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MASK IMPORTANCE IN BURNED AREA MAPPING BASED ON REMOTE SENSING, GIS AND OPEN-SOURCE PRODUCTS

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KEY WORDS: burned area mapping, masks, spectral indices, change detection, Sentinel-2, SNAP, QGIS, INSPIRE open data

ABSTRACT:

Forest and field fires are an increasing problem for EU countries located in the southern parts of Europe. With each passing day, the need to develop a technological scheme for monitoring the territories affected by fires and the timely provision of open data in order to recover damages is increasing.

In this study, the method used to study burned areas is based on the analysis of multispectral satellite images, the differences in terrain reflectivity and the use of indices to highlight the differences between areas with healthy vegetation and burned areas, taking into account their different signatures. Open source software - SNAP, QGIS, images from Sentinel-2 with bands in the green, red, near-infrared and short-wave infrared spectral bands were used for the purposes of the research. Data from the Inspire Directive was also used to analyze the types and characteristics of affected areas.

In many cases, water bodies show a similar difference as the Normalized Burn Ratio (NBR) index, for this reason the need for their preliminary masking arises. Clouds that appear in each input image are also masked. A combined water and cloud mask is applied. To detect the water bodies, NDWI was used to maximize the reflectance of the water body in the green band and minimize the reflectance of the water body in the NIR range.

1. INTRODUCTION

In recent decades, the devastating impact of forest fires has increased globally, causing significant environmental, social and economic consequences. Monitoring and analysis of burned areas play a critical role in understanding wildfire dynamics, improving response strategies, and promoting effective land management practices. With the advent of satellite technology, remote sensing has become a valuable tool for the systematic assessment of wildfire-affected regions.

Satellite imagery-based analysis offers numerous advantages over traditional ground-based approaches, mainly due to its ability to capture large-scale information with high temporal resolution. Through the use of multispectral sensors, satellite imagery enables the detection of fire-affected regions, the identification of vegetation damage and the assessment of the extent of the burned area, thus facilitating timely and accurate assessment of the impact of these disasters.

The application of masks is crucial when mapping burned areas using satellite images to ensure accurate and reliable results. Masks help filter out non-burned pixels or areas, preventing them from being erroneously classified as burned, thus improving the overall precision of the analysis.

Through the combination of satellite images and geographic information systems, it becomes possible to obtain valuable conclusions such as fire ignition points, degree of fire, type of affected territories, etc., which allows the development of more effective fire management strategies and recovery planning procedures.

The increase in the frequency of forest fires and the associated threats to the environment and the population require a deeper understanding of the processes of occurrence and analysis of the burned areas. Due to the high summer temperatures and the small amount of precipitation, forest fires are one of the most important threats to the environment in Bulgaria and around the world, as they annually damage and destroy thousands of hectares of forest and agricultural areas.

The research is mainly focused on the burned areas in the summer months of 2022 in Haskovo region. It is located in the southern part of the Republic of Bulgaria. The region is of strategic importance as it borders Greece and Turkey (Fig. 1).

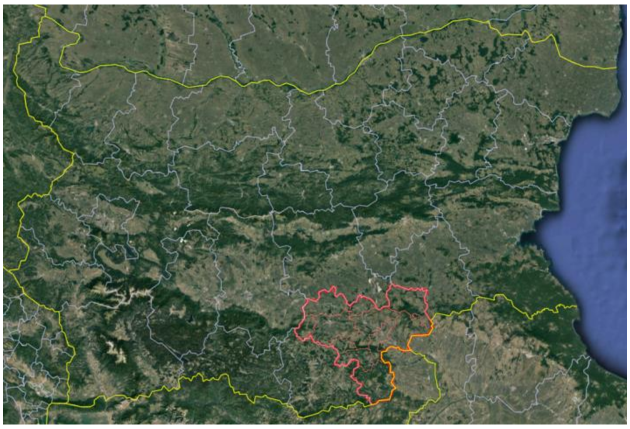

Figure 1. Location of case study: Haskovo Region, Republic of Bulgaria.

This paper is focused on the use of open-source products and data. Images that are freely available through The Copernicus Open Access Hub were used. Processing and analyzes were performed using the programs SNAP (Sentinel Application Platform), QGIS and Google Earth Pro.

The research is created with open data and open source software so that it can contribute to reproducibility, iteration, community engagement, accessibility, reusability and innovation.

2. STUDY AREA AND DATASET

2.1 Study area

As mentioned, the study covers Haskovo region, consisting of 11 municipalities - Dimitrovgrad, Ivaylovgrad, Lyubimets, Madzharovo, Mineralni Bani, Svilengrad, Simeonovgrad, Stambolovo, Topolovgrad, Harmanli and Haskovo (Fig. 2).

