COMPARATIVE ANALYSIS OF OLD-GROWTH STANDS JANJ AND LOM USING VEGETATION INDICES

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ABSTRACT:

Old-growth forests represent a very valuable field for research of natural processes. The application of remote sensing was carried out on two old-growth forests in the northwestern part of the Republic of Srpska. The sample plots from OG Janj show relatively higher mean values (NDVI, SAVI and EVI) compared to OG Lom, with the exception of the VARI. Karstified terrain and poor delay of snags in the top-layer of stand due to the impact of weather disasters and the tendency of OG Janj toward the terminal phase of old-growth forest development are potential reasons for the higher mean value of the VARI index.

Keywords: *vegetation indices, Janj, Lom, old-growth forest, remote sensing*

INTRODUCTION

The research was conducted within the core area in two old-growth stands, located in the northwestern part of the Republic of Srpska (Bosnia & Herzegovina). The management of these areas is defined based on the characteristics of a strictly natural reserve in accordance with the IUCN categories.

The Lom forest reserve is located on the mountain massif Klekovača near Drinić municipality (between 44°27´ and 44°28´ N, and 16°27´ and 16°30´ E and covers a total area of about 300 ha. The entire reserve is made of limestone bedrock with typical karst geology with scattered sinkholes throughout the area. This forest reserve is located in the inner Dinarides area, in the higher subzone of the mountain belt, in the elevation range of 1223-1500 meters. The climate of this area is transitional continental, which is characterized by the collision of continental and maritime air masses. The forest consists of three main species; silver fir (*Abies alba* Mill.), Norway spruce (*Picea abies*(L.) Karsten), and European beech (*Fagus sylvatica* L.) [1,2].

The Janj forest reserve is located on the western slopes of the Stolova massif in the municipality of ipovo. The geographic position of the core area of Janj forest reserve is between 44°07' and 44°10' N and between 17°15' and 17°17' E, between 1260 and 1400 meters above sea level and covers a total area of about 300 ha. Most of the area of the reserve is flat terrain that is made of dolomite bedrock with deep rendzina and brown soil types of various depths. The core area of old-growth forest Janj has been classified as plant association *Piceo-Abieti-Fagetum* (Figure 1) [3,4]. Detailed previous research on the structure elements of living and deadwood mass was carried out in these old-growth forests [2,4].
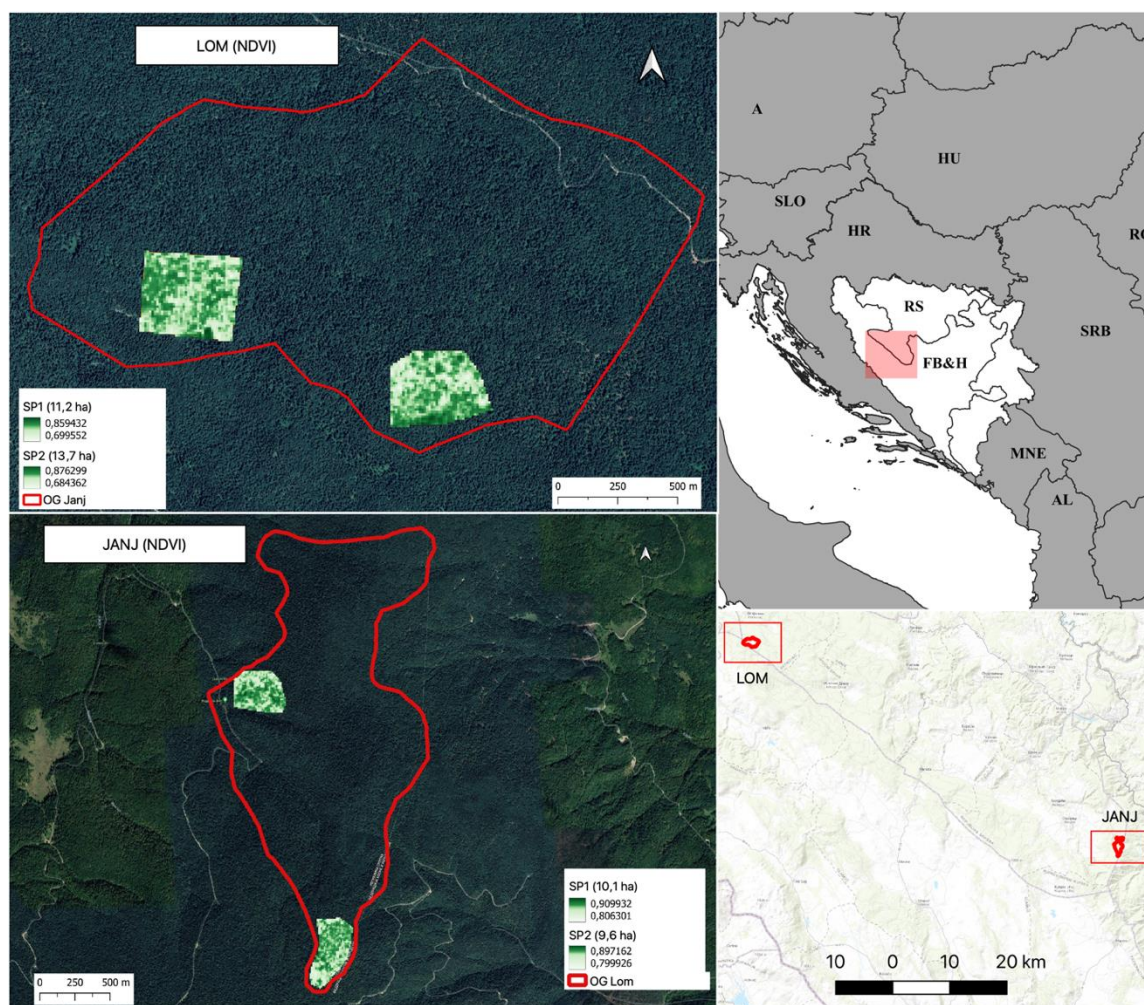
Figure 1. Geographic location of the old-growth forest Lom and Janj

