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Monitoring of forest areas based on remote sensing images

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Abstract Monitoring forest areas based on remote sensing technologies is very useful in the context of sustainable development and their efficient and safe management. This study aims to analyse and characterize the dynamics during 7 years of the Domogled National Park - Cerna Valley in Caras Severin County, based on GIS technologies and Landsat 8 images, vegetation indices and specialized programs. Domogled National Park - Cerna Valley is a naturally protected area located in the south-western part of Romania, on the territories of the Caraş - Severin, Mehedinți and Gorj wetlands. Since 1932, the Domogled Mountain Floristic and Landscape Reserve has been established here, one of the 11 reservations in the current park. Over 58 years, in 1990, the area became Domogled - Valea Cernei National Park, which covers an area of over 61 thousand hectares. These secular beech forests must be preserved, in their current state, for their social and conservative value, and not for production. Secular beeches are part of a landscape of great cultural and natural value, in which the local community has offered us for hundreds of years an example of living in communion with nature and preserving the Romanian architecture and traditions in the Banat Mountain area, which ensures an exceptional value for the national park, attracting many tourists annually. Based on the spectral bands of the Landsat 8 system, NDMI, NDBR, NDVI, NDWI vegetation characterization indices were calculated. The values of the vegetation indices were analysed, from the aspect of statistical security, based on the appropriate statistical-mathematical methods (p, R^2, F-test), and to highlight a series of interdependence relations between certain indices, regression analyzes were used. The basis of which polynomial functions with related safety parameters have results. Based on the values of the correlation coefficient between the studied indices, interdependence relations were analysed in the case of indices with a good correlation. Thus, the NDVI variation relative to NDWI was described under conditions of $R^2 = 0.981$, $p < 0.01$, and the NBR variation relative to NDMI was described under conditions of $R^2 = 0.854$, $p < 0.01$.

Key words

vegetation indices, forest monitoring, Landsat 8, NDVI, NDMI, NBR, MNDWI

Monitoring forest areas based on remote sensing technologies is very useful in the context of sustainable development and efficient management [20] and their safety [11; 21]. Remote sensing methods, techniques and technologies are increasingly used in the study and monitoring of agricultural land [19; 1], forest [8], vegetation or urban areas [3; 4]. Spectral information is very useful and has a high precision in characterizing large areas of land [9; 10]. This study aims to analyze and characterize the dynamics over 7 years of Domogled National Park - Cerna Valley in Caras Severin County, based on GIS technologies [16] and Landsat 8 images, vegetation indices [6] and specialized programs [13. Domogled National Park - Cerna Valley is a protected natural area located in the southwestern part of Romania, on the territories of Caraş-Severin, Mehedinți and Gorj counties. Since 1932, the Mount Domogled Floristic and Landscape Reserve has been established here, one of the 11 reservations in the current park. Over 58 years, in 1990, the area becomes Domogled - Valea Cernei National Park, which covers an area of over 61 thousand hectares [23].

These secular beech forests must be preserved, in their current state, for their social and conservative value, and not for production. Secular beeches are part of a landscape of great cultural and natural value, in which the local community has offered us for hundreds of years an example of a way of life in communion with nature and preserving the Romanian architecture and traditions in the Banat Mountain area, which ensures an exceptional value for the national park, attracting many tourists annually [23].

Material and Method

The main purpose of this research was to monitor the vegetation dynamics within the Domogled Valea Cernei National Park based on remote sensing images from the Landsat 8 system [7; 24; 25; 26; 27].. Satellite images that were used to characterize the arboreal vegetation were taken from the portal www.planet.com si sunt din perioada 2013-2019 [17].