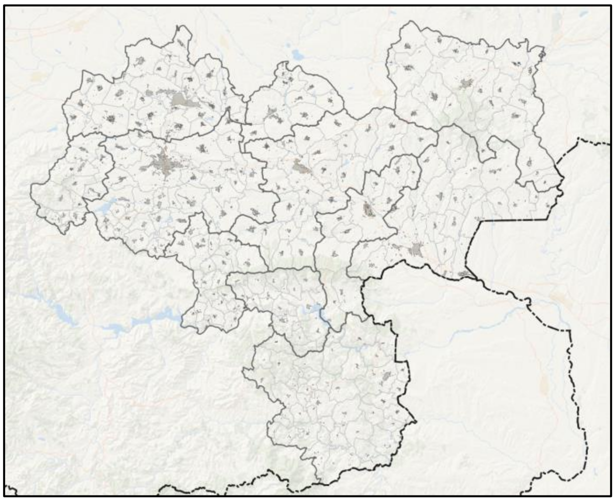

Figure 2. Area of interest: the municipalities of Haskovo region

It was chosen as an object of interest because it has a high risk of forest fires and the region is of strategic importance. The border regions of the district are extremely risky for the development of large-scale forest fires, given the rugged and difficult-to-access terrain, the lack of road infrastructure, and they can easily cross the border. One of the prerequisites for their development is the severe depopulation of the areas, which contributes to their late discovery and the lack of human resources for their mastery.

The study covers the period from May 2022 to October 2022, as conducive conditions for the occurrence of large fires are then available. In Fig. 3 can be seen some of the damages caused by one of the fires that occurred in the same year. Even without further analysis, changes in land cover can easily be observed with the naked eye. Large massifs of deciduous and coniferous forests were destroyed.

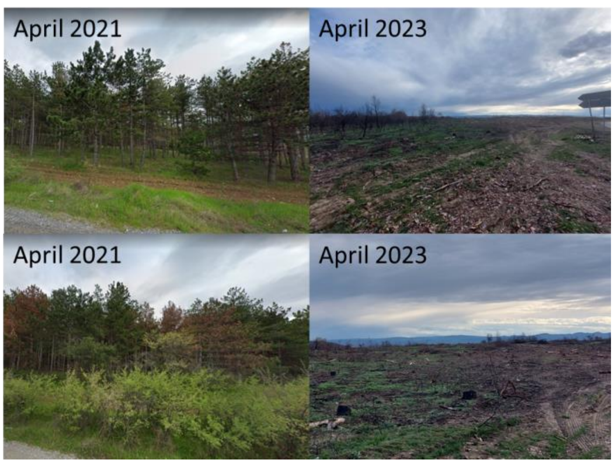

Figure 3. **Left:** Google Street View images from April 2021 before the fire. **Right:** Images captured during a field survey in April 2023 several months after the territory was burned.

2.2 Dataset

For this paper, images from the Sentinel-2 are used. They are provided free of charge by ESA as part of the Copernicus program. All images used in the study were obtained through the Copernicus Open Access Hub.

The Level-2A products delivered by Sentinel-2 were chosen because they met the requirements for the survey of the desired area. Optical multispectral images have medium spatial resolution. The frequency of the obtained images is within several days and the necessary ranges of the electromagnetic spectrum are covered.

The Level-2A single product is composed of a 110x110 km² tile, it is an orthoimage in UTM/WGS84 projection. According to the tiling grid of the Republic of Bulgaria, Haskovo region falls into a set of three tiles with identifiers: 35TLG, 35TMG and 35TMF (Fig. 4).

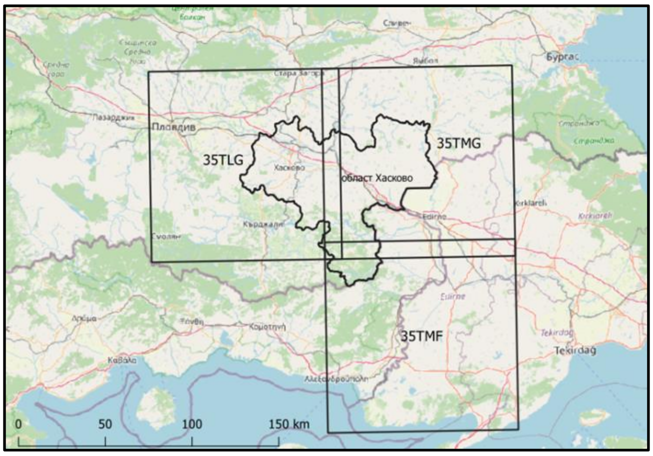

Figure 4. A set of tiles covering Haskovo region

A total of 15 multispectral images from Sentinel-2 were used. In order to determine the changes in the land cover, it is necessary to analyze the images covering the same area, but in different periods of time. For this purpose, images were selected at the beginning and at the end of each of the months falling within the study period. Since the studied area falls into three different tiles, for each of the dates it is necessary to download 3 images providing the coverage of the Haskovo area. A list of information about the used images is presented in Table 1.

