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APPLICATION OF VEGETATION INDICES AS A STEP TOWARDS THE RELEVANCE OF THE STATE OF BEECH FOREST HABITATS: A CASE STUDY FROM BOATIN RESERVE, CENTRAL BULGARIA

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Abstract

The present study examines the application of two vegetation indices, SAVI and MSAVI, to advance our understanding of the state of beech forest habitats. The research object is Boatin Reserve, located in Central Bulgaria. Landsat eight images were derived, and beech forest habitats were used as the basic territorial unit for the analysis. The main focus was the months of June, July, and August. The results of the study showed certain patterns. Luzulo-Fagetum beech forests (9110), Asperulo-Fagetum beech forests (9130), and Moesian beech forests (91W0) are the beech forest habitats within the study area. MSAVI results were higher than those of SAVI.

Introduction

Satellite technology offers scientists improved options for analysis. Several satellites are crisscrossing the sky, run by a wide range of programs. Landsat is among them, and it remains the longest-functioning provider of multi-spectral satellite images. Landsat-8 and Landsat-9 satellites feature an Operational Land Imager (OLI) optical sensor and a Thermal Infrared Sensor (TIRS) [1], which enables the provision of useful data across different wavelengths that can be applied for imagery analysis with a focus on vegetation [2].

The current study aims to take a step toward revealing the state of beech forest habitats in Boatin Reserve by applying two vegetation indices: SAVI and MSAVI.

The Soil-Adjusted Vegetation Index (SAVI) was developed by Huete [3] as a vegetation index that attempts to minimize the influence of soil brightness using a soil-brightness correction factor. The values of SAVI range between -1.0 and 1.0. The index is similar to the Normalized Difference Vegetation Index

(NDVI). However, it is used for correcting it, because the latter exhibits instabilities when it comes to soil features (such as color, mechanical composition, and humidity). SAVI saturates more quickly than NDVI, making it the better option for dense vegetation.

The modified soil-adjusted vegetation index (MSAVI) is a corrected index that addresses some of the NDVI's limitations in areas with open soil spaces. A weakness of SAVI is the "L" coefficient, which is typically calculated by assigning a 0.5 value, but this is not always accurate. Therefore, Qi et al. [4] developed MSAVI as a more reliable index for calculating soil factors.

SAVI and MSAVI have been applied in various geographical areas and with different scientific focus. Gu et al. [5] conducted research in China, using MSAVI. Gebreslasie et al. [6] applied MSAVI for the study of the *Eucalyptus* genus in South Africa. Gonsamo [7] utilized a single-date satellite image for LAI research in Quebec, Canada, and concluded that MSAVI provided the best results, particularly in the context of high-resolution imagery applications. Yan et al. [8] conducted a biomass study in the Chinese desert of Mu Us, using Landsat imagery, in which MSAVI and SAVI provided better results than NDVI. Vani & Mandla [9] applied the index in India, concluding that SAVI is the best index for semi-arid areas. Oon et al. [10] applied SAVI along with other vegetation indices for analyzing Landsat-8 images. Rhyma et al. [11] studied mangrove vegetation with SAVI. da Silva et al. [12] employed vegetation indices in their study on land cover research. SAVI is among the indices that provide good results. Aljahdali et al. [13] monitored the degradation and restoration of a mangrove forest on the Red Sea coast of Saudi Arabia, with MSAVI presenting the best results regarding the green vegetation spectrum.

The object of the present research represents a reserve – a unit protected by national, as well as European, legislation and of great importance on a continental scale. The present study represents an amalgam of a protected territory – the Boatin Reserve, a part of the National Ecological Network - and the presence of Natura 2000 beech forest habitats within it. The Natura 2000 protected areas network spans all EU Member States and has been established in Bulgaria since 2002. Nowadays it covers almost 35% of the territory. Beech forests, especially in this region, are a national treasure of Bulgaria and a valuable natural asset on a continental scale. Studying their condition is essential.

The vegetation indices that are a focus of the present study have already been applied in Bulgaria. Avetisyan et al. [14] utilized them in their studies on landscapes and winter wheat, while Radeva and Kirilova [15] conducted research on watersheds. Forests were a study object in other studies [16, 17].

