environmental sciences proceedings

Proceedings

Application of Tasseled Cap Transformation of Sentinel-2 - MSI Data for Forest Monitoring and Change Detection on territory of Natural Park "BLUE STONES" †

Andrey Stoyanov[1], *

[1] Space Research Technology Institute Bulgarian Academy of sciences, Sofia 1113, str. "Acad. Georgy Bonchev" bl. 1; e-mail: andreiIKIT@space.bas.bg
* Correspondence: e-mail: andreiIKIT@space.bas.bg
† Presented at the title, place, and date.

Abstract: The goal of the present research is monitoring the forest vegetation's condition and detect changes occurred in the territorial disturbance of the forest cover in the area of Natural Park "Blue Stones", located in Bulgaria, by the use of combinative approach of Remote Sensing's methods. Tasseled Cap Orthogonal Transformation is applied to the selected satellite images, resulting in three segmented TCT components - *"brightness"*, *"greenness"* and *"wetness"*. On the basis of the *"greenness"* component from different temporal points (satellite scenes), Normalized Differential Greenness Index has been calculated which is giving an accurate and precise data on dynamics of the forest vegetation for short-termed and long-termed time periods.

Keywords: forest monitoring; Sentinel-2; Tasseled Cap Transformation; *greenness*; NDGI;

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Environ. Sci. Proc.* **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Firstname Lastname

Published: date

1. Introduction

In the Balkans, in the Southeastern part of Bulgaria, above the town of Sliven, over an area of 11380 ha is situated The Natural Park "Blue Stones" (Figure 1). The specific climate and lay conditions of the park determines the great diversity of flora and fauna. The territory of the park is covered with mono-dominant and mixed broadleaf forests (9000 ha) and 600 ha are covered with conifers [1]. It was created in 1980 as a national park to preserve and protect the forest formations of the species *Fagus sylvatica ssp. moesiaca* and *Fagus orientalis*. Other forest formations in the park are presented by species of: *Qvercus sessiliflora*, *Carpinus betulus*, *Qvercus cerris*, *Qvercus conferta*, *Acer pseudoplatanus*, *Carpinus orientalis*, *Tilia tomentosa* [1].

The **aim** of the following study is advantages of the proposed TCT model for segmenting Sentinel-2 imagery [2] to be used for needs of forest vegetation monitoring and the spatial disturbance's change detecting of forest cover. Short-termed and long-termed temporal periods when the forest vegetation's phenophase is most active (from April to August) were chosen as a different time frame suitable for application of NDGI and analyzing its quantitative values.

The Tasseled Cap Transformation (TCT) first developed by Kauth and Thomas was initially applied as a data compression and visualization tool from the Landsat-1 Multispectral Scanner (MSS) to extract information about the features and characteristics of agricultural lands [3]. Kauth and Thomas envisioned the creation of TCT by comparing the phenological characteristics of vegetation from a given image with the overall structure and shape of the reflectance data represented in multidimensional spectral space [3]. The main advantage of TCT is its ability to visualize multi- and hyperspectral data from satellite imagery in a condensed and meaningfully defined feature space [4]. TCT can also be used as a vegetative index, which is an indicator for evaluating the "healthy" state of vegetation and for evaluating changes that have occurred on the earth's surface [5, 6].

2. Materials and Methods

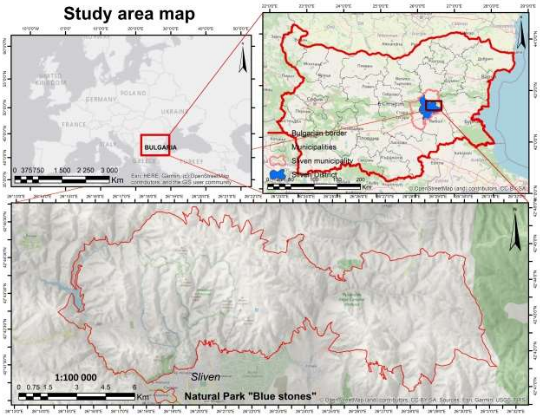


Figure 1. Study area map.

In the following research imagery data from mission Sentinel 2-MSI of the European Space Agency (ESA) is used [7]. Multi Spectral Instrument (MSI) register data in the optical bands with variable spatial and spectral resolution. For the MSI the 13 spectral bands span from the visible (VIS) and the near infra-red (NIR) electromagnetic spectrum regions to the short wave infra-red (SWIR) one (Table 1.).