№	Mission	Type	Date	Tile №
1	Sentinel-2A	S2MSI2A	May 20, 2022	35TLG
2	Sentinel-2A	S2MSI2A	May 20, 2022	35TMF
3	Sentinel-2A	S2MSI2A	May 20, 2022	35TMG
4	Sentinel-2B	S2MSI2A	July 4, 2022	35TLG
5	Sentinel-2B	S2MSI2A	July 4, 2022	35TMF
6	Sentinel-2B	S2MSI2A	July 4, 2022	35TMG
7	Sentinel-2B	S2MSI2A	July 24, 2022	35TLG
8	Sentinel-2B	S2MSI2A	July 24, 2022	35TMF
9	Sentinel-2B	S2MSI2A	July 24, 2022	35TMG
10	Sentinel-2A	S2MSI2A	August 28, 2022	35TLG
11	Sentinel-2A	S2MSI2A	August 28, 2022	35TMF
12	Sentinel-2A	S2MSI2A	August 28, 2022	35TMG
13	Sentinel-2B	S2MSI2A	October 22, 2022	35TLG
14	Sentinel-2B	S2MSI2A	October 22, 2022	35TMF
15	Sentinel-2B	S2MSI2A	October 22, 2022	35TMG

Table 1. Information about Sentinel-2 images

Each of the 15 images consists of 13 bands and the features with their names, resolutions, bandwidths and central wavelengths are presented in Table 2 (Sentinel-2 User Handbook, 2015). In this particular case, for the purposes of the study, the following bands are used: B2, B3, B4, B8, B8A, B11, B12.

Sentinel-2 Bands	Central wavelength (nm)	Bandwidth (nm)	Resolution (m)
Band 1 - Coastal aerosol	443	20	60
Band 2 - Blue	490	65	10
Band 3 - Green	560	35	10
Band 4 - Red	665	30	10
Band 5 - Vegetation Red Edge	705	15	20
Band 6 - Vegetation Red Edge	740	15	20
Band 7 - Vegetation Red Edge	783	20	20
Band 8 - NIR	842	115	10
Band 8A - Vegetation Red Edge	865	20	20
Band 9 - Water vapour	945	20	60
Band 10 - SWIR - Cirrus	1375	30	60
Band 11 - SWIR	1610	90	20
Band 12 - SWIR	2190	180	20

Table 2. Features of Sentinel-2 images

3. METHODS

3.1 Workflow

The approval of a certain technological scheme in the analysis of the burned territories allows an effective, accurate and comprehensive assessment of the impact of forest fires. It assists in decision-making, resource allocation and long-term monitoring, contributing to effective post-fire management and understanding of fire-prone ecosystems.

Based on an in-depth analysis related to the physical foundations of remote sensing, the spectral signatures of various surfaces, the physical characteristics of forest fires, and the methods of processing and analyzing satellite images, a workflow for the analysis of burned areas has been derived. It is presented in Figure 5.

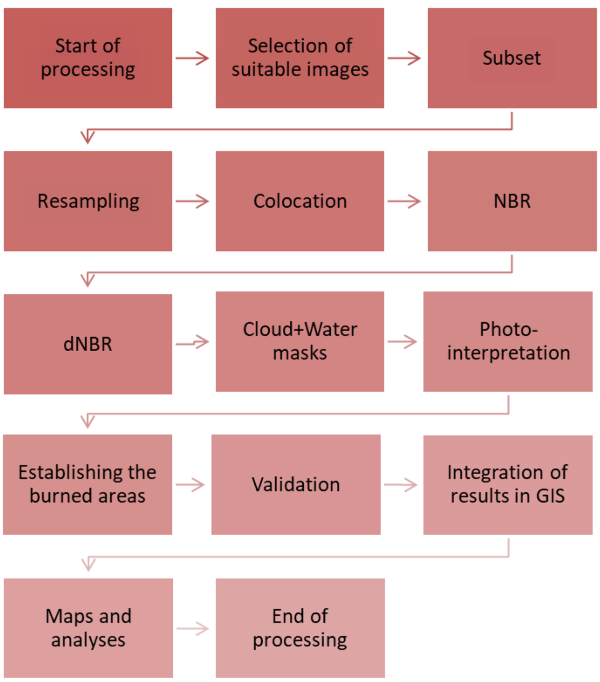

Figure 5. Burned Area Mapping Workflow

3.2 Processing

As mentioned above, 15 multispectral optical satellite images were used and processed for the purpose of the study (Table 1). The dates of capture and percentage of cloud cover were taken into account when selecting the appropriate images.

3.2.1 Subset

The subset is used to extract a specific study area from the larger original remote sensing dataset. This allows a shorter processing time and more precise analysis of a smaller area, which is also the main purpose of the study.

The spatially desired extraction area is defined by specifying its geographic coordinates (Fig. 6). The generated subsets preserve the metadata associated with the original dataset. This includes information about the sensor, acquisition parameters, spatial reference system, etc. This ensures that the subset preserves the essential information of the original image and maintains its relevance.