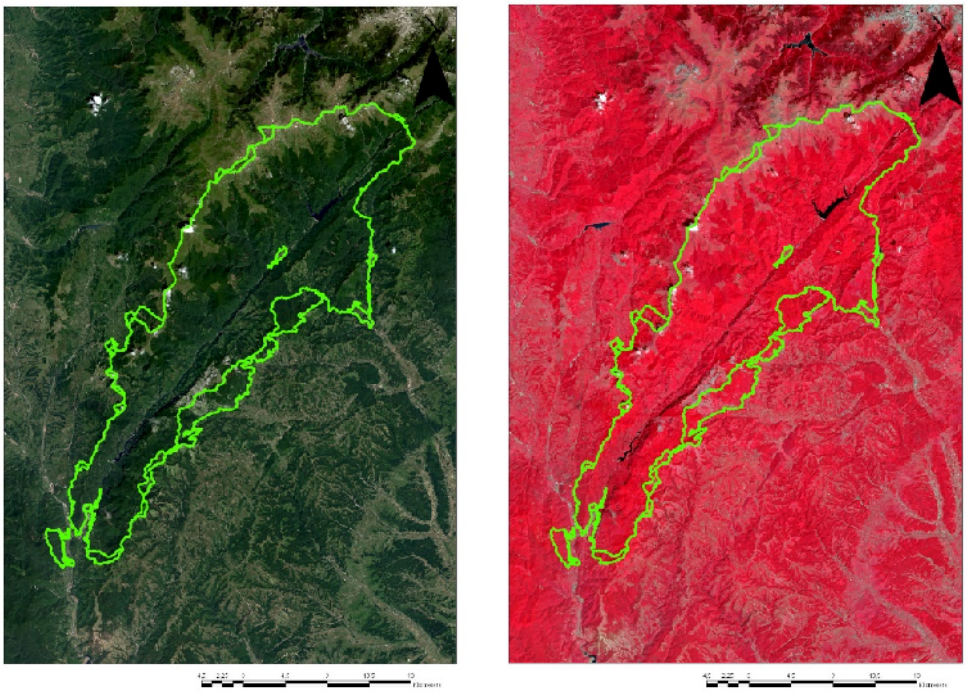

Figure 1. The combination of Red Green Blue and NIR Red Green for the studied area

In order to process these images for the 7 years analysed, the programs ArcGIS v. 10.5, Erdas Imagine 2014, Past and Microsoft Excel were used [5].

Based on the spectral bands of the Landsat8 system, vegetation characterization indices were calculated NDMI [12], NDBR [14; 15; 22], NDVI [18], NDWI (with a modified formula from the initial one) [2] relations (1), (2), (3) and (4).

$$NBR = (NIR - MIR)/(NIR + MIR) \quad (1)$$

$$NDVI = (NIR - RED) / (NIR + RED) \quad (2)$$

$$NDMI = (NIR - RED) / (NIR + RED) \quad (3)$$

$$MNDWI = (Green - SWIR) / (Green + SWIR) \quad (4)$$

Results and Discussions

Based on formulas (1) - (4), the maps of each described index were generated, figures 2 - 5, using the ArcGIS v. 10.5 software and the images preprocessed with the Erdas Image 2014 software. The average values of the studied indices, calculated for each year are shown in table 1.