Table 1. Satellite imagery used

Satellite, sensor	Date of aquisition	Spectral band	GSD (m)
Sentinel 2-MSI	10.06.2017 24.08.2017 31.05.2018 19.08.2018 25.04.2020 15.05.2020 28.08.2020 25.05.2021 08.08.2021	All spectral channels [7]	10x10 20x20 60x60

The proposed Tasseled Cap Transformation model for orthogonalization of satellite images from Sentinel-2 has been proven as a highly effective method for interpretation, classification, and analysis of phenomena and processes related to the dynamic changes of the main Earth Surface 's components: *soil*, *vegetation* and *water* [2,5]. The matrix of TCT for Sentinel 2 was developed and created by Roumen Nedkov [2], and is extracting the information contained in all 13 spectral channels of the MSI sensor resulting in three clusters -*"brightness"*, *"greenness"* and *"wetness"*.

Normalized Differential Greenness Index (NDGI) (equation.1) is created on the basis of *greenness* component derived through decomposing of optical satellite images by the applied orthogonal TCT matrix [8]. "NDGI reflects the vegetation's dynamics change depending on the temporal period. The index have ranging values from - 1 to + 1, which are corresponding to vegetation's negative and positive changes that had been occurred [8].

$$\boldsymbol{NDGI} = \frac{GR_n(t_2) - GR_n(t_1)}{|GR_n(t_2)| + |GR_n(t_1)|}, \quad (1)$$

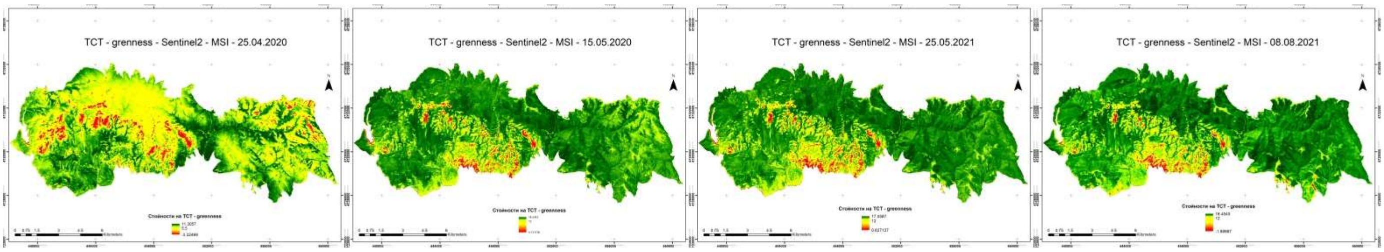
where $GR_n(t_1)$ and $GR_n(t_2)$ represent the normalized values of the *greenness* component at time points t_1 and t_2, and $|GR_n(t_1)|$ and $|GR_n(t_2)|$ represent the absolute values of the same components [8].

The most commonly used vegetation indices (e.g. NDVI) are not sufficiently sensitive to the minimal changes in the state of the vegetation that have occurred, which is most noticed in the studies on the restoration processes of forest ecosystems after a fire [9]. The three differentiated classes obtained as a result of the applied orthogonalization are highly sensitive to the minimal changes that occur in the requirements of the vegetation. When NDGI values are less than 0, it indicates that negative changes in vegetation condition have occurred. When they are above 0, there are positive changes, and the degree of changes corresponds to the obtained index values. Extreme values – NDGI = –1 reflect complete degradation of vegetation, while NDGI = +1 indicates intensive increase in leaf biomass or growth of vegetation. This indicates that the positive and negative values of the index represent a quantitative scale that can be used to assess the changes in vegetation that have occurred [8].

Based on the *greenness* component, of each selected time point, NDGI values were generated for short-term periods: between the "spring" and "summer" images for each of the years 2017, 2018, 2020 and 2021 including one super short-term period of 20 days (25.04.20 -15.05.20) as a showcase “capturing” the leaf growth of forest vegetation in areas around 600-700 m a.s.l., and for long-term periods: between the "spring" and between the "summer" images for each of the years.

