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SPATIO-TEMPORAL CHARACTERIZATION OF NATURAL GRASSLANDS FROM BUCEGI NATURAL PARK USING REMOTE SENSING RESOURCES

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Abstract

The present paper presents a spatio-temporal characterization of the natural grasslands from Bucegi Natural Park using remote sensing resources such as radiometric information from the multispectral satellite images – S10 MERIS of ENVISAT, and aerial high-resolution orthophotos, to provide the Normalized Difference Vegetation Index (NDVI) of the natural grasslands and their delineation. The sampled data were georeferenced in stereographic 1970 coordinate system and were used to create thematic layers in GIS environment and to perform statistic inferences. A procedure that correlates and reclassifies radiometric data was developed using previous terrestrial observations and thematic information from the satellite images of the studied area. The multispectral images photointerpretation allowed the generation of thematic maps with attributes from database and radiometric information between 2010 and 2011 vegetation seasons, which were correlated using multi-temporal archives of NDVI values. In our study based on two subsequent years of satellite observations in the vegetation seasons, a NDVI threshold of 0.45 seemed to be appropriate to be considered as a start of season in the Bucegi Natural Park. NDVI weighted averages were computed based on available pixels for each month of the studied years as follows: 0.38 in March, 0.54 in April, 0.60 in June, 0.75 in July, 0.74 in August, and 0.71 in September. The lowest NDVI values were recorded in the northern part of Bucegi Natural Park, while the southern grasslands presented higher values correlated with earlier start of vegetation growth.

Key words: *canopy reflectance, GIS analysis, natural grasslands, NDVI, satellite images.*

INTRODUCTION

Forage resources that are available from Romanian grasslands provide, on average, over 50% of fodder requirements for sheep and cattle in green fodder equivalent. In hilly and mountainous areas, this proportion exceeds 60% of forage consumption (Vîntu et al., 2004). This potential depends on a number of measures of which the most important are the improvement or maintenance of herbaceous closed canopy with valuable forage species, grazing rationalization, and proper water sources and access roads in the productive grasslands (Motcă et al., 1994). The efficient application of these measures strictly necessary to meet the goals of functional and stable forage systems requires the information support of a multi-criteria decision-making system with geospatial analysis functions. On this line, the purpose of this paper is twofold. Firstly, it presents the use of aerial high-resolution orthophotos in delineating updated boundaries of natural grasslands from Bucegi Natural Park, together with their geospatial classification based on previous inventories for phytosociological associations' distribution. Secondly, it provides a spatio-temporal characterization of vegetation cover by using information extracted from S10 MERIS 10-days composite images acquired in the vegetation seasons (April - September) of 2010 and 2011 by the ENVISAT satellite.

Previous inventories of Bucegi Natural Park (Maruşca, 2012) have established the status of grasslands' degradation revealing that only 6,275 ha had herbaceous canopy justifying their membership in this cadastral class of use. The remaining 1,071 ha belonged to another category of use as they were covered with over

60-80% woody vegetation, denuded or eroded land. Moreover, from 6,275 ha established in field on the map, 15% were affected by surface and depth erosion, 13% were on rocks, 12% were covered in varying degrees with bushes of juniper and spruce in areas where pastures were in various stages of abandonment. The grasslands' inventory performed in 2008 also identified 250 ha (4% of the surface) invaded by nitrophile weeds because of overgrazing (Maruşca et al., 2013).

These surveys have concluded that the grasslands of Bucegi Natural Park are in an advanced stage of degradation, requiring further detailed studies of grasslands' boundaries, types and productivity, to determine the possible loading with animals and other measures to stop the degradation, to reconstruct ecologically the degraded herbaceous canopy.

The rules that regulate the environmental factors action in correlation with the technological ones, especially in natural grasslands are little known and studied. On the biological efficiency of the species that form the phytosociological associations of natural grasslands, acts genetic factors related to the characteristics of each species, eco-climatic conditions and anthropic factors related to grasslands' field operations (e.g. grazing, fertilization, weeding etc.). It is well known that a larger amount of photosynthetically active solar radiation (PAR) captured by the canopy means greater amount of dry matter synthesized from it (Dunea and Moise, 2008). Satellite observations improve and update the knowledge regarding the land surface characteristics, the structure of vegetation and other biophysical properties such as PAR, LAI, chlorophyll etc. (Darvishzadeh et al., 2008). Franklin (2009) made an extensive review of the remote sensing applications in mapping and surveying of the habitat and species distribution. Reflectance, surface temperature, *Normalized Difference Vegetation Index* (NDVI) summaries, and other spectral indices from a variety of sensors have been used in many studies to predict the species richness of different taxonomic groups. Three growth parameters from 15 alpine and subalpine grassland sites were investigated between 2001 and 2005 in a study that evaluated the ability to track grassland growth phenology in the Swiss Alps with NOAA-16 Advanced Very High Resolution Radiometer (AVHRR) NDVI time series (Fontana et al., 2008). Findings showed that the application of various thresholds to NDVI time series allows the observation of the temporal progression of vegetation growth at the selected sites with high consistency.

