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Original Research Article

AN INVESTIGATION OF THE FORESTS OF PERNIK PROVINCE (WESTERN BULGARIA) BY THE USE OF THE PERPENDICULAR VEGETATION INDEX (PVI)

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A b s t r a c t

The current research represents a pilot study for application of the Perpendicular Vegetation Index (PVI) for an area with forests in Bulgaria. It is the first of its kind when it comes to forest studying in the country to the best knowledge of the author. When it comes to soil background Landsat images and other spectral data may be used for monitoring forest territories as well. The study area is Pernik Province which is located in the western parts of Bulgaria. The main aim is to investigate the PVI for the forests of Pernik Province. The index has been calculated by the application of Landsat 8 bands. The PVI has been processed for several months of different years. The main focus is both on the beginning and the end of the growing season when there are significant changes in leaf biomass. The results are promising and show typical vegetation features in the beginning of the growing season (April), a well-developed vegetation (July) and a steadily decreasing biomass in November.

Keywords: remote sensing, biomass, vegetation index, Landsat

1. INTRODUCTION

Forests represent an indispensable part of the whole ecosystem [2], [4], [5]. Vegetation indices (VI) are typically used for the investigation of these territories around the world. VIs provide plenty of data and depend on the remote sensing

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source. The Perpendicular Vegetation Index (PVI) is one of these indices. While NDVI is the most commonly used index it has some limitations, including soil emissivity. PVI fixes this issue. It was applied for several decades ago the first time when Richardson and Wiegand [12] investigated sorghum fields. PVI represents a distant-based index, which is close to a difference vegetation index. It is measuring the reflectance values given per pixel relative to the reflectance of a bare soil reference. This means that the index provides quantitative data. We can use it to distinguish areas with vegetation and areas without vegetation. There are differences in the biomass of leaves in forests in the beginning and in the end of the growing season, so a possible application of the index is to check the extend of these differences. PVI is useful for an analysis of forest physiology during different climatic seasons.

Throughout the years a number of authors used the PVI for a vast array of goals and in a number of land cover types that include vegetation [1], [3], [9], [10], [11], [13].

The current pilot study in Pernik Province is the first in Bulgaria, to the best knowledge of the author, that will be incorporating the Perpendicular Vegetation Index (PVI) in the investigation of forests. Up to now Kamenova et al. [8] and Kamenova and Dimitrov [7] have applied PVI in Bulgaria with a focus was on agricultural areas and more specifically – the winter wheat culture. The present research aims to check the index's suitability to detect differences within the vegetation during the growing season.

2. MATERIALS AND METHODS

The study area (Pernik Province) is located in the western parts of Bulgaria (Fig. 1). It is neighboring the Republic of Serbia and covers an area of almost 2400 km^2. The relief is diverse. The mountains of Zavalska, Viskyar, Lylin and Vitosha surround it from the northwest to the southeast. The mountains of Verila, Konyavska and Zemenska are lying to the south and the mountains of Ryi and Karvav kamak are to the west. The valleys of Radomirska and Breznikshka are located in-between. Climate is temperate or mesothermal Cfb according to Köppen classification.