3. Results and Discussion

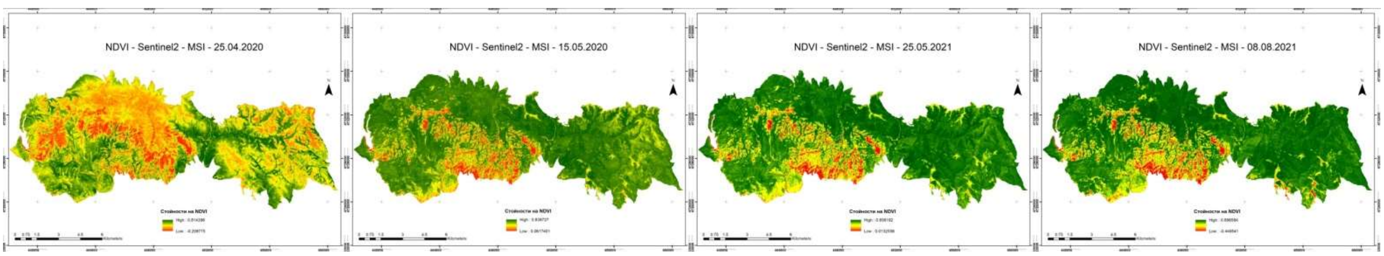
On Figure 2. maps with the *greenness* component of *spring* and *summer* temporal points, serving as input data for generating NDGI, are shown as a showcase for the years 2020 and 2021.



(**a**) (**b**) (**c**) (**d**)

Figure 2. Maps of TCT - *greenness* component values from: (**a**) 25.04.2020; (**b**)15.05.2020; (**c**) 25.05.2021; (**d**) 08.08.2021.

On Figure 3. maps with the NDVI values of the same temporal points from Figure 2 are shown which served as a reference data for interpratation and as a base for comparative analysis between the values of TCT-*greenness* component and those of NDVI. The TCT-*greenness* values are showing a bit more detailed information about the territorial distribution of vegetation compared to that of the NDVI values.

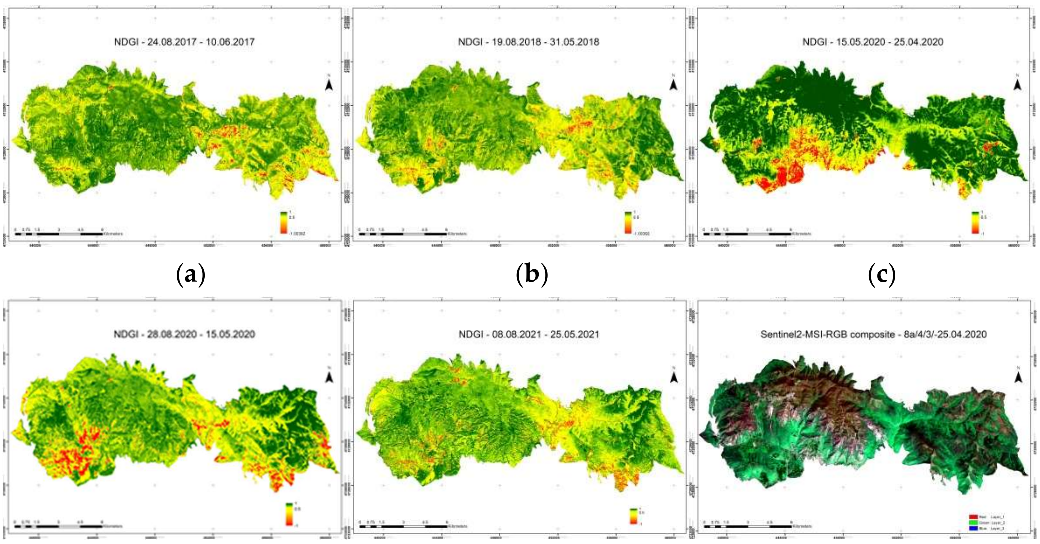


(**a**) (**b**) (**c**) (**d**)

Figure 3. Maps of NDVI values from: (**a**) 25.04.2020; (**b**)15.05.2020; (**c**) 25.05.2021; (**d**) 08.08.2021