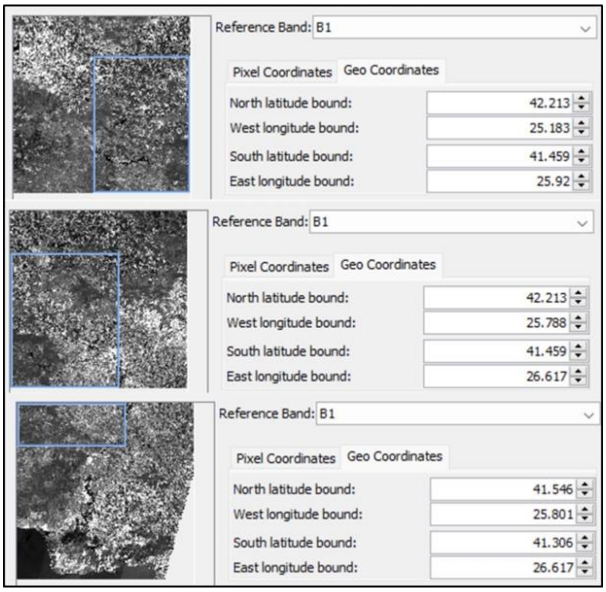

Figure 6. Geographic coordinates of the extracted subsets

Figure 7 shows subsetting for each of the three tiles - 35TLG, 35TMG and 35TMF. This step is applied to all 15 images. After the generation of the subsets, the study covers only the area of interest (Haskovo region), the computing resources are optimized, the processing time is reduced and the extraction of significant information is facilitated when analyzing the burned areas.

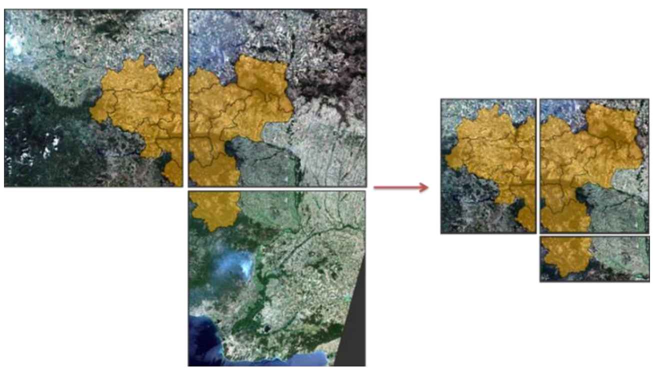

Figure 7. Generated subsets

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3.2.2 Resampling

Resampling of remote sensing products refers to the process of changing the sampling rate (changing the pixel size). This involves transforming the pixel grid of the original image into another grid with a different spatial resolution. The purpose of this operation is to resize the pixel to a desired level to allow comparison of images/bands with different resolutions.

The used images (subsets) are of different spatial resolution, which necessitates their unification. Four of the bands – B2, B3, B4 and B8 – have a pixel size of 10 m and three of them – B8A, B11 and B12 – have a pixel size of 20 m. The "Nearest Neighbor" resampling method is selected, where the nearest pixel from the source image is searched and its value is copied to the corresponding element of the new image. For the purpose of the study, B2 was chosen as the reference band because it has one of the highest resolutions of 10 m. Respectively each band is resampled to match this size.

3.2.3 Collocation

Collocation in remote sensing refers to the process of comparing and aligning data obtained from different sensors or at different times to ensure spatial and temporal compatibility. In the particular study, this operation is applied because multiple images of the same area but obtained on different dates are used. This ensures that the data can be combined and analyzed effectively. The result of the operation is a new product that contains a copy of all the components of the main image – spectral band data, connection point networks, metadata, etc. Metadata for slave products is not transferred to the resulting product. Alignment is established by using the geographic position of a sample from the master image to find the position of the corresponding sample in the slave image.

To analyze burned areas in the matching process, the master image is the one taken before the fire, and the one taken after the fire subsides is chosen as the slave image. For the purposes of the research, the affected areas are analyzed month by month for each of the three tiles. Table 3 presents the distribution of the images.

Period	Master image date	Slave image date
June 2022	20.05.2022 г.	04.07.2022 г.
July 2022	04.07.2022 г.	24.07.2022 г.
August 2022	24.07.2022 г.	28.08.2022 г.
September 2022 and October 2022г.	28.08.2022 г.	22.10.2022 г.

Table 3. Master and slave images

3.2.4 Spectral analysis

The application of spectral indices is a very effective method because it exploits the differences in spectral response between burned and unburned vegetation, soil, and charred surfaces. By analyzing multispectral satellite imagery using these indices, mapping and monitoring of fire extent is possible, which can aid disaster risk management and ecological studies.

For the correct analysis of burned areas, it is necessary to select the appropriate spectral indices. For this purpose, knowledge of the spectral signatures of the various surfaces is important. Burned vegetation, charred materials, ash and exposed soil show different spectral characteristics compared to unburned vegetation or unburned areas. This is because fire changes the reflective properties of the ground, leading to changes in the spectral signatures of different land cover types.

In Figure 8, the spectral signature of healthy vegetation is represented in green. It exhibits very high reflectance in the near infrared range (NIR) and low reflectance in the short wave infrared range (SWIR). In the same figure, the signature of the burned areas is represented in red. These areas demonstrate low reflectance in the near infrared (NIR) range and high reflectance in the shortwave infrared (SWIR) range.