MATERIALS AND METHODS

In the first phase, aerial high-resolution orthophotos were used to delineate the perimeter of natural grasslands in Bucegi Mountains through raster-vector conversion and digitization. The resulted vectors were compared and combined with 2006 Corine Land Cover layers (version 16; 04/2012) that corresponded to the natural grasslands and related categories (e.g. 321, 231, and 324). The general thematic layer was populated with the phytosociological associations' distributions using data from previous inventories (Maruşca et al., 2013). The sampled data were georeferenced in stereographic 1970 coordinate system and were used to create thematic layers in GIS environment and to perform statistic inferences. Remote sensing resources such as radiometric information from the satellite images (in this paper ENVISAT-MERIS S10 images were used) provided the *Normalized Difference Vegetation Index* (NDVI) of the natural grasslands and its spatio-temporal fluctuations in the envisaged area. The NDVI provides an index to present the vitality of the vegetation on the earth's surface being a measure of the photosynthetic activity within the area covered by a pixel of image. The algorithm uses the abrupt rise of the reflection level of 0.7 mm. The NDVI is computed using the following equation:

$$NDVI = (R_{s,NIR} - R_{s,RED})/(R_{s,NIR} + R_{s,RED}),$$

where $R_{s,RED}$ and $R_{s,NIR}$ are the atmospherically corrected surface reflectances in the RED and Near Infrared (NIR) bands. The ENVISAT-MERIS S10 are near global 10-daily composite images synthesized from the adequate observations registered in the course of every decade by the orbiting earth observation system ENVISAT-MERIS.

All the daytime spectral registrations of ENVISAT-MERIS were further processed into

global, 10-daily synthesis images, comparable with the S10 of SPOT-VEGETATION from SPOT-5 satellite. Within this paper, only the TOC NDVI (Top of Canopy) was processed out of the MERIS Reduced Resolution data.
All geo-referencing operations, conversions, statistical analysis, and mapping were performed with ESRI ArcGIS 9.3.

RESULTS AND DISCUSSIONS

In Romania, most researches conducted on mountainous grassland productivity till present, were aimed at the influence of technological factors, considered as factors with direct influence on the yield formation and less on finding out rules between growth and development factors (natural and plant-related) and yield components using spatio-temporal characterizations. In this stage, the research results have a reduced degree of generalization, and grasslands management practices have a weak scientific foundation. Research objectives should be oriented towards increasing net efficiency, competition capacity, persistence and viability of the valuable forage species in the mixed canopy of natural grasslands. Global land monitoring using orthoimagery and photointerpretation can actively support the assessment of productivity, vegetation structure, habitat stability and heterogeneity, and biochemical diversity of natural grasslands.
The results obtained in the first phase were related to the distribution of natural grasslands in the envisaged region (Figure 1).
Vector data from Corine land cover - version 16 (04/2012) was overlapped on the SRTM 90 m digital elevation model. Figure 1 presents the areas (ha) of the delineated natural grasslands (INSPIRE 321 category) existent in the region. The areas of interest were the polygons having 5,570.6, 853.9, 93.9, and 65.9 ha.
Aerial orthoimagery (Figure 2) was used to obtain a more detailed delineation of the boundaries of these areas using conventional raster-vector transformations. Figure 3 presents the resulted new vector layers, which were used to locate the boundaries of six previous established on ground phytosociological associations.

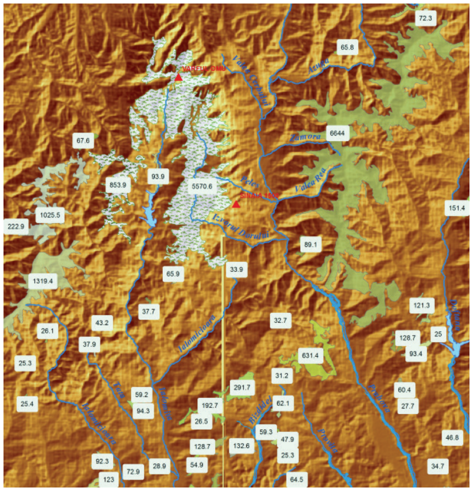

Figure 1. Distribution of natural grasslands in the envisaged region and their corresponding areas (ha)

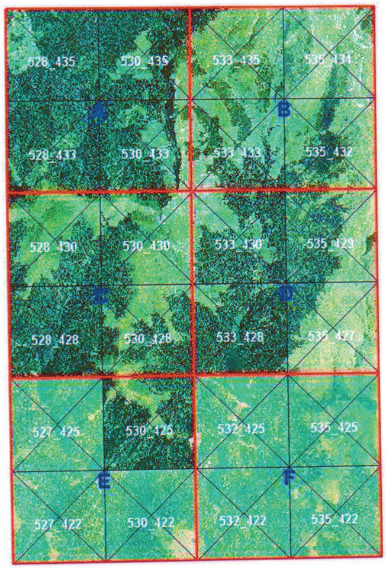

Figure 2. Ortho-photo with raster tiles used for raster-vector conversion to obtain grasslands delineation

