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Study of forest fires according to remote sensing data (on the example of the Chornobyl exclusion zone)

A. Sevruk, *L. Babiy, A. Babushka, B. Chetverikov *(Lviv Polytechnic National University)*

SUMMARY

Remote sensing of the Earth plays an important role in monitoring and assessing the effects of forest fires. With the help of various methods of processing multispectral space images, it is possible to determine the risk of fire spread, identify hot spots and set thermal parameters, map the affected areas and assess the consequences. The aim of the work is to assess the severity associated with the post-fire phase on the example of the forests of the Chornobyl Exclusion Zone. The objectives of the study are to determine the area of burned areas from different time space images obtained from the satellite Sentinel-2 using a normalized burn ratio (NBR). Implemented researches show that the use of remote data of high periodicity and the presence of additional bands of surveying systems significantly expands the range of tasks that can be solved using them. Normalized burned ratio allows quickly and efficiently to identify and calculate the area damaged by fires, that gives possibility operatively assess the consequences of such fires and estimate the damage. It is established that in the studied area the accuracy of area calculation using the normalized burned ratio is 6.7% of the template area, which is sufficient for this type of task.

Keywords: Sentinel-2, remote sensing data, forest fires

Introduction

Fire is one of the most significant causes of disturbance in most plant areas around the world, such as forests and meadows. Fires are a challenge for ecosystem management because they can be both beneficial and harmful. At the same time, current estimates of the extent and consequences of vegetation fires around the world still remain a problem. Remote sensing of the Earth plays an important role in monitoring and assessing the consequences of forest fires. With the help of various methods of multispectral space images processing, it is possible to determine the risk of fire spread, identify hot spots and set thermal parameters, map the affected areas and assess the consequences.

A large number of scientists both in Ukraine and in the world are involved in study of possibility of determining the consequences of fire emergencies using space or aerial images.

In (Burshtynska et al., 2018) the study of forest fires in Arizona, USA was implemented using space images. There is described the determination of fire area and its changes for the period 30.05.-15.06.2011 using methods of unsupervised and supervised classification. Studies (Kumar & Roy, 2018; Pleniou & Koutsias, 2013) are devoted to the analysis of spectral indices in the identification of the burned area on OLI/Landsat-8 satellite images. The indices for images before and after the fire were calculated using the red and near infrared bands: NDVI, MSAVI, SAVI and GEMI, as well as the near and short-wave infrared bands: NBR, BAIMmod and MIRBImod. The difference between the index before and after the fire was also calculated: dNDVI, dMSAVI, dSAVI, dGEMI, dNBR, dBAIMmod and dMIRBImod. From these indexes, the authors created six different compositions (RGB), which were later segmented and classified in an unsupervised manner, and then the area of interest was identified. The results of this classification were confirmed by control data obtained by visual interpretation of the image. The methods showed good classification quality, the best results show dNBR, NBRpost-fire and dMIRBImod indices in RGB composite. Studies (Filipponi, 2018; Quintano et al., 2018) are devoted to the determination of burned areas using the Sentinel-2 satellite. These studies present the recently developed Sentinel-2 burned area index (BAIS2) based on Sentinel-2 spectral bands for detecting burnt areas with a spatial resolution of 20 m. The new index was tested in various studies in Italy on the 2017 fire, and the results show good performance of the index and highlight critical issues related to the processing of Sentinel-2 data.

The object of our research is the Chornobyl Exclusion Zone, on the territory of which powerful fires took place in 2020. The Chornobyl Exclusion Zone is a restricted area that has been heavily contaminated with long-lived radionuclides as a result of the Chernobyl accident. The zone was established in 1986, after the evacuation of the population from the 30-kilometer zone around the station (Figure 1).

Figure 1 *The Chornobyl Exclusion Zone*

The aim of the study is to assess the severity associated with the post-fire phase on the example of the forests of the Chornobyl Exclusion Zone. The objectives of the study are to determine the area of burned areas from different time space images obtained from the satellite Sentinel-2 using a normalized burn ratio (NBR).

Method

The input data for the study are Sentinel-2 satellite images for dates before and after the fire. The images were uploaded from the Copernicus Open Access Hub service and their spatial resolution is 10m for visible and near infrared bands, and 20m for medium infrared bands. The first image obtained before the fires in the Chornobyl Exclusion Zone on April 7, 2020, composited in natural colors is presented in Figure 2, and the second, after the fires on June 26, 2020, in Figure 3.

Figure 2 *Fragment of the Sentinel-2 satellite image composited in natural colours. Date: 07/04/2020*

Figure 3 *Fragment of the Sentinel-2 satellite image composited in natural colours. Date:* 26/06/2020

For the research it was chosen one of the sites in the Chornobyl zone, where the forest was actively burning during the large-scale fires of 2020. Visual assessment of the consequences can be performed on any images, in particular composited in natural colours. However, in order to obtain a quantitative estimation, namely to calculate the area of burned forest area, it is necessary to digitize the damaged areas. If the scale of the fires is significant, then this approach requires a significant amount of time. The process is even more complicated in case when the fire occurred in several sites, each of which must be digitized separately. Obviously, an automated approach is needed for rapid and prompt assessment of fire consequences, which will reduce the time to obtain area determination results without significant loss of accuracy.

In this study, digitization of fire-damaged sites was performed at the test site to obtain template values of areas. This process was performed applying band composition of images with a resolution of 10m

(Figure 4). As a result of counting the areas of all digitized sites, it was established that the area of the territory destroyed by fires is 1223 hectares.