According to previous research [4], old-growth forest Janj is characterized by high growing stock (1215 $m^3 \cdot ha^{-1}$) and mean tree density of 516 trees ha^{-1} due to good site quality and large participation of conifers (84%). Old-growth forest Lom has a lower growing stock (763 $m^3 \cdot ha^{-1}$) with less participation of conifers than Janj (82%) with a density of 638 trees ha^{-1} [5].

RESEARCH METHODOLOGY

The research methodology is divided into three phases. The first phase includes data collection; the second phase includes data processing, and the third phase includes data analysis.

For the purposes of this research, Sentinel 2A satellite images were downloaded from the database of the European Space Agency (ESA). The Sentinel 2 mission consists of two identical satellites (Sentinel 2A and Sentinel 2B) that have multispectral sensors with 13 spectral channels (Bands) at a spatial resolution of 10, 20 and 60 m. The multispectral images that were used for the purposes of this research were recorded on June 8, 2021 for the old-growth forest Janj (Sentinel 2B) and August 15, 2021 for the old-growth forest Lom (Sentinel 2A), and downloaded on March 21, 2022 from the ESA database. The time difference between multispectral recordings is 38 days, and the reason for this is unfavorable weather conditions (high cloudiness) for recording. The recordings were chosen so that they cover the summer period when the cloud cover is low and the vegetation is in its vital phase.

The software program QGIS (version 3.22.4) was used for processing the collected multispectral images (Phase 2). Using the Semi-Automatic Classification Plugin (SCP) tool, which is a plugin within QGIS,

atmospheric correction was performed using the DOS 1 method. Atmospheric correction is performed in order to avoid imperfections that can damage the information, thereby allowing the physical surface reflectance value to be obtained without the influence of atmospheric disturbances [6].

In the third phase, an analysis of previously collected and then processed data was performed. The first step included setting the boundaries of the old-growth forests, and then two sample areas for each old-growth forest were set up within those boundaries, so that a comparative analysis could be performed. Topographical correction was not performed because the sample areas were placed so that the influence of the relief is negligible. The complete analysis was done using QGIS. The second step included the calculation of vegetation indices, the creation of graphical representations (histograms) and zonal statistics (Zonal Statistics) for each sample area, through the form of descriptive statistics.