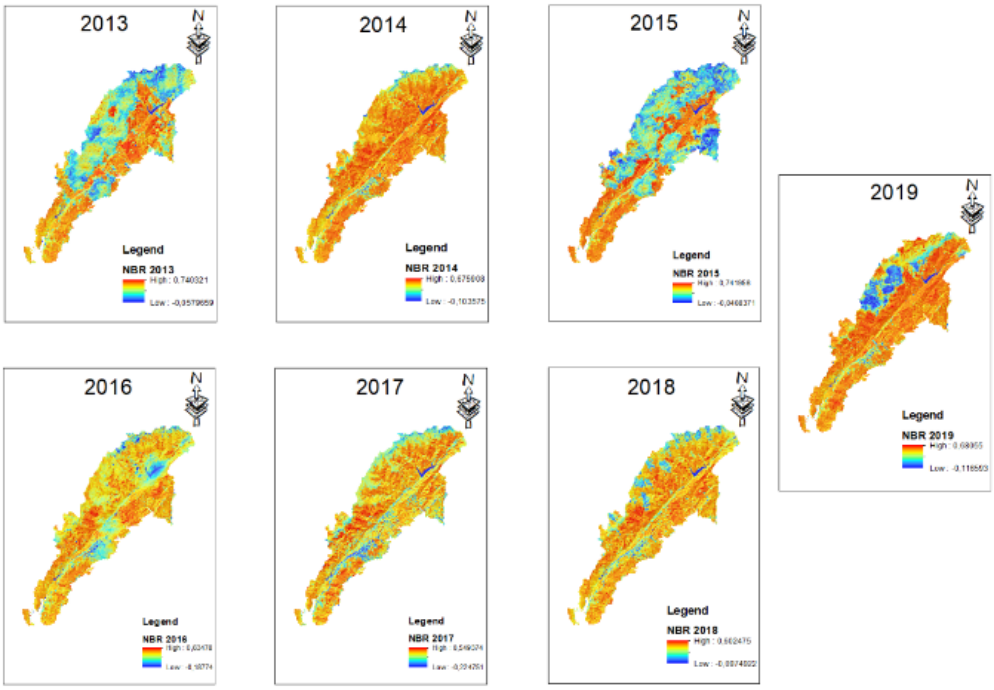

Figure 2. The Map of NBR index

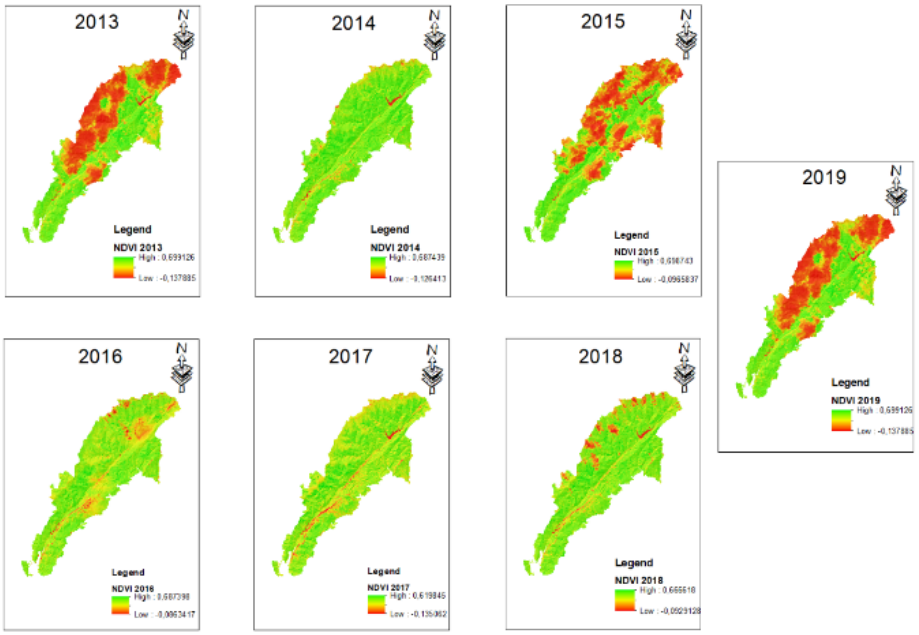

Figure 3. The Map of NDVI index

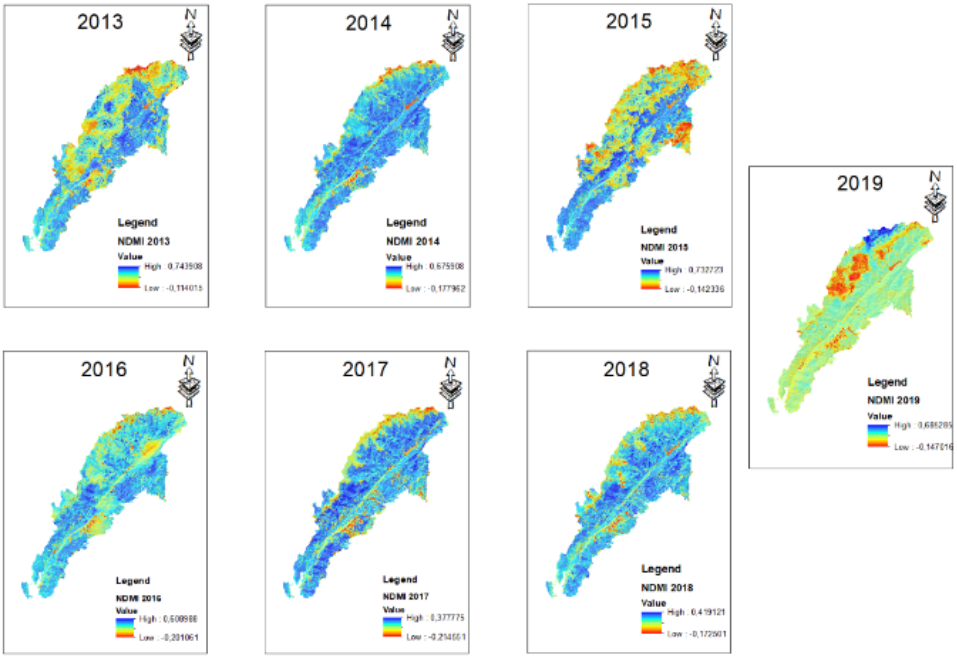

Figure 4. The Map of NDMI index

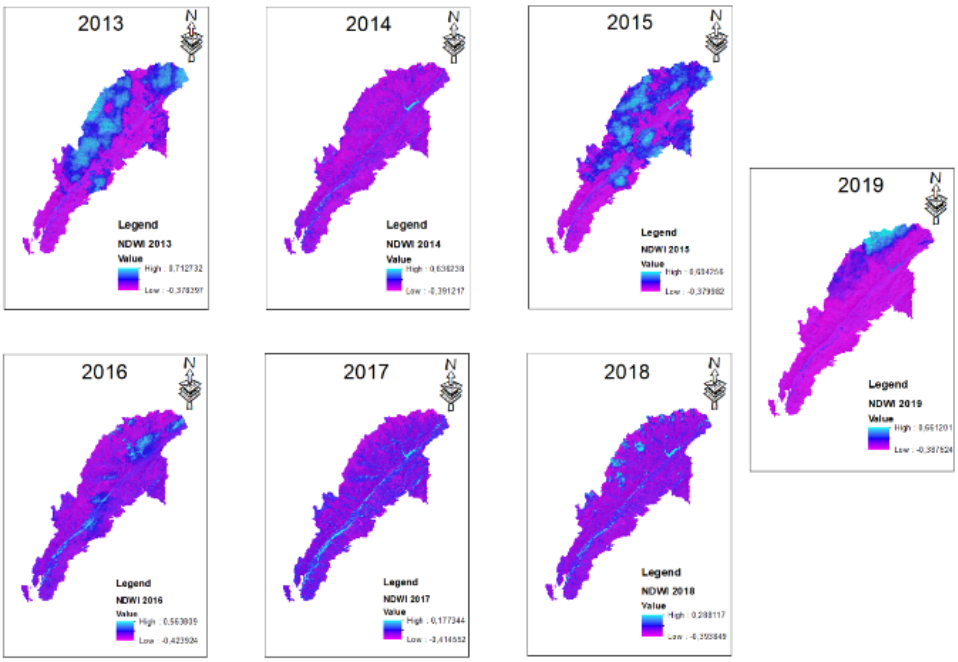

Figure 5. The Map of NDWI index

The values of the indices for Domogled National Park, period 2013 - 2019 are presented in table 1.

Table 1

Index values NBR, NDVI, NDMI, NDWI

	NDMI	NDWI	NDVI	NBR
2013	0.251914	-0.071367	0.338173	0.400253
2014	0.282347	-0.230127	0.538072	0.464052
2015	0.248629	-0.078151	0.341907	0.387522
2016	0.250638	-0.212170	0.488711	0.427921
2017	0.197611	-0.187132	0.412765	0.356372
2018	0.225787	-0.191454	0.447544	0.398582
2019	0.279154	-0.161429	0.338173	0.447412

The values of the vegetation indices were analysed, from the aspect of statistical security, based on the appropriate statistical-mathematical methods (p, R^2, test F), and to highlight a series of interdependence relations between certain indices, regression analyses were used (Table 2, 3) on the basis of which polynomial functions with afferent safety parameters have results (Figure 6, 7, 8, 9).