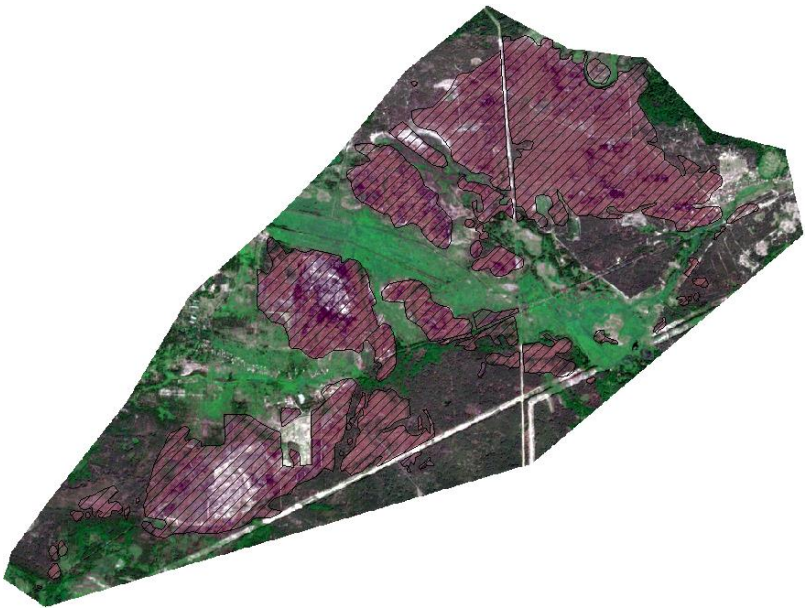

Figure 4 *Digitized areas damaged after fires in the study region.*

Results

The Normalized Burn Ratio (NBR) was used to automatically calculate the area of fire-damaged areas. This index is designed to identify areas where active combustion has taken place, and is calculated by the formula:

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

This index uses near infrared and shortwave infrared bands for calculations. Figure 5 shows the calculated indices for images before (a) and after (b) fires, respectively.

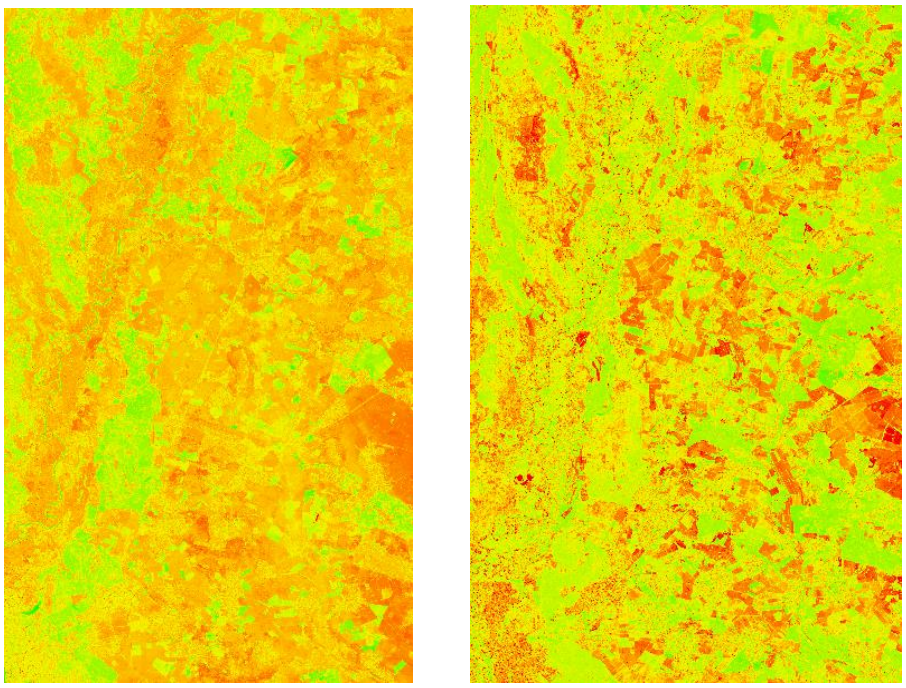

Figure 5 *Image fragment with calculated normalized burn ratio indexes in the study region*

The difference between NBR obtained from the images before fire and after fire is used to calculate the dNBR, which can be used to estimate the areas with different burn severity. To calculate the areas, the resulting image of dNBR was reclassified according to Table 1. Then higher is value of dNBR than more severe damage, and areas where dNBR values are negative may indicate regrowth of vegetation after a fire.

Table 1 *Burning severity levels used to reclassify the difference image (Source: https://un-spider.org/advisory-support/recommended-practices/recommended-practice-burn-severity/in-detail/normalized-burn-ratio)*

	Severity level	dNBR range (scaled to 10^3)	dNBR range (not scaled)
	Enhanced regrowth, high (postfire)	-500 to -251	-0,500 to -0,251
	Enhanced regrowth, low (postfire)	-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
	Moderate high severity	+440 to +659	+0,440 to 0,659
	High severity	+660 to +1300	+0,660 to +1,300

After calculating the areas of all classes (for all severity levels), the area of classes from low to high levels was calculated. The total area of burnt area with varying degrees of severity is 1141 hectares. The difference between the template and calculated area is 82 ha or 6.7% of the template area.

Conclusions

The use of remote data of high periodicity and the presence of additional bands of surveying systems significantly expands the range of tasks that can be solved using them.

Normalized burned ratio allows quickly and efficiently to identify and calculate the area damaged by fires, that gives possibility operatively assess the consequences of such fires and estimate the damage.

It is established that in the studied area the accuracy of area calculation using the normalized burned ratio is 6.7% of the template area, which is sufficient for this type of task.

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