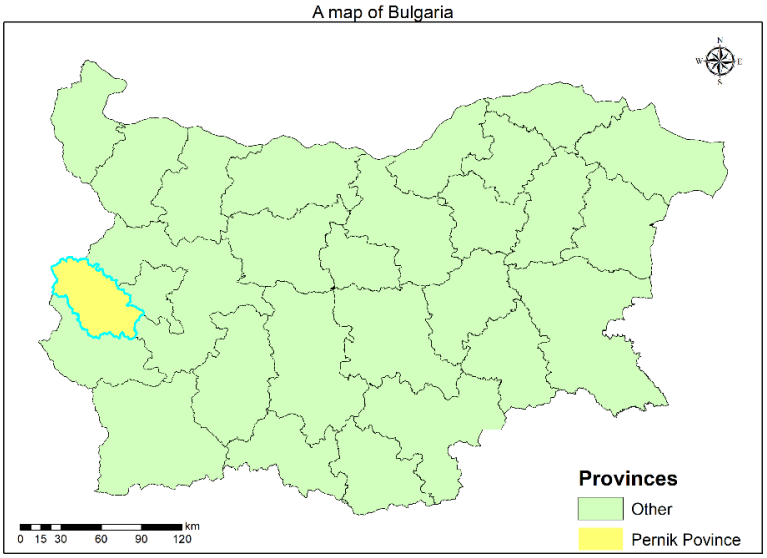


Fig. 1. Location of Pernik Province in Bulgaria

Typical land cover types for 2018 are displayed in figure 2 [15]. Artificial surfaces are covering 130.97 km^2, agricultural areas - 991.24 km^2, forests and seminatural areas - 1255.49 km^2, wetlands - 3.35 km^2 and water bodies - 10.84 km^2

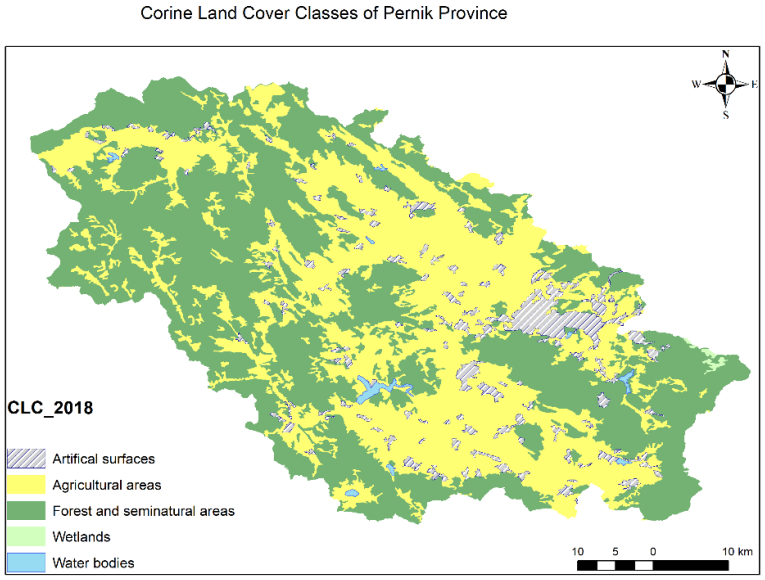


Fig. 2. Land cover of Pernik Province for 2018 [15]

Images from the Landsat Collection 2 Level-2, Landsat 8-9 OLI/TIRS C2 L2 have been downloaded from USGS EarthExplorer website [14]. Normally, the Perpendicular Vegetation Index (PVI) is being calculated with the application of the following formula:

Perpendicular Vegetation Index (PVI) = (NIR - a * Red - b) / ($\sqrt{(1 + a^2)}$), where

a—slope of the soil line
b—gradient of the soil line
NIR – pixel values from the near-infrared band
Red – pixel values from the red band [16]

The index is known to be sensitive to atmospheric variations. The values of the PVI vary between -1.0 and 1.0. The index also considers the emissivity of soil.
The PVI has been processed for seven months: April (8.4.2020), May (10.5.2020), July (5.7.2017), August (17.8.2021), September (18.9.2015), October (1.10.2014) and November (5.11.2015). The focus is on the beginning and the end of the growing season when there are significant changes in leaf biomass, that is why the choice for the particular months is not accidental. June was omitted because there were technical problems with its processing. The omission of December, January, February and March is due the presence of significant snow cover that will eventually alter the results.
Forestry data has been provided by the National Forestry Inventory. The dominant forest stands are represented by *Fagus sylvatica*, *Carpinus betulus*, *C. orientalis*, *Quercus cerris*, *Q. dalechampii*, *Q. frainetto*, *Pinus sylvestris* and *P. nigra*.
The analysis has been done by the use of QGIS 3.22.10 and ArcMap 10.6.1.

3. RESULTS

Figure 3 shows PVI values for April. The prevailing low PVI values is a proof for typical vegetation features in the beginning of the growing season. Leaf biomass is still building up. When the results are compared to those for July (Figure 4), an obvious difference is comes to being.