Table 2

ANOVA single factor

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.547018646	3	0.515672882	162.5723285	4.46496E-16	7.554460812
Within Groups	0.076127034	24	0.00317196			
Total	1.62314568	27				

Table 3

Correlation table

	NBR	*NDVI*	*NDMI*	*NDWI*
NBR				
NDVI	0.405			
NDMI	0.913	0.075		
NDWI	-0.403	-0.858	-0.011	

Based on the values of the correlation coefficient between the studied indices, interdependence relations were analysed in the case of indices with a good correlation. Thus, the NDVI variation in relation to NDWI was described by equation (5), under conditions of $R^2 = 0.981$, $p < 0.01$, and the graphical distribution is shown in figure 6.

$$NDVI = 145.37x^3 + 85.087x^2 + 13.635x + 0.9428 \quad (5)$$

where: x – NDWI index

The variation of NBR in relation to NDMI was described by equation (6), in conditions of $R^2 = 0.854$, $p < 0.01$, and the graphical distribution is shown in figure 7.

$$NBR = 6.4303x^2 - 1.9578x + 0.497 \quad (6)$$

where: x – NDMI index

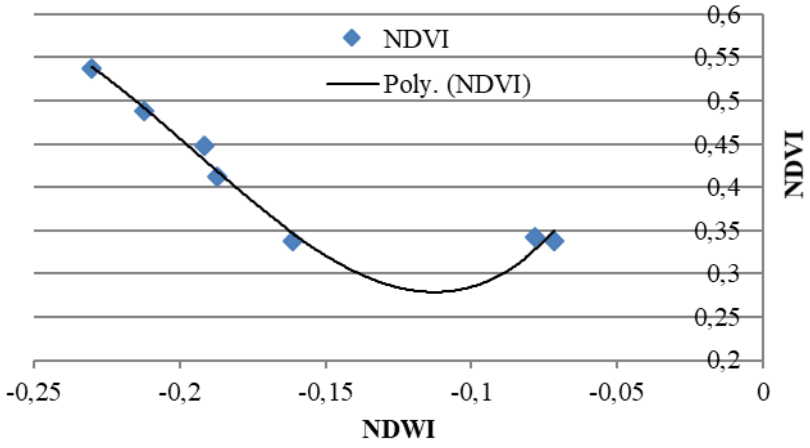

Figure 6. The variation of NDVI based on NDWI

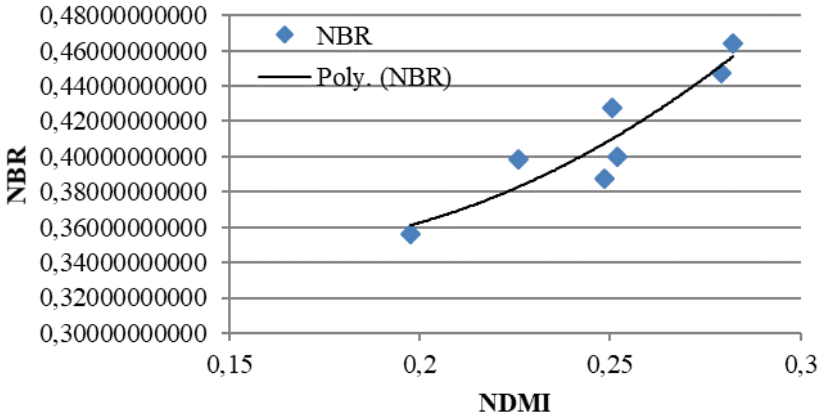

Figure 7. The variation of NBR based on NDMI

The PCA analysis led to the distribution in Figure 8, where PC1 explained 79,081% of the variance, and PC2 explained 15,291% of the variance. From the spectral information contained in the analysed images, as an expression of the ground reality studied, and the calculated index values, it was found the differentiated grouping of the years studied, 2013, 2015 with NDWI, 2019 with NDMI and NBR, 2016 (partially 2014 and 2018) with NDVI, and the year 2017 had a relatively independent position in relation to the studied indices.

Cluster analysis led to grouping of variants according to time of remote sensing acquisition based on affinity and resulted in the diagram in Figure 9 under moderate statistical accuracy (Coph.corr. = 0,791).

Conclusions

The main purpose of this study was to monitor for 7 years - 2013 -2019 - the Domogled Valea Cernei National Park based on remote sensing images from the Landsat 8 system.

Mathematical functions were found that expressed the interdependence between indices.