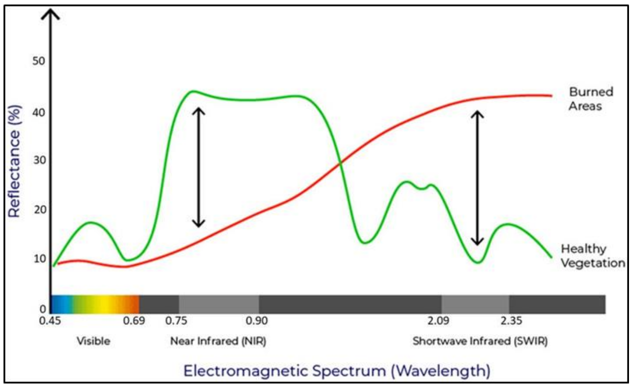

Figure 8. Spectral signature of healthy vegetation and burned areas

To highlight burned areas, the Normalized Burn Ratio (NBR) is used. It takes advantage of the magnitude in amplitudes of spectral signatures by using the ratio between near-infrared (NIR) and short-wave infrared (SWIR) according to Equation 1.

$$\text{NBR} = \frac{(\text{NIR}-\text{SWIR})}{(\text{NIR}+\text{SWIR})} = \frac{(\text{B8}-\text{B12})}{(\text{B8}+12)}, \quad (1)$$

where: NIR = Near-infrared spectral band
SWIR = Short-wave infrared spectral band
B8 = NIR band in Sentinel-2 image
B12 = SWIR band in Sentinel-2 image

Index values close to 1.00 indicate healthy vegetation, while those close to -1.00 indicate bare ground and recently burned areas. Values close to zero represent unburned areas. Figure 9 shows the result of applying the index.

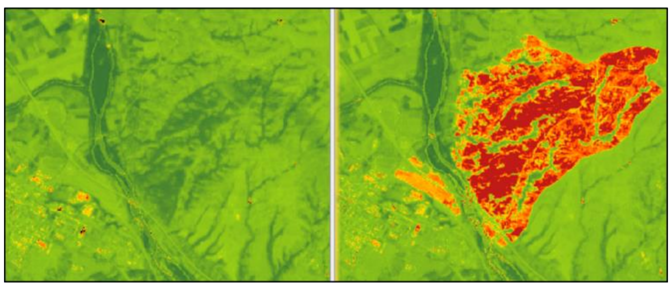

Figure 9. NBR results before and after fire

The Differenced Normalized Burn Ratio (dNBR) is calculated from NBR and measures the change in NBR values between pre- and post-fire conditions (Equation 2). It gives an indication of the amount of vegetation loss and the extent of the fire. Higher positive dNBR values correspond to more severe burns and greater extent of vegetation loss.

$$\text{dNBR} = \text{NBR}_{\text{pre}} - \text{NBR}_{\text{post}}, \quad (2)$$

where: dNBR = Differenced Normalized Burn Ratio
NBR_{pre} = NBR applied to a pre-fire image
NBR_{post} = NBR applied to a post-fire image

dNBR is useful for quantifying the impact of fires on vegetation to better target post-fire management and recovery efforts. It helps identify areas that have suffered a more severe burn and require specific intervention or monitoring. In Figure 10, orange and red colors represent the area burned by fire, and green areas show areas where there is no change in vegetation.

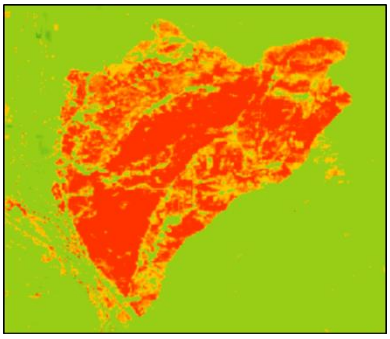

Figure 10. dNBR results

3.2.5 Cloud and water masks

- Cloud mask

Clouds pose a significant challenge to optical remote sensing, which relies on capturing and analyzing images of the Earth's surface using sensors that detect visible and near-infrared light. The main problems with cloud cover images include:

- Data Loss – Clouds obstruct the view of the Earth's surface, resulting in incomplete image coverage. In this way, a burned area can be missed if there is cloud cover above it.
- Shadowing effect - leads to errors in the results as clouds cast a shadow over the earth's surface.
- Change in reflectance - clouds have their own reflectivity and their presence can change the reflectance values of the surface below them.
- Temporal variability – cloud cover is highly dynamic and constantly changes in size, shape and position. This affects the consistency and comparability of optical remote sensing data captured at different times.
- Atmospheric effects - the presence of clouds in the atmosphere creates additional difficulties due to the scattering and absorption of light. This can introduce atmospheric noise and affect subsequent analysis.

When choosing images, those without cloud cover were selected. However, there may be single clouds in places that would compromise processing. The Level-2A product includes a vector dataset containing cloud and cirrus masks. They are created as a product of atmospheric correction. A new band is created according to Equation 3. This algorithm identifies and masks cloudy pixels in the images, which allows the removal of the areas of the analyzed territory covered by clouds.

$$if\ (scl\_cloud\_medium + scl\_cloud\_high + scl\_thin\_cirrus) < 255\ then\ 0\ else\ 1 \quad (3)$$

Figure 11 shows the new band - mask, which includes all types of clouds contained in the studied images.