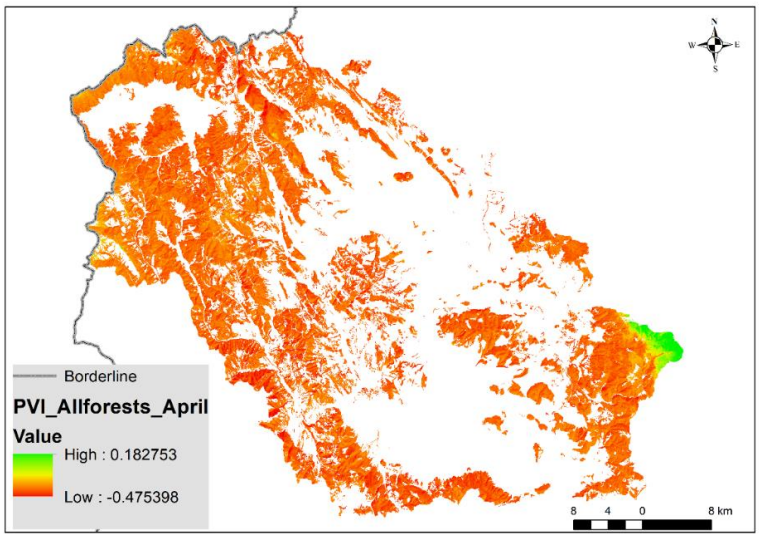


Fig. 3. PVI map of the forests in April

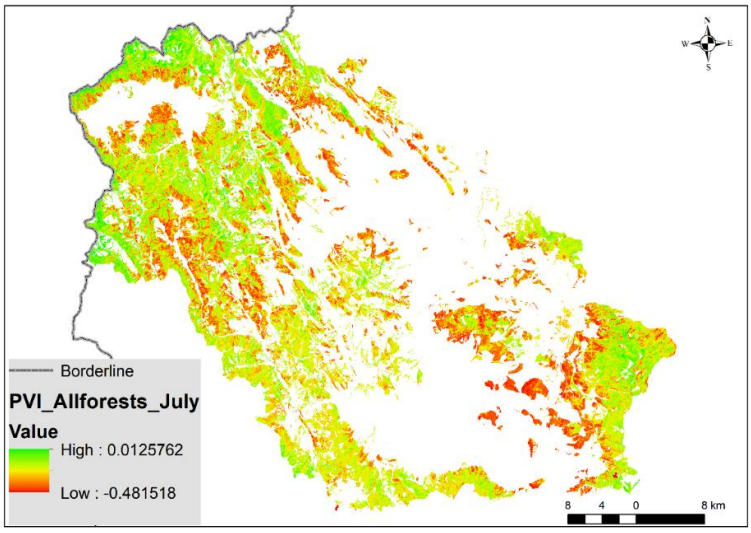


Fig. 4. PVI map of the forests in July

Forest vegetation is well-developed in July (Figure 4). There is a strong correlation between the low values and the presence of coniferous forests. A large proportion of the areas with low PVI values is covered with forests, dominated by

Pinus sylvestris and *Pinus nigra*. At the same time, territories in the green spectra that are resenting high PVI values, are covered by broadleaved forests. Jinguo and Wei [6] identified forest vegetation using vegetation indices, including PVI, they concluded that the index can be used for the identification of broadleaved and coniferous forests and the current study supports this as well.

Figure 5 displays PVI values for the forests of Pernik Province in November, which is at the end of the growing season. Leaf biomass is steadily decreasing, when it comes to broad-leaved species. At the same time, coniferous forests are still green and vital. A large proportion of the areas that were with high PVI values in July have now moved to the opposite direction and this is more valid for territories with broad-leaved forests.