The PCA analysis facilitated the distribution and association of the years of the study period in relation to the values of the indices calculated based on the spectral data and explained the variant in the set of results.

The cluster analysis facilitated the grouping of the years from the study period, based on similarity in relation to the values of the studied indices and which reflected the condition of the vegetal carpet in the study area.

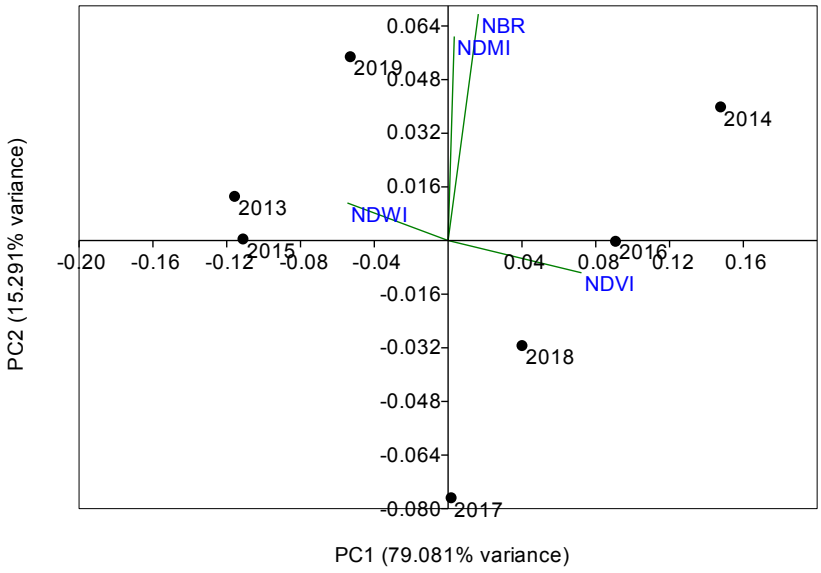

Figure 8. The graph of PCA analysis

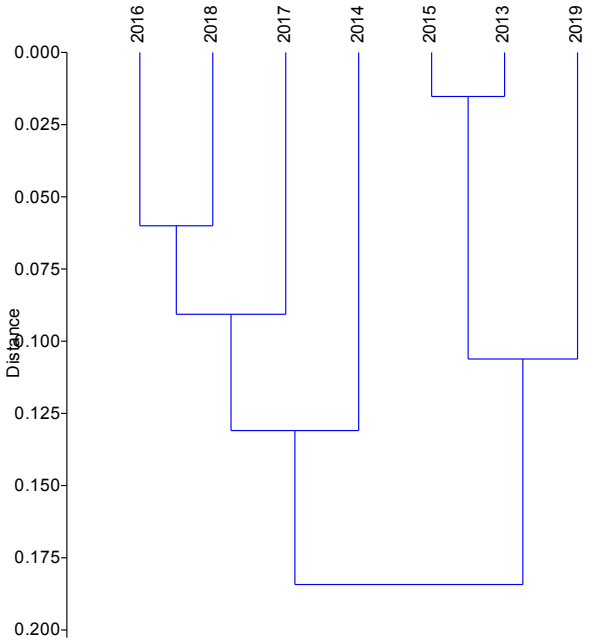

Figure 9. Cluster analysis chart

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References

1. BADULESCU, C., MARCHIS, D. M., NISTOR, M. C., 2016 - Benefits of using FGD gypsum in agriculture. Research Journal of Agricultural Science, 48(4): 247-253.
2. DU Y.; ZHANG Y.; LING F.; WANG Q.; LI W.; LI X., 2016- Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band. Remote Sens., 8: 354.
3. GOVEDARICA M., BADNJAREVIĆ I., JOVANOVIĆ D., PETROVAČKI D., 2011 - The analysis of remote sensing technology and the application of satellite imagery of WorldView-2 satellite platform: detection, identification and assessment of vegetation quality in the area of the special nature reserve upper Danube. Architecture and urban planning, civil engineering, geodesy - past, present, future 1(1): 767-778
4. GOVEDARICA. M., RISTIC. A., HERBEI M.V., SALA. F., 2015 - Object oriented image analysis in remote sensing of forest and vineyard areas. BulletinUASVM Horticulture. 72(2):362-370.
5. HAMMER, Ø., HARPER, D.A.T., RYAN, P.D., 2001 - PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4(1):1-9.
6. HAVAŠOVÁ, M., BUCHA, T., FERENČÍK, J., JAKUŠ, R., 2015 - Applicability of a vegetation indices-based method to map bark beetle outbreaks in the High Tatra Mountains. Annals of Forest Research, 58(2), 295-310.
7. HERBEI M. V., DRAGOMIR L.O., ONCIA S., 2012 - Using Satellite Images Landsat TM for Calculating Normalized Difference Indexes for the Landscape of Parang Mountains, RevCAD 13: 158 – 167
8. HERBEI M.V., SALA F., 2014 - Using GIS technology in processing and analyzing satellite images–case study CheileNereiBeusnița National Park, ROMANIA. JOURNAL of Horticulture, Forestry and Biotechnology. 18(4): 113-119.
9. HERBEI, M. V., SALA, F., 2020 - Evaluation of urban areas by remote sensing methods in relation to climatic conditions: Case study City of Timisoara. Carpathian journal of earth and environmental sciences, 15(2): 327-337.