3.1. short-term temporal periods of NDGI

On Figure 4. Maps with the spatial distribution of the NDGI values for short-term temporal periods are shown. The values of NDGI represent the spectral reflectance characteristics (SRC) of the vegetation recorded by the sensor, indicating the maximum and minimum changes that occurred. After a long comparative and visual analysis of the histograms (including those in the *visible* spectrum) and using the borderline between grassland and forests as a benchmark, an optimal threshold of 0.5 was set in order pixels with values above it to correspond with the areas covered by forest vegetation. This was also done for values of the TCT-*greenness* component. All pixels in green color (NDGI > 0.5) represent areas of the Earth's surface where positive changes in forest vegetation status occurred during the period, the new vegetation that developed during the given period (including vegetation on streams and river valleys, low bushes, etc.). Pixels in yellow color (NDGI ≥ 0 ≤ 0.5) represent areas where minimal or no positive changes in vegetation status occurred during the period. Pixels with red color (NDGI < 0) represent areas of the earth's surface where negative changes in the state of vegetation have occurred (due to drought, logging, dried grass formations, etc.) or correspond to terrains occupied by rock formations, where vegetation is absent. In the case of 20-days period (Fig. 4c) saturation of the green color is due to the defoliation of the forests in the high altitude areas occurred during the period.



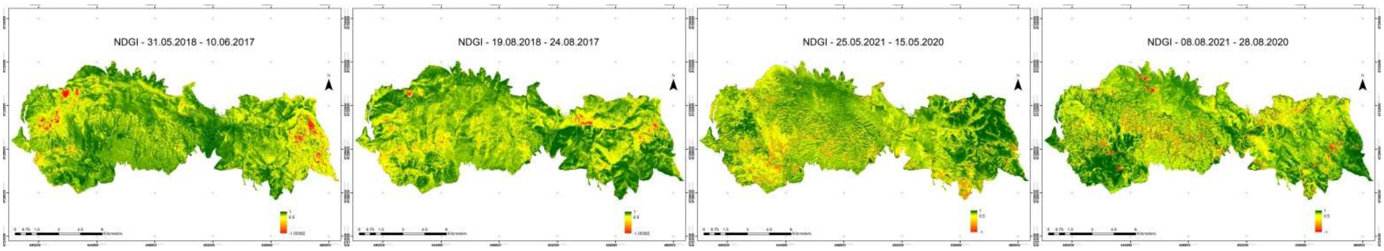
(**a**) (**b**) (**c**)

(**d**) (**e**) (**f**)

Figure 4. Maps with NDGI values for short-term periods: (**a**) 10.06.17 – 24.08.17; (**b**) 31.05.18 – 19.08.18; (**c**) 20-days period 25.04.20 – 15.05.20; (**d**) 15.05.20 – 28.08.20; (**e**) 25.05.21 – 08.08.21; (**f**) RGB composite in band combination 8a/4/3 from 25.04.20.

3.2. long-term temporal periods of NDGI

The used approach for monitoring vegetation is more suitable for studies whose time periods are short-term because it allows the tracking of vegetation dynamics in very short time intervals. This approach can also be used to monitor the development of agricultural crops (with a shorter growing season), fires, droughts, soil moisture calculation, etc. [10, 11, 12]. However, the presented results on Figure 5 including one-year periods are showing what changes had been occurred in the current state of the vegetation in comparison with that of the previous year.



(**a**) (**b**) (**c**) (**d**)

Figure 5. Maps with NDGI values for long-term periods (**a**) 10.06.17 – 31.05.18; (**b**) 24.08.17–19.08.18; (**c**) 15.05.20 – 25.05.21; (**d**) 28.08.20 – 08.08.21.

On figure 6. Change detection map is shown the green pixels are showing the restoration in the forest vegetation and in the forest road after a legal logging occurred in 2014 for the period 2015-2021, and the denser red lines are new forest roads, the red spot below the peak of Karaborun is a new logging site developed in 2020.

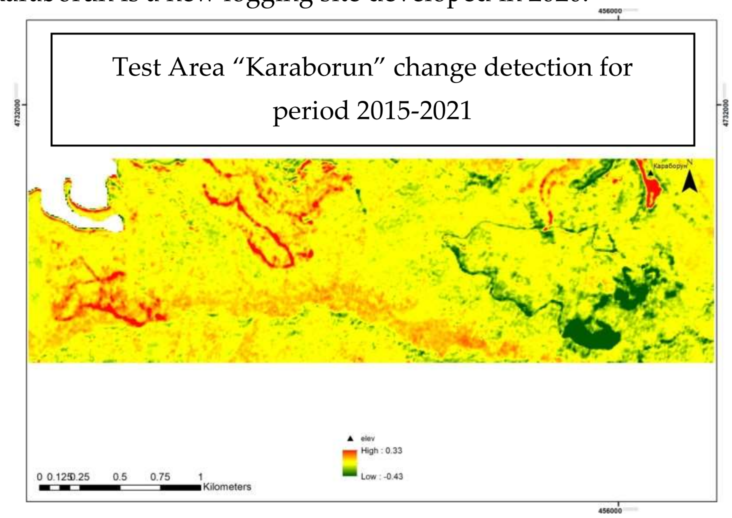


Figure 6. Map of change detection in forest vegetation for period of 2015-2021.

