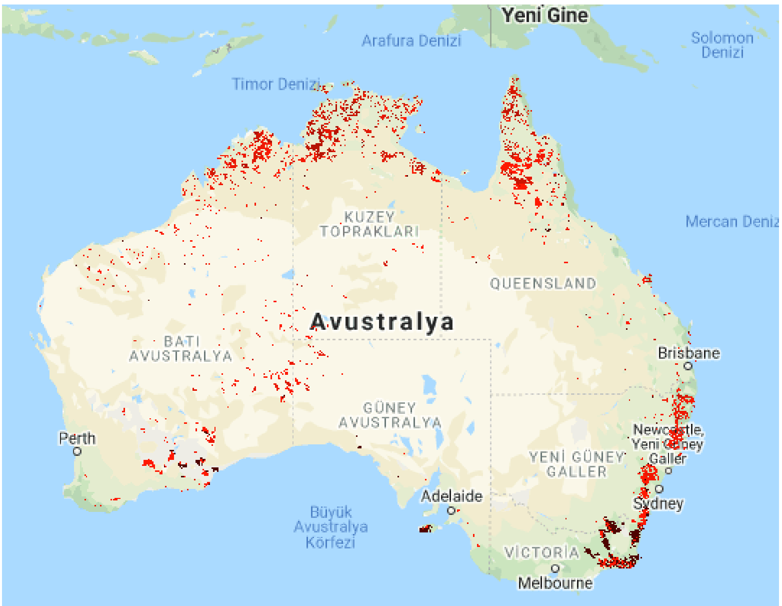


Figure 5. Damaged areas obtained by MODIS-based results

According to the report published by BBC (2020), the total burned area is ca. 110,000 sq.km, the area calculated by subtracting the forest cover binary image of the January 2020 from that of the September 2019 is 103,098 sq.km in our study. This shows the use of GEE gives efficient, quick, and reliable response for forest fire damage assessment. On the other hand, there is a real time bushfire monitoring system provided by Australian Government called 'Australia Sentinel Hotspots', which provides live fire monitoring system with use of AVHRR, MODIS (Figure 5) and VIIRS datasets.

5. Conclusion

Australia has been facing with bushfires regularly happen from past to present. The first fire was reported in 1642 and a huge fire, which is called 'Black Thursday', was reported in 1851 around the region of Virginia. During the 20. Century, Australia also faced with the high-extent forest fires in the years of 1925, 1938 and 1966 (Wikipedia, 2020). A series of bushfire events occurred during the second half of 2019 and beginning of 2020, affecting the whole country. This was reported as one of the biggest disasters that humanity faced in 2020. As presented in this paper, the climate change and other external factors can be investigated with enough available data related to the occurred natural hazards. Remote sensing methodologies and satellite datasets provide powerful functionalities to assess the damages caused by the wildfires. Two important factors for efficient monitoring is the availability of the datasets and the software packages. The methodology used in this study is based on open-access datasets and Google Earth Engine, an open-access cloud-based remote sensing data analysis platform. The future studies may focus on the identification of the damages of the wildfires in global scale.

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