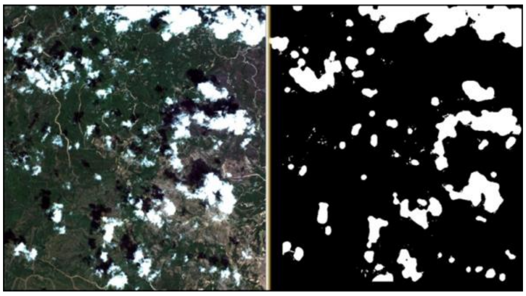

Figure 11. Cloud mask

- Water mask

Water bodies have different spectral characteristics compared to burned areas, but under certain circumstances it is possible to show similar results after applying the Normalized Burn Ratio (NBR). Including water bodies in the analysis can introduce noise or confusion, leading to inaccurate classification and mapping of burned areas. By applying a water mask, water bodies are excluded from the analysis.

For this purpose, a Normalized Difference Water Index (NDWI) is calculated (Equation 4). It maximizes the reflectivity of the water body in the green spectral range and minimizes the reflection of the water body in the near infrared spectral range. It is particularly effective at distinguishing between open water areas and other types of land cover, such as vegetation and bare soil. The resulting NDWI values range from -1 to +1, with higher positive values indicating the presence of water.

$$\text{NDWI} = \frac{(\text{Green} - \text{NIR})}{(\text{Green} + \text{NIR})} = \frac{(\text{B3} - \text{B8})}{(\text{B3} + \text{B8})}, \quad (4)$$

where: NIR = Near-infrared spectral band
Green = Green spectral band
B8 = NIR band in Sentinel-2 image
B3 = Green band in Sentinel-2 image

The process of creating a water mask is an important step in burned area mapping, as it avoids misinterpretation and improves the accuracy of the results. By accurately identifying water bodies and excluding them from the analysis, more reliable information about affected areas is provided.

- Impact of masks on the results

In order to optimize the work process, the already created cloud masks and water masks are applied to the dNBR results according Equations 5. The masks are applied to all collocation products.

$$if\ (cloud\ mask_{before} > 0\ or\ cloud\ mask_{after} > 0\ or\ NDWI \geq 0.0)\ then\ 1\ else\ 0 \quad (5)$$

where:
$cloud\ mask_{before}$ - cloud mask applied to an image captured before a fire occurred;
$cloud\ mask_{after}$ - cloud mask applied to an image captured after a fire has occurred;
$NDWI$ - Normalized Difference Water Index.

Figure 12 shows the effect of the water mask. The images on the left show the result of applying the dNBR, with the large red areas identified as burned areas. The images on the right again show the dNBR result, but after a mask has been used to remove the water bodies. This ensures that only the areas affected by fires will be taken into account in the analysis of the final results.

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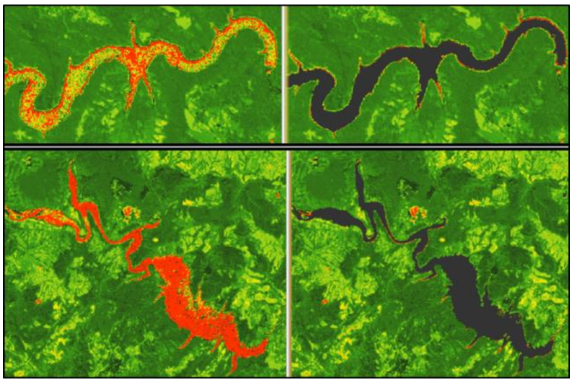

Figure 12. Effectiveness of the water mask

Figure 13 shows the influence of the cloud mask. Analogous to the previous figure, the result of applying dNBR is shown here on the top, and the result after removing the clouds by mask is on the bottom. Again, the clouds were initially recognized as burned areas, but were then successfully excluded.

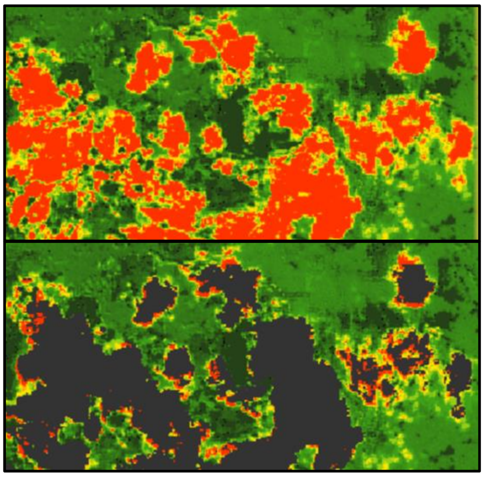

Figure 13. Effectiveness of the cloud mask

3.2.6 Photointerpretation

In order to assess the degree of burning, a visual comparison is also made between the images before and after the fire. The pre-fire images serve as a baseline for determining affected areas. For easier photointerpretation, in addition to the image before and after the fire in natural colors, composite images in false colors are also used (Fig. 14). In this particular case, a combination of bands B12, B1 and B8A is used to highlight the burned area.