Materials and methods

The study area – Boatin Reserve (Fig. 1) encompasses some of the westernmost parts of BG0000494 Central Balkan, designated as a Natura 2000 site under the Habitats Directive. The reserve was designated in 1948. It is part of the UNESCO Man and the Biosphere Program. The bedrock is mainly composed of granodiorites and granites. Only a slight section to the north contains marine terrigenous and terrigenous-carbonate rocks. Climate is temperate with mountainous specifics. Soils are represented by *Umbrosols* and *Cambisols*. Forests, especially beech forests, dominate the habitats in the reserve's area.

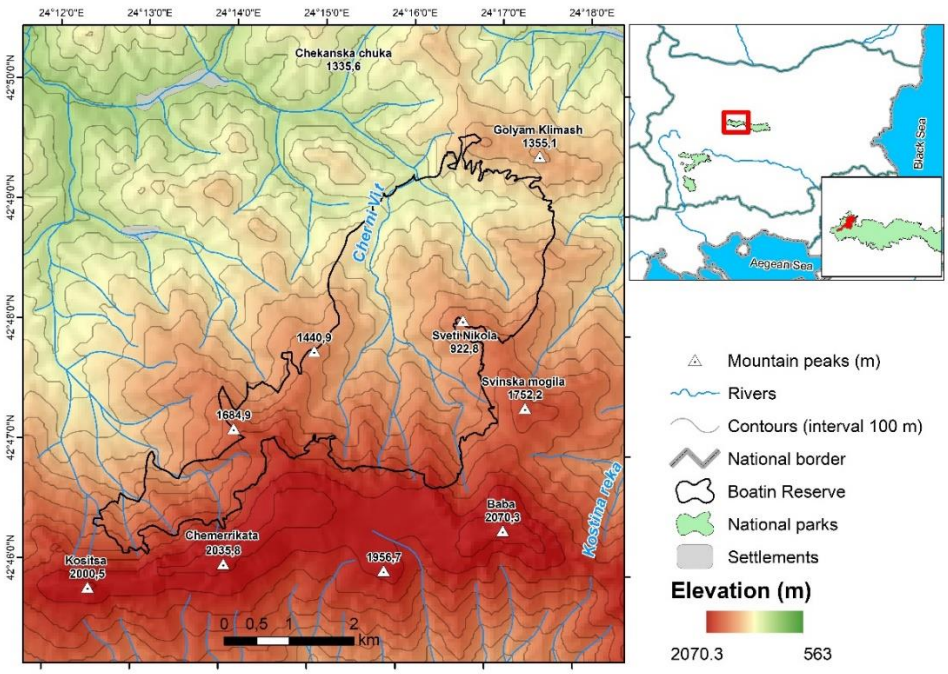

Fig. 1. Location of the study area

Habitat types in the Boatin Reserve were examined by following Kavrakova et al. [18]. Spatial data, including habitat mapping of NATURA 2000 in Bulgaria [19], were also incorporated.
SAVI and MSAVI were calculated by using the following formulas:

(1) $$\mathrm{SAVI} = ((NIR - Red) \div (NIR + Red + L)) \times (1 + L)$$

(2) $$\mathrm{MSAVI} = (NIR - Red) \div (NIR + Red + L) \times (1 + L)$$

(3) $$\mathrm{L} = 2 \times s \times (NIR - Red) \times (NIR - s \times Red) \div (NIR + Red)$$

where NIR denotes pixel values from the near infrared band, Red represents pixel values from the near red band, L is the amount of green vegetation cover and s is the slope line inclination, which represents the slope of the soil line from a plot of red versus near-infrared brightness values.

L equals 1, in areas with no green vegetation, L = 0.5 in areas with moderate vegetation, and when vegetation cover is very high L = 0 (Huete, 1988).

We adopted the approach of using L = 0.1, based on the specifics of the Boatin Reserve.

Images from Landsat 8 (Landsat Collection 2 Level-2, Landsat 8-9 OLI/TIRS C2 L2) [20] serve as the basis for calculating SAVI and MSAVI. Composite bands were created by using the Image analysis tool in ArcGIS 10.6.1. We used images from July 5, 2017, June 30, 2021, and August 17, 2021. The months of June, July, and August are all considered summer months in the country, and beech forests are expected to have a fully developed leaf cover, allowing for comparable results.

SAVI was calculated following the steps:

- the Raster Calculator tool was used to apply the formula for SAVI for the whole area of Boatin Reserve;
- polygons with beech habitats were used for clipping;
- MSAVI's calculation followed the same steps.