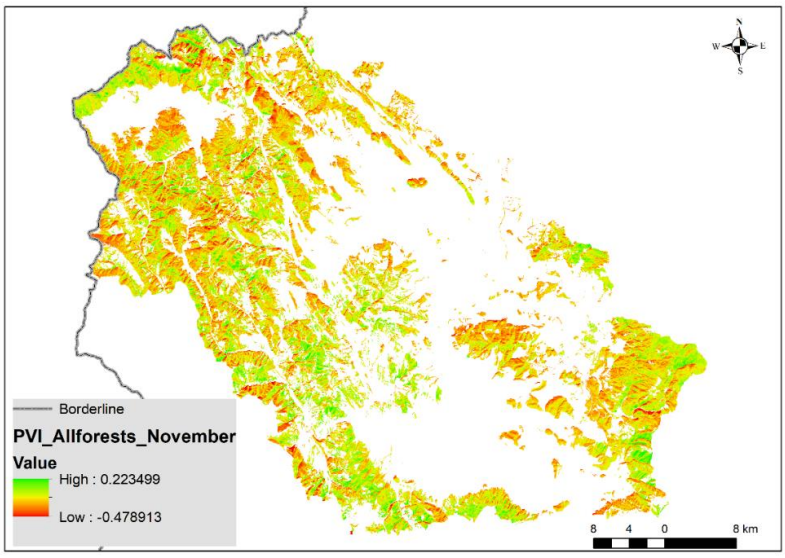
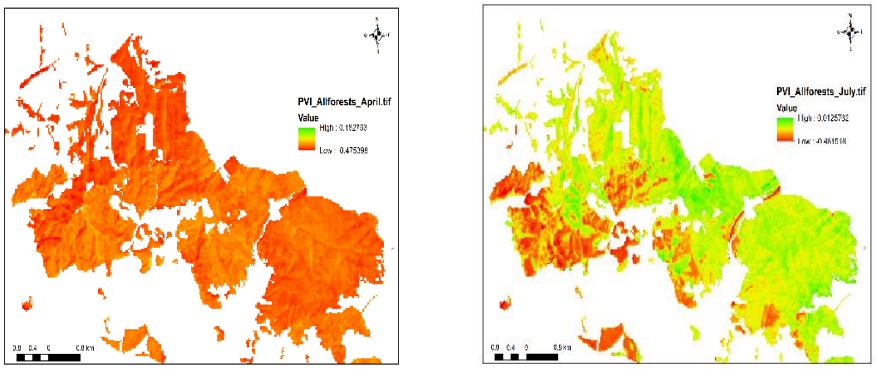


Fig. 5. PVI map of the forests in November

Figure 6 presents large-scale maps of eastern parts of Pernik Province. It may be used to observe some specifical forestry particularities that are following the already established patterns in the sections above.

a b



c

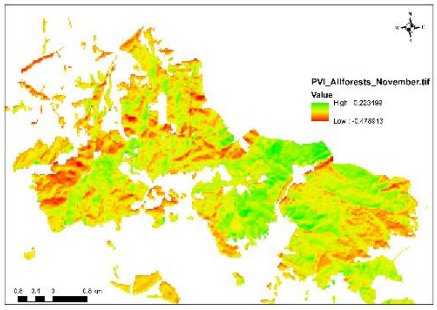


Fig. 6. Large-scale PVI maps of the forests in April (a), July (b) and November (c) in eastern parts of Pernik Province.

4. CONCLUSIONS

The use of satellite imagery in scientific research today is almost a must. It provides a vast array of opportunities for analysis. The current research dealt with Landsat 8 data and the forests of Pernik Province were analyzed by the application of Perpendicular Vegetation Index (PVI). Seven different months were picked up, marking key moments of the growing season. The index's values proved the presence of differences in the beginning and the end of the growing season. Negative values were the same for the different months and positive values increased, starting from the months with well-developed leaf biomass. The application of PVI has also provided specific data for analysis that allows us to distinguish coniferous from broadleaved forests.

More work needs to be done, regarding the incorporation of the Perpendicular Vegetation Index in the studying of forests in Bulgaria. There are still a lot of uncertainties, yet the results of the current investigation are showing promise and they can be used as a basis for more in-depth research.

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