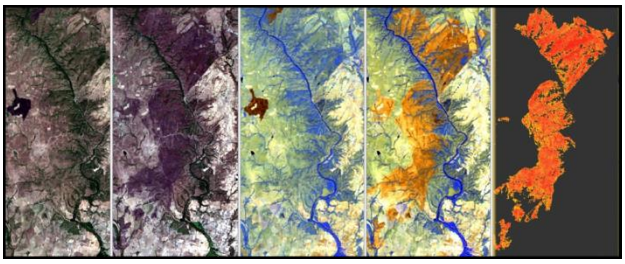

Figure 14. Left to right: Images before and after fire in natural (RGB) colors; Images before and after fire in false colors (B12, B11, B8A) and the result of applying dNBR.

In RGB images, burned areas appear as dark black and purple patches due to the destruction of vegetation and the denudation of deforested land. But with them, establishing the exact burned area is more difficult to identify. In false color images these areas are brown and orange and sharper transitions are observed in the color and texture of the land cover.

Through a combination of the various composite images and the results of the applied spectral indices, the exact boundaries of the burned areas were unambiguously determined. In addition to this, various attributes such as size, shape and spatial distribution are extracted. These attributes provide valuable information for assessing fire behavior, understanding impacts on the landscape, and properly targeting damage reduction efforts.

The results of the digital processing and analysis of the multispectral images are exported in formats suitable for reading by QGIS. This software was used to generate maps for better visual representation of burned areas and to perform detailed and in-depth analyzes related to understanding the relationships and patterns between different land surface features.

3.2.7 Validation

Since there was no mapping of the burned areas in the Haskovo region for 2022 and there is no information about the affected area, the validation was performed only on the basis of information on the dates and approximate locations of the fires that occurred for the studied period, obtained from:

- Analyzes of the activities of the Regional Directorate "Fire Safety and Protection of the Population" - Haskovo - open access reports published on the website of the Ministry of Internal Affairs;
- Decision with Reg. No. 812104-38 on an application for access to public information - provided by the General Directorate "Fire Safety and Protection of the Population" solely for the purposes of the study.

For research purposes, affected areas are analyzed month by month for each of the three tiles. As a result of this research, groups of burned areas are obtained for each of the months of June, July, August, September and October 2022. In this way, the positioning of each burned area in time is guaranteed, which in turn can be compared with the information of the date of occurrence of the fires received by the Ministry of the Interior.

But the information about the month of occurrence does not lead to the validation of these zones, since it is necessary to position them correctly in space. For this purpose, vector data for the Administrative Units in the Republic of Bulgaria were used. This information is publicly available through the National Spatial Data Portal under the INSPIRE Directive.

Information about administrative units in vector shapefile (.shp) format and burned areas in GeoTIFF raster format are integrated and combined in the Quantum GIS software product. This data has been processed for easier visual interpretation and comparison of the obtained results. For each of the burned areas found, a reference is made which lands and municipalities are affected.

According to the results of the digital processing of satellite images and the information received from the indicated sources, 23 burned areas caused by forest fires that occurred in the summer months of 2022 in the territory of Haskovo region were established and validated.

3.2.8 Integration of results in GIS

According to the Haskovo District Disaster Risk Reduction Program for the period 2021-2025, one of the activities for the implementation of the operational goals of the program contains: "Development, publication and periodic updating of risk maps using GIS". This includes creating maps with information on various sites of critical infrastructure: landslides and collapses, soils, land cover and others.

To support the creation of such types of maps in the future, data has been added to QGIS for:

- Distribution of soils in Bulgaria - created by the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov", publicly available through the National Spatial Data Portal under the "INSPIRE" Directive;
- Boundaries of the earth's surface that follow permanent topographic elements - created by the Ministry of Agriculture, publicly available through the National Spatial Data Portal under the "INSPIRE" Directive;
- Boundaries of Natura 2000 protected areas – publicly available through the Natura 2000 Protected Areas Information System.

In QGIS, processing and analysis of the newly received information was carried out. A comparison was made between the locations of the validated burnt areas and the spread of soils, the boundaries of the earth's surface and the protected areas of the ecological network Natura 2000. As a result, a database was created containing information on:

- Fire identification number;
- Location showing the affected lands and municipalities;
- Date of occurrence of the fire;
- Area of burnt territory;
- Has it affected protected areas under the Natura 2000 ecological network;
- What is the type of affected land cover;
- What types of soils it affected.

№	Location	Date	Affected by the fire			
			Area, ha	Natura 2000	Land cover	Soils
1	Shishmanovo village, Harmanli municipality	14 July 2022	10.7	YES	Cultivable lands; Grasslands, moors and meadows	LVx Chromic Luvisols medium LVxq lithi-chromic Luvisols medium

Figure 15. Part of the created database

A multi-component analysis of the affected territories was made, comparing results with and without applied cloud and water masks.