Results and Discussion

SAVI and MSAVI data, along with Natura 2000 habitats, reveal some trends (Fig. 2, 3, 4). It may be noted that SAVI and MSAVI values follow a similar pattern. Overall, the highest values are for the date of June 30, 2021. Another pattern that was revealed is that MSAVI values are generally higher than those of SAVI. Boatin Reserve comprises three Natura 2000 habitats, which are dominated by beech forests. They are as follows: Luzulo-Fagetum beech forests (9110), Asperulo-Fagetum beech forests (9130), and Moesian beech forests (91W0).

When it comes to the *Luzulo-Fagetum* beech forests (9110), the highest SAVI value was recorded on June 30, 2021 – 0.54, while the lowest was on July 5, 2017 – 0.33. MSAVI was also the highest on 30.06.2021 – 0.66, and it was the lowest again on 05.07.2017 – 0.47 (Fig. 3).

If *Asperulo-Fagetum* beech forests (9130) are in focus, the highest SAVI value was recorded on 30.06.2021 – 0.57, and the lowest was 0.17 on 17.08.2021. MSAVI reached its highest value on 05.07.2017, at 0.697, and its lowest value, 0.17, was also recorded on the same date (Fig. 3).

Moesian beech forests (91W0) had their highest SAVI values on 05.07.2017, at 0.59, and the lowest were at the same date, equaling 0.1. As for the

MSAVI, the highest was on 30.06.2021 – 0.64 and the lowest was on 17.08.2021 – 0.48 (Fig. 3).