Vegetation indices are data calculated from different channels of multispectral images based on the absorption, transmission and reflection of vegetation energy in different spectral channels. They serve as a graphic indicator of vegetation activity assessment in the observed area. Vegetation indices on areas with vegetation show higher pixel values than on areas without vegetation [7].

Chlorophyll in plants absorbs wavelengths in the red and blue parts of the spectrum, and reflects green light. Vegetation indices represent a dimensionless radiometric measure, which is obtained by combining information from different channels where the red and near infrared (NIR) parts of the electromagnetic spectrum are mainly used [8].

Using the vegetation indices: NDVI, EVI, VARI and SAVI, the vitality of the Janj and Lom old-growth stands was analyzed (Figure 3). These indices were chosen because they represent the vegetation indices that are most often applied in research of this type [6]. Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Visible Atmospheric Resistivity Index (VARI), and Soil Adjusted Vegetation Index (SAVI) were calculated according to the formulas shown in Table 1.

Table 1. Equations for calculating vegetation indices

Vegetation index	Equation	Reference
NDVI	$NDVI = \dfrac{nir - red}{nir + red}$	Rouse et al, 1973
VARI	$VARI = \dfrac{green - red}{green + red - blue}$	Gitelson et al, 2002
SAVI	$SAVI = \dfrac{nir - red}{nir + R + L} \times (1 + L)$	Huete, 1988
EVI	$EVI = \dfrac{2{,}5(nir - red)}{((nir + 6red - 7{,}5blue) + 1)}$	Justice et al, 1998

High NDVI values (0,6 – 0,9 μm) correspond to dense vegetation which can be found in temperate and tropical forests or crops at peak growth [9]. Index values are on a scale of -1 to 1, where negative values indicate the absence of vegetation cover such as cultivated areas or water bodies, while positive values refer to the existence of vegetation cover [10]. Enhanced Vegetation Index (EVI) is a modified NDVI with increased sensitivity in areas with a greater amount of biomass and with minimal soil influence. Because it uses the blue part of the spectrum, it is limited to the design of individual sensors and limited to a time period. Coefficients C1 and C2 refer to the correction of aerosols, the improvement factor is marked with G, while L is the soil factor. This index is more sensitive at high concentrations of biomass, and improves the possibilities of monitoring vegetation through the reduction of the influence of the leaf background [11].

Soil Adjusted Vegetation Index (SAVI) is applied when it is necessary to remove the influence of soil (substrate) on images with reduced vegetation cover [12]. The Visible Atmospheric Resistance Index (VARI) is designed to emphasize vegetation in the visible part of the spectrum, but at the same time mitigates differences in illumination and atmospheric effects. What is significant is that it can determine the proportion of vegetation with an error of less than 10% [13].

Within the scope of this research, an analysis of the vitality of the stands was performed on two sample plots in the Janj and Lom old-growth forests using vegetation indices. The sample plots are rectangular and the area of each plot is 5 hectares.

RESULTS AND DISCUSSION

The NDVI index varies between 0,684 to 0,897 on the sample plots. The highest mean values of the NDVI index have SP1 Janj (0,874) and SP1 Janj (0,868). The lowest mean values of the NDVI index are SP2 Lom (0,789) and SP1 Lom (0,796). Plots from OG Janj show relatively higher mean values of the NDVI index by 5%. The VARI index varies between -0,084 to 0,324 on the sample plots. Both plots, SP1 Lom (0,173) and SP2 Lom (0,166) have a higher mean value of the VARI index compared to SP1 Janj (0,122) and SP2 Janj (0,152). The SAVI index varies between 0,222 to 0,586 on the sample plots. SP1 Janj has the highest mean value of the SAVI index (0,514) and SP2 Lom has the lowest mean value (0,369). Plots from OG Janj show relatively higher mean values of the SAVI index by 14%. The EVI index varies between 0,212 to 0,629 on the sample plots. SP1 Janj has the highest mean value of the EVI index (0,533) and SP2 Lom has the lowest mean value (0,378). Plots from OG Janj show relatively higher mean values of the EVI index by 14% (Figure 2).