4. Conclusions

The applied methodology for forest monitoring can be used for accurately and precisely determination of the spatial distribution and quantitative assessment of the forest cover on the territory of the Natural Park "Blue Stones" for the selected temporal periods. The use of matrix for Orthogonal transformation is another way of extracting and processing the satellite imagery for the purpose of monitoring Earth surface’s main components: soil, vegetation and water. The setting of the threshold of the NDGI values for masking out the forest vegetation and the interpretation and validation of the results are still in experimenting level and in the future they will still undergo development. The proposed forest monitoring method can be integrated into forest management, forestry and forest resource inventory.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

Funding: This research received no external funding

Institutional Review Board Statement: “Not applicable”

Data Availability Statement: Not applicable

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The author declare no conflict of interest

References

1. http://dppsk.org/en/flora/
2. Roumen Nedkov. Orthogonal Transformation of Segmented Images from the Satellite Sentinel-2. *Comptes rendus de l'Academie bulgare des Sciences, 70, 5, Prof.Marin Drinov Publishing House of Bulgarian Academy of Sciences*, **2017**, ISSN:1310–1331, 687-692.
3. Kauth, R.J., & Thomas, G.S., Tasselled Cap – A graphic description of the spactral-temporal developement of agricultural crops as seen by Landsat. *In*, *Symposium on Machine Processing of Remotely Sensed Data* **1976**. (pp. 41–51). West Lafayette, IN, USA: NTC Conference Record – National Telecommunications Conference.
4. Yarbrough Lance D, **2006**, Thesis for: PhD, "The Legacy of the Tasseled Cap Transform: A Development of a More Robust Kauth-Thomas Transform Derivation", The University of Mississippi.
5. Crist, E.P., & Cicone, R.C. Application of the Tasseled Cap concept to simulated Thematic Mapper data. *Photogrammetric Engineering and Remote Sensing*, *50*, **1984** 343–352.
6. Baig, M.H.A.; Zhang, L.; Shuai, T.; Tong, Q. Derivation of a tasselled cap transformation based on Landsat 8 at-satellite reflectance. *Remote Sens. Lett.* **2014**, *5*, 423–431.
7. https://sentinel.esa.int/web/sentinel/missions/sentinel-2
8. Nedkov R.. Normalized Differential Greenness Index for Vegetation Dynamics Assessment. *Comptes rendus de l'Academie bulgare des Sciences, 70, 8, Prof. Marin Drinov Publishing House of Bulgarian Academy of Sciences*, **2017**, ISSN:1310–1331, 1143-1146.
9. Stankova N., Nedkov R., 2015, Monitoring forest regrowth with different burn severity using aerial and Landsat data, *In: Geoscience and remote Sensing Symposium (IGARSS), IEEE International*, 26-31 July **2015**, 2166-2169, doi: 10.1109/IGARSS.2015.7326233.
10. Daniela Avetisyan, Roumen Nedkov, "Monitoring the dynamics of phenological development of winter wheat using orthogonalization of multispectral satellite data", *Proc. SPIE 11528, Remote Sensing for Agriculture, Ecosystems, and Hydrology XXII, 115280Y* (20 September **2020**); doi: 10.1117/12.2573274.
11. Roumen Nedkov, Emiliya Velizarova, Daniela Avetisyan, Nikolay Georgiev, "Assessment of forest vegetation state through remote sensing in response to fire impact," *Proc. SPIE 11524, Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020), 115240Q* (26 August **2020**); doi: 10.1117/12.2570808.
12. Emiliya Velizarova, Roumen Nedkov, Daniela Avetisyan, Kameliya Radeva, Andrey Stoyanov, Nikolai Georgiev, Iliyana Gigova.(2019) Application of remote sensing techniques for monitoring of the climatic parameters in forest fire vulnerable regions in Bulgaria. *Proc. SPIE 11174, Seventh International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2019), 111741E* (27 June **2019**); doi: 10.1117/12.2533656.