4. RESULTS AND ANALYSES

For the purposes of the study, after the implementation of the proposed technological scheme, more than 2451 ha of burned areas were mapped. Based on these obtained results and the derived fire records, a multicomponent analysis was performed. It has identified various sites and areas that require immediate attention through the implementation of preventive measures to reduce future fire risks.

The results of processing with and without application of cloud and water masks were compared. Figures 16, 17 and 18 present the obtained results.

Even without an in-depth analysis, it is easy to see the differences with and without the application of masks. As many objects are mistakenly recognized as fires, the number of affected objects has increased many times. The change in affected land cover is most strongly observed. There is a very large number of recorded affected water areas because without applying NDWI, all rivers and dams are shown as fires.

This shows how powerful the influence of water bodies and clouds is when mapping burned areas. Therefore, it is necessary to always take them into account during processing.

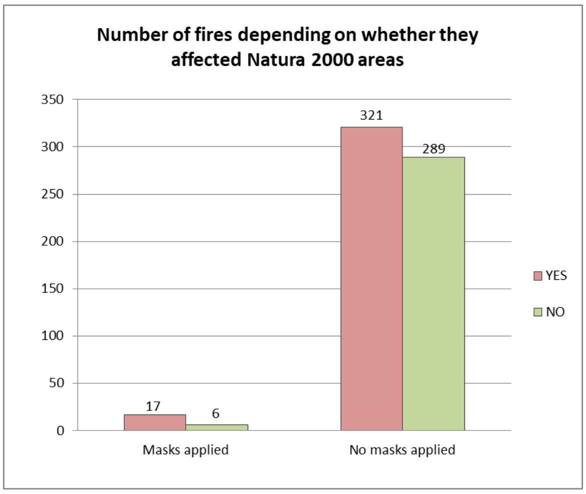

Figure 16. Number of fires depending on whether they affected Natura 2000 areas

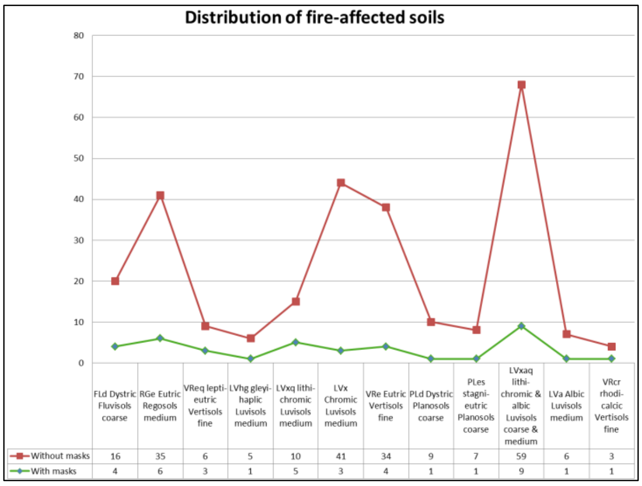

Figure 17. Distribution of fire-affected soils

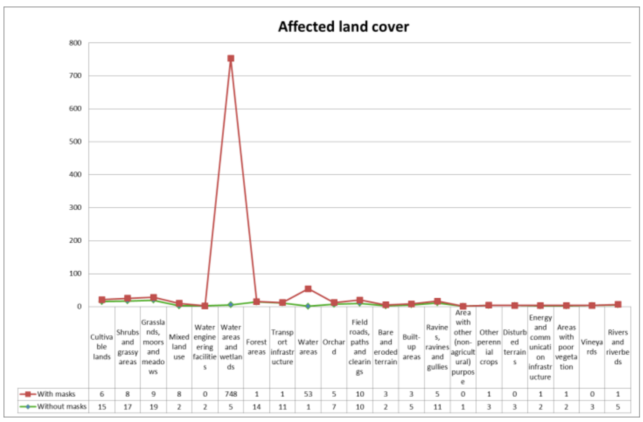

Figure 18. Affected land cover

https://doi.org/10.5194/isprs-archives-XLVIII-1-W2-2023-1013-2023 | © Author(s) 2023. CC BY 4.0 License.

5. CONCLUSION

By using the spatial and temporal capabilities of satellite sensors, data were collected on the burned areas for the study period. This information serves as a basis for comparison with other spatial data sets. Through them, parts of the earth's surface were analyzed to determine the most affected municipalities, soils, land cover, etc. This information helps skilled professionals make informed decisions related to prioritizing post-fire recovery efforts, assessing ecosystem resilience, and developing disaster prevention and mitigation strategies.

Although satellite image-based analysis of burned areas demonstrates great potential, it is important to acknowledge some limitations. Factors such as cloudiness and the presence of water bodies can affect the availability of suitable images and the accuracy of the results obtained. Therefore, it is extremely important to apply the specified cloud and water masks.

On the basis of the obtained results, it is proved that with the correct selection of images obtained by remote sensing, the applied digital processing methods can be used to map burned areas and their degree of burning. The importance of the integration of different types of information in GIS, both for validating the obtained results and for comparing them with specific data on the earth's surface to compile multi-component spatial analyses, is confirmed. By using the proposed technological scheme, reliable, efficient and fast results are obtained.

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