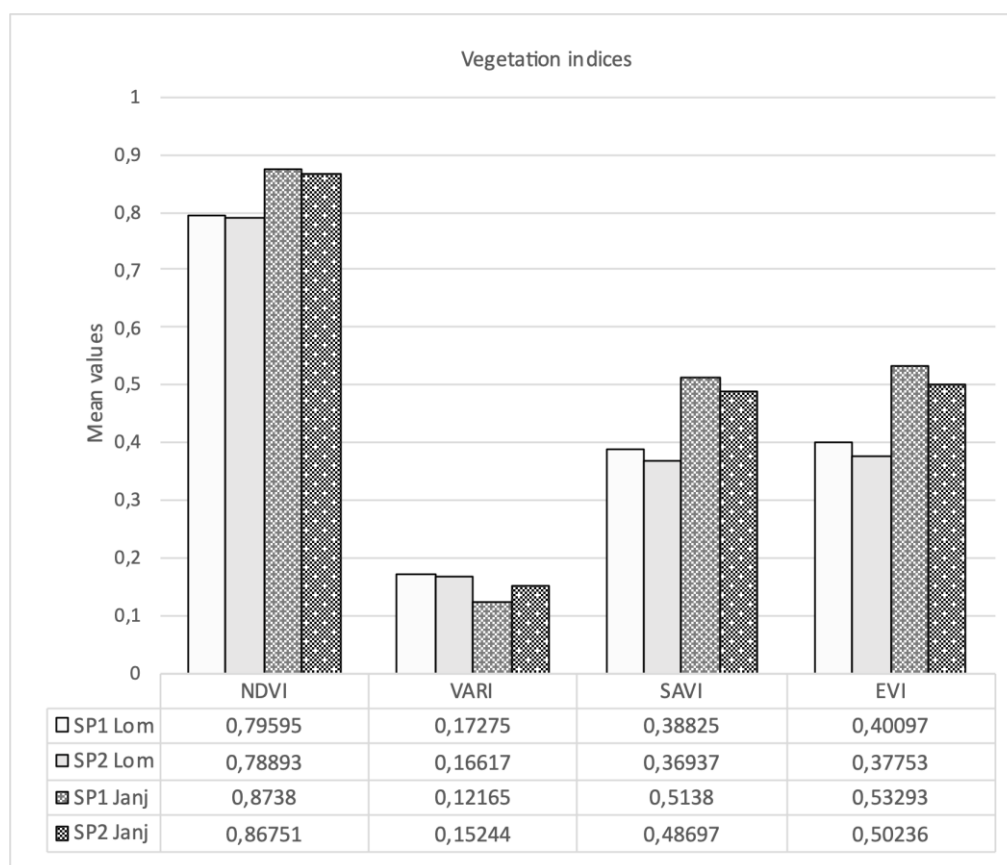| Vegetation indices	NDVI	VARI	SAVI	EVI
SP1 Lom	0,79595	0,17275	0,38825	0,40097
SP2 Lom	0,78893	0,16617	0,36937	0,37753
SP1 Janj	0,8738	0,12165	0,5138	0,53293
SP2 Janj	0,86751	0,15244	0,48697	0,50236

Figure 2. Mean values of NDVI index for all sample plots

In general, the plots from OG Janj show relatively higher all mean index values (NDVI, SAVI and EVI) compared to OG Lom with the exception of the VARI index. Higher values of the NDVI, SAVI and EVI indices in OG Janj are the consequences of higher growing stock, higher tree density, terrain without sinkholes, and potentially more retained water due to the dolomite bedrock.

VARI index reduces atmospheric effect by removing the blue channel in the [14] and VARI allowed the estimation of green vegetation fraction with an error of less than 10% [15]. The new research [16] shows that the VARI index can be used to assess the vitality of stands. According to their classification, values

from -2 to 0 indicate no longer functional trees due to vascular and leaves discoloration. Values between 0 to -0,05 indicate splitting of the trunk at the stem with stippling leaves and discoloration. Values between 0,06 to 0,16 indicate distortion of foliage and shoots dieback. Values above 0,17 indicate no sign of infestation on leaves and trunk.