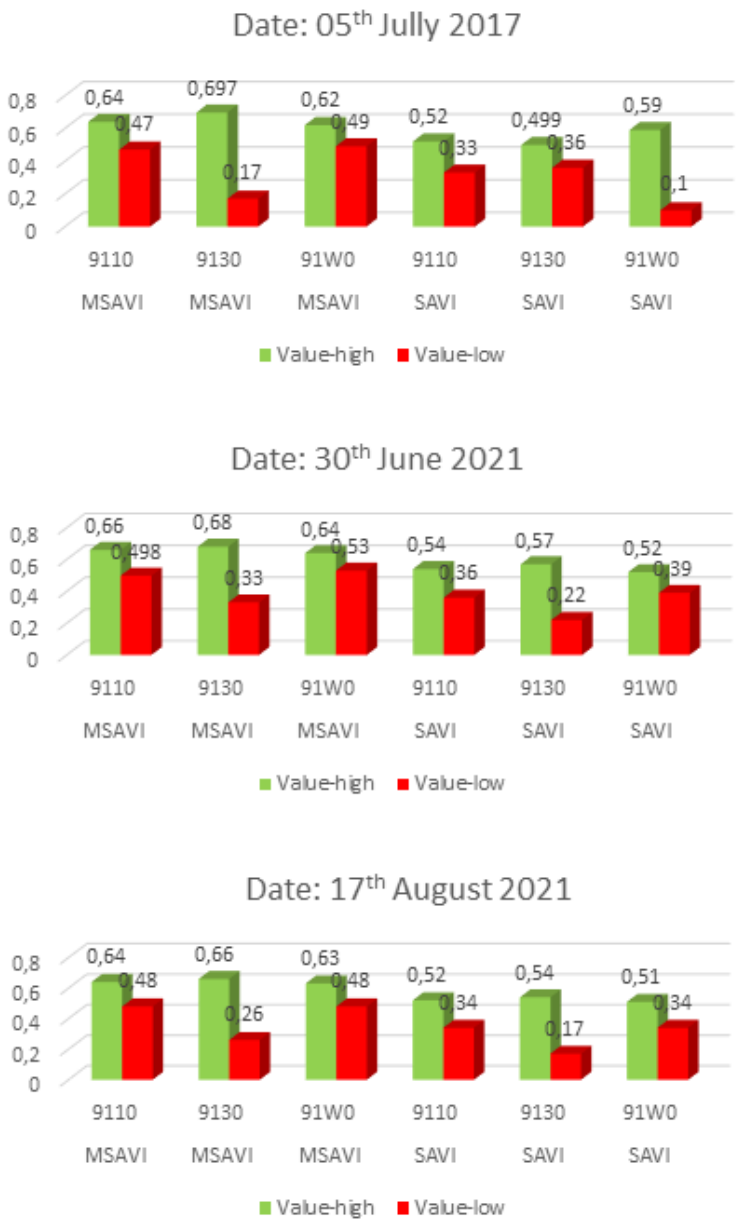

Fig. 2. SAVI and MSAVI values for given dates

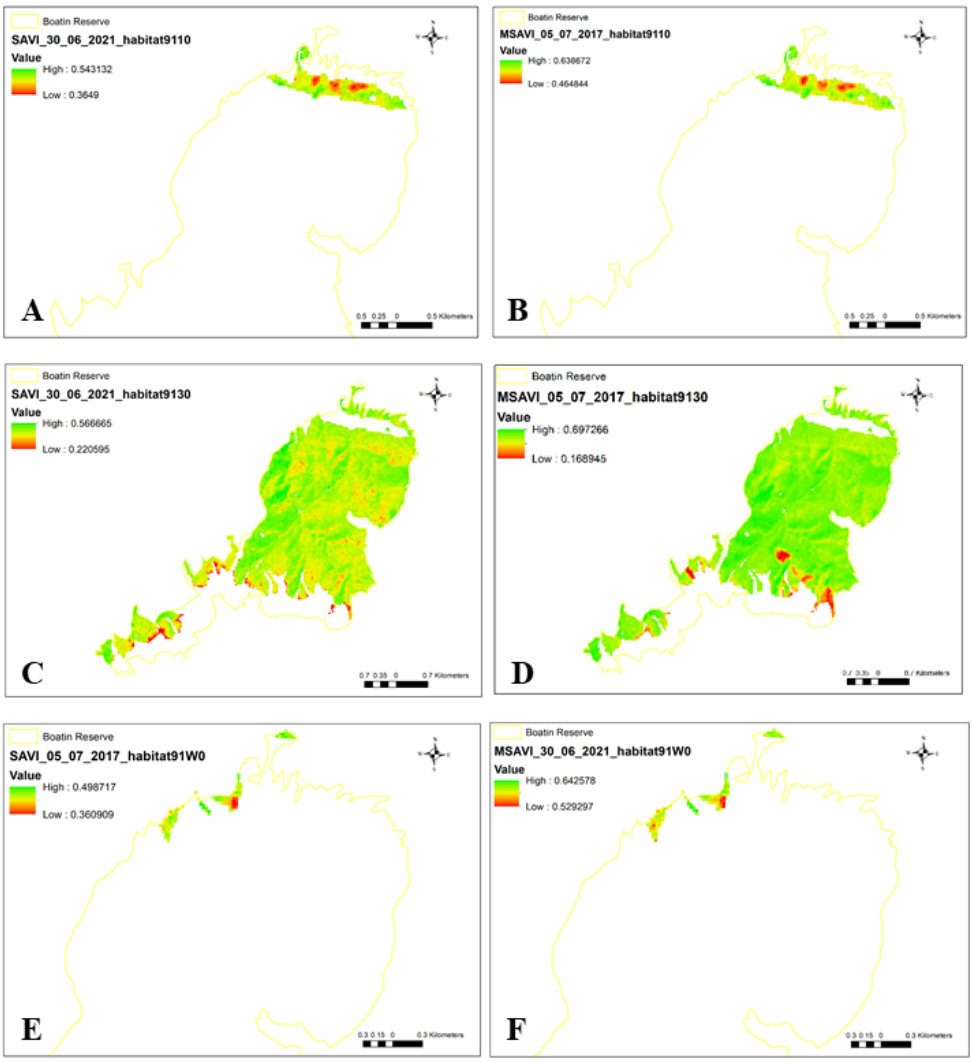

Fig. 3. Chosen SAVI and MSAVI values for the different habitats

Higher values are observed at areas where the beech forests are denser and healthier. On the contrary, where there is a fragmented forest cover and the presence of pathways, SAVI and MSAVI values are lower (Fig. 4*).*