10. Herbei, M., Sala, F., Boldea, M., 2015, Relation of Normalized Difference Vegetation Index with some spectral bands of satellite images, AIP Conf. Proc., 1648:670003-1 – 670003-4.
11. IENCIU, I., VOROVENCII, I., OPREA, L., POPESCU, C., 2013 - The urban development of mountain areas with the aim of developing local tourism. Journal of Environmental Protection and Ecology, 14, (3): 980–985
12. JI, L., ZHANG, L., WYLIE, B. K., ROVER, J., 2011 - On the terminology of the spectral vegetation index (NIR− SWIR)/(NIR+ SWIR). International journal of remote sensing, 32(21): 6901-6909.
13. JOVANOVIĆ D., ŠOŠKIĆ S., GOVEDARICA M., BADNJAREVIĆ I., 2011 - Mapping agricultural crops

using remote sensing techniques. Application of GIS technology in protection and usage of agricultural land 1(1): 102-106.
14. KEY C. H., BENSON N. C., 2005 - The Normalized Burn Ratio (NBR): A Landsat TM radiometric measure of burn severity, report. US Geol. Surv., Boulder, Colo. Available at http://nrmsc. usgs. gov/research/ndbr. htm.
15. KEY C. H., BENSON N. C.., 2006 - Landscape assessment (LA). In: Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. LA-1-55 : 164.
16. MANOLE M., NISTOR M., MARCHIS D., 2015 - Using Modern Software in Surveying, GIS and Agricultural Road Design. Research Journal of Agricultural Science, 47(4): 104-114.
17. PLANET TEAM, 2018 - Planet application program interface: In Space for Life on Earth; Planet Team:San Francisco, CA, USA
18. ROUSE, J.W., HAAS, R.H., SCHELL, J.A., DEERING, D.W., 1973 - Monitoring vegetation systems in the great plains with ERTS. In: Proceedings of the third ERTS symposium. Washington DC: NASA (SP-351): I, 309–317
19. SALA F., POPESCU C.A., HERBEI M., 2020 - Fractal analysis in estimating the fragmentation degree of agricultural lands, Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development. 2020, 20 (3): 517-524.
20. ŞMULEAC A., HERBEI M., POPESCU G., POPESCU T., POPESCU C. A., BARLIBA C., ŞMULEAC L., 2019 - 3D Modeling of Patrimonium Objectives Using Laser Technology. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture, 76(1): 106-113.
21. STULEANEC, A., HERBEI, M. V., 2018 - Can I be tracked by Google?, Research Journal of Agricultural Science, 50(4): 351-360.
22. WILSON, E.H., SADER, S.A., 2002 - Detection of Forest Harvest Type Using Multiple Dates of Landsat TM Imagery. Remote Sensing of Environment, 80: 385-396
23. http://www.domogled-cerna.ro/
24. https://www.usgs.gov/
25. www.planet.com
26. https://landsat.gsfc.nasa.gov/landsat-8/ https://earth.esa.int/web/eoportal/satellite-missions/l/landsat-8-ldcm