The values of VARI index from the OG Janj show a lower value of 0,16 which indicates diseased trees or a higher presence of snags.

On the other side, EVI index could be more sensitive for detecting the different successional stages between intermediate-aged regenerating and primary forest [17] higher values of the index indicate a more mature phase of old-growth forest development, Figure 3.
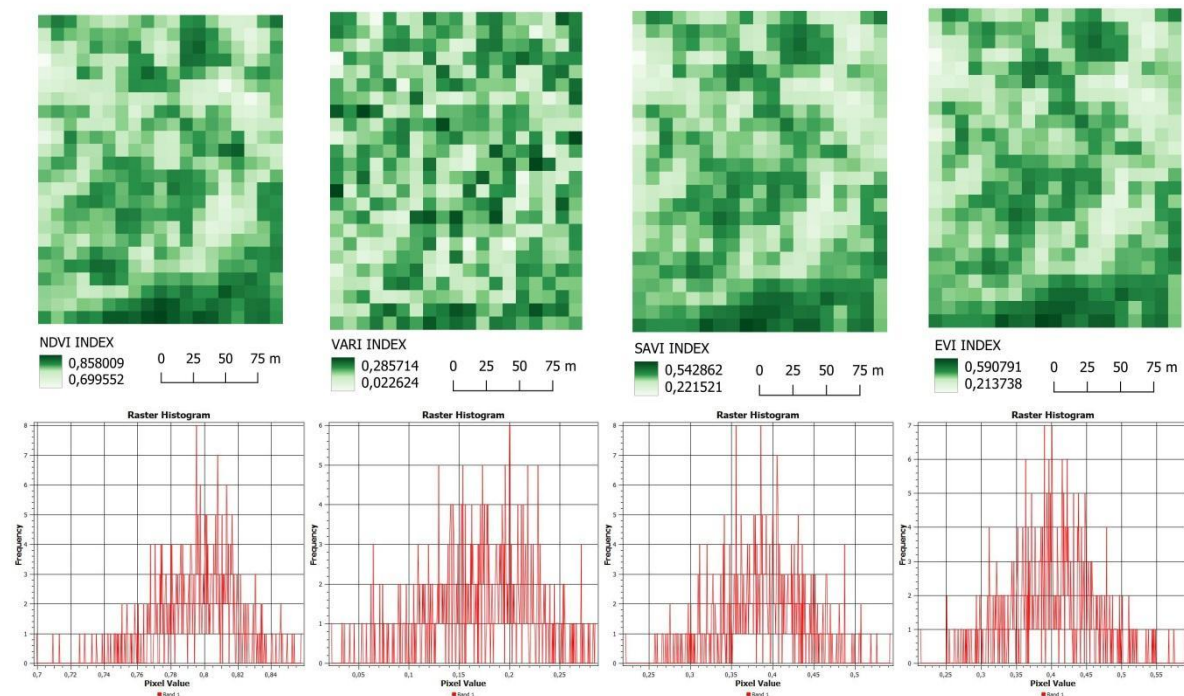

Figure 3. The values of the vegetation indices on the sample plot 1 (OG Lom)

CONCLUSION

Remote sensing and application of vegetation indices showed significant matches with previous field research of two old-growth forests in Republic of Srpska. Sample plots in OG Janj have higher values of the NDVI, SAVI and EVI indices compared to plots in OG Lom. OG Janj has a much higher overall growing stock, flat terrain without sinkholes and dolomite bedrock, which affects higher mean values of these indices. VARI index can be used to assess the vitality of trees and stands.

Higher values of VARI index in OG Lom can be related to an average volume of Coarse Woody Debris (CWD) in OG Lom (327 $m^3 \cdot ha^{-1}$) compared to OG Janj (386,5 $m^3 \cdot ha^{-1}$). Slope terrain and poor delay of snags in the top-layer of the stand due to the impact of weather disasters and the tendency of OG Janj toward the terminal phase of old-growth forest development, are potential reasons for the higher mean value of the VARI index.

Vegetation index datasets can be used as cost-effective tools in monitoring old-growth development phases. Further studies that cover different old-growth forests and direct comparative measurements in the field would be useful.

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