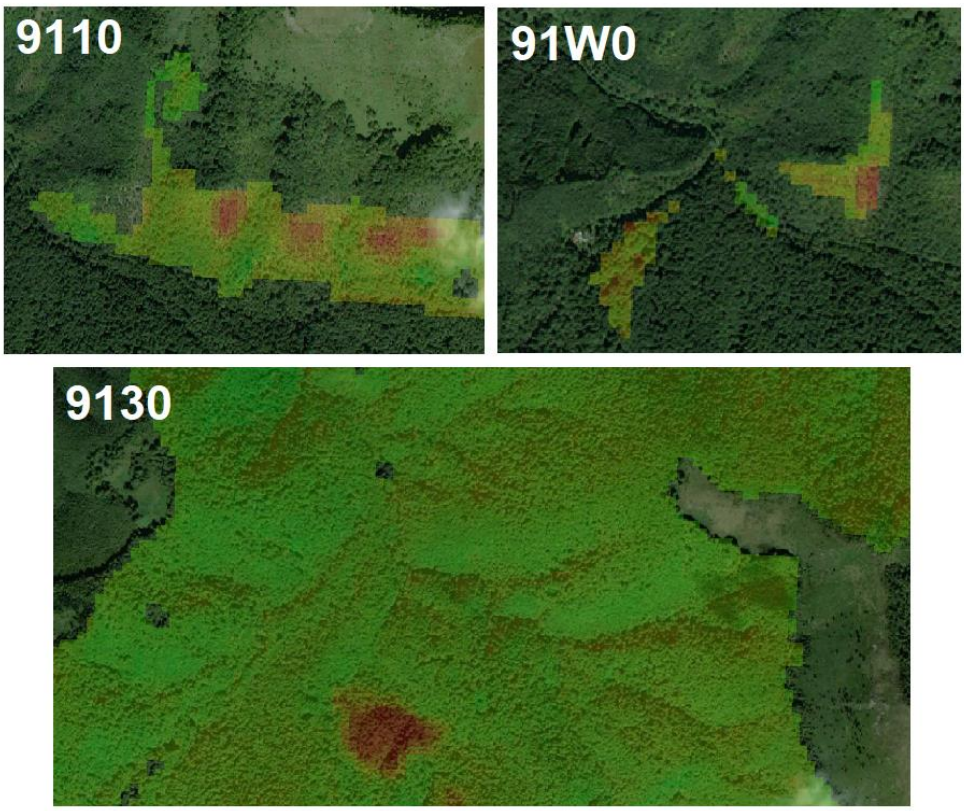

Fig. 4. Basemap images of the habitats of 9110, 91W0, and 9130

Conclusion

The present study dealt with the vegetation indices of SAVI and MSAVI. They were applied to study the state of the beech forest habitats in Boatin Reserve, Central Bulgaria. Three beech forest habitats were studied: Luzulo-Fagetum beech forests (9110), Asperulo-Fagetum beech forests (9130), and Moesian beech forests (91W0). The study showed that MSAVI values were generally higher. Another pattern was that both SAVI's and MSAVI's values were higher on June 30, 2021. Lower values were discovered to be typical for areas where the beech forest cover was more fragmented. A general conclusion of the study is that SAVI and MSAVI can be used to reveal the state of beech forest habitats, provided that proper calculations and analysis are carried out. Naturally, terrain data is more than needed in such a process. Among the other weaknesses of the present study are the need for more Landsat images, additional vegetation indices, and even images from other satellites to get the full picture. Nevertheless, the authors of the present study

believe that this is a step in the right direction for a better understanding of the current state of beech forest habitats in Boatin Reserve. The promising results of the research may be used to extend the study area into neighboring protected areas.

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ПРИЛОЖЕНИЕ НА РАСТИТИТЕЛНИ ИНДЕКСИТЕ КАТО СТЪПКА КЪМ ИЗСЛЕДВАНЕ НА СЪСТОЯНИЕТО НА МЕСТООБИТАНИЯ С БУКОВИ ГОРИ: РЕЗЕРВАТ БОАТИН, ЦЕНТРАЛНА БЪЛГАРИЯ

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Резюме

Настоящото изследване е насочено към прилагането на два вегетационни индекса: SAVI и MSAVI с цел да се направи стъпка към разкриване на състоянието на местообитания на буковите гори. Обект на изследване е резерватът Боатин, Централна България. Изведени са изображения от Landsat 8 и като основна териториална единица за анализа са използвани местообитания от букови гори. Основен акцент са месеците юни, юли и август. Резултатите от изследването показват определени закономерности. Буковите гори *Luzulo-Fagetum* (9110), буковите гори *Asperulo-Fagetum* (9130) и мизийските букови гори (91W0) са местообитанията на букови гори в района на проучването. Резултатите на MSAVI са по-високи от тези на SAVI.