The delineated herbaceous associations were as follows: *Potentillo ternatae – Nardion* (PON), *Seslerion bielzii* (SEB), *Oxytropis-Elynion* (OXE), *Junicion trifidi* (JUN), and *Cynosurion* (CYN). A shrub category present in the area was Kotschy's alpenrose heaths (RHV) of the subalpine and lower alpine levels (1700-2000 m) occupying small surfaces (138.5 ha), being dominated by *Rhododendron myrtifolium*, *Vaccinium gaultherioides* and *Vaccinium vitis-idaea* (Figure 3).

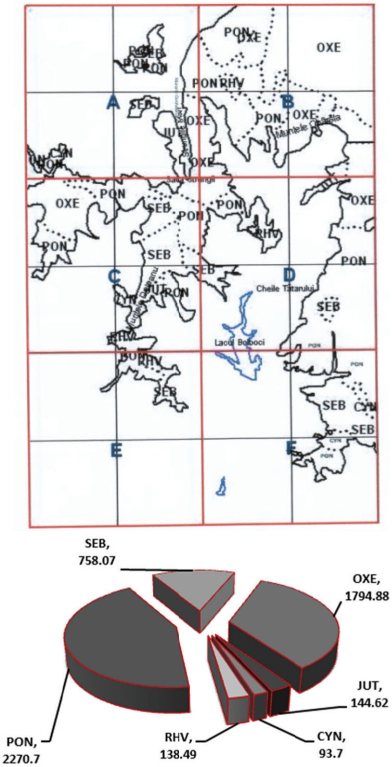

Figure 3. Resulted distribution of phytosociological associations in Bucegi Natural Park – Carpathian Mountains using raster-vector conversion and by merging typology inventory performed by Maruşca et al. (2013); Areas are expressed in hectares (ha)

Figure 3 shows that the PON grasslands dominated by *Nardus stricta* and *Festuca airoides* species had the highest percentage on the resulted map, occupying around 45% of the area. This indicates the advanced stage of degradation of herbaceous canopy. The next categories were the alpine meadows on the highest peaks (OXE) with 34%, SEB rocky meadows with 14%, and the rest of JUT and CYN with 4.4%. RHV reached 2.6% of the total grassland area. The reclassification of grasslands distribution based on dominant species provided general information regarding the phenology of canopy growth and development, which can be correlated with NDVI fluctuations during the vegetation season or between different years. Vegetation indices rely on the reflectance characteristics of various surfaces for different types of light spectrum. Photosynthetically active canopies absorb the incident red light and reflect the near infrared (NIR) light. Consequently, NDVI provides a good approximation of the absorbed PAR fraction (fAPAR) by the plant canopies. NDVI values range from -1.0 to +1.0, but S10 MERIS composite images have physical values from -0.08 to 0.92 associated to digital numbers from 0 to 250. Values less than zero did not have an ecological significance, and were excluded from map (i.e. clouds and snow cover). Very low and low NDVI values characterized areas with little NIR light reflectance or with little photosynthetic activity (e.g. water bodies, bare soils, and stressed vegetation). Superior values occurred in PAR active canopies when the ENVISAT-MERIS sensor recorded larger differences between the red and NIR radiation. Previous study (Fontana et al., 2008) established three suitable thresholds to determine grassland growth phenology in the Swiss Alps with NDVI time series such as melt-out (0.6), start of growth (0.75), and end of growth (0.98). In other approach, Stöckli and Vidale (2004) applied a threshold of 0.4 to the entire Alps to derive start of season dates for a period of 20 years.

In our study, based on two subsequent years of satellite observations in the vegetation seasons (i.e. 2010 and 2011) a NDVI threshold of 0.45 seemed to be appropriate to be considered as a start of season in the Bucegi Natural Park.

Figure 4 presents the thematic maps of each corresponding decade of the month between April and September periods of 2010 and 2011. It can be observed that in 2010 the vegetation season of the grasslands was tardier than in 2011. However, NDVI maps of June month in both years have similitudes concerning the NDVI spatial distributions. The phenological advancing was faster in 2011 comparing with 2010 taking into account August and September months.

Table 1 presents the statistics of the NDVI data extracted from S10 MERIS during 2010 and 2011 vegetation seasons. Count column presents the available number of pixels for analysis after excluding redundant values (snow cover and clouds). A general comparison between 2010 and 2011 vegetation seasons for the natural grasslands of Bucegi Natural Park was difficult to perform since there are differences between the available numbers of pixels for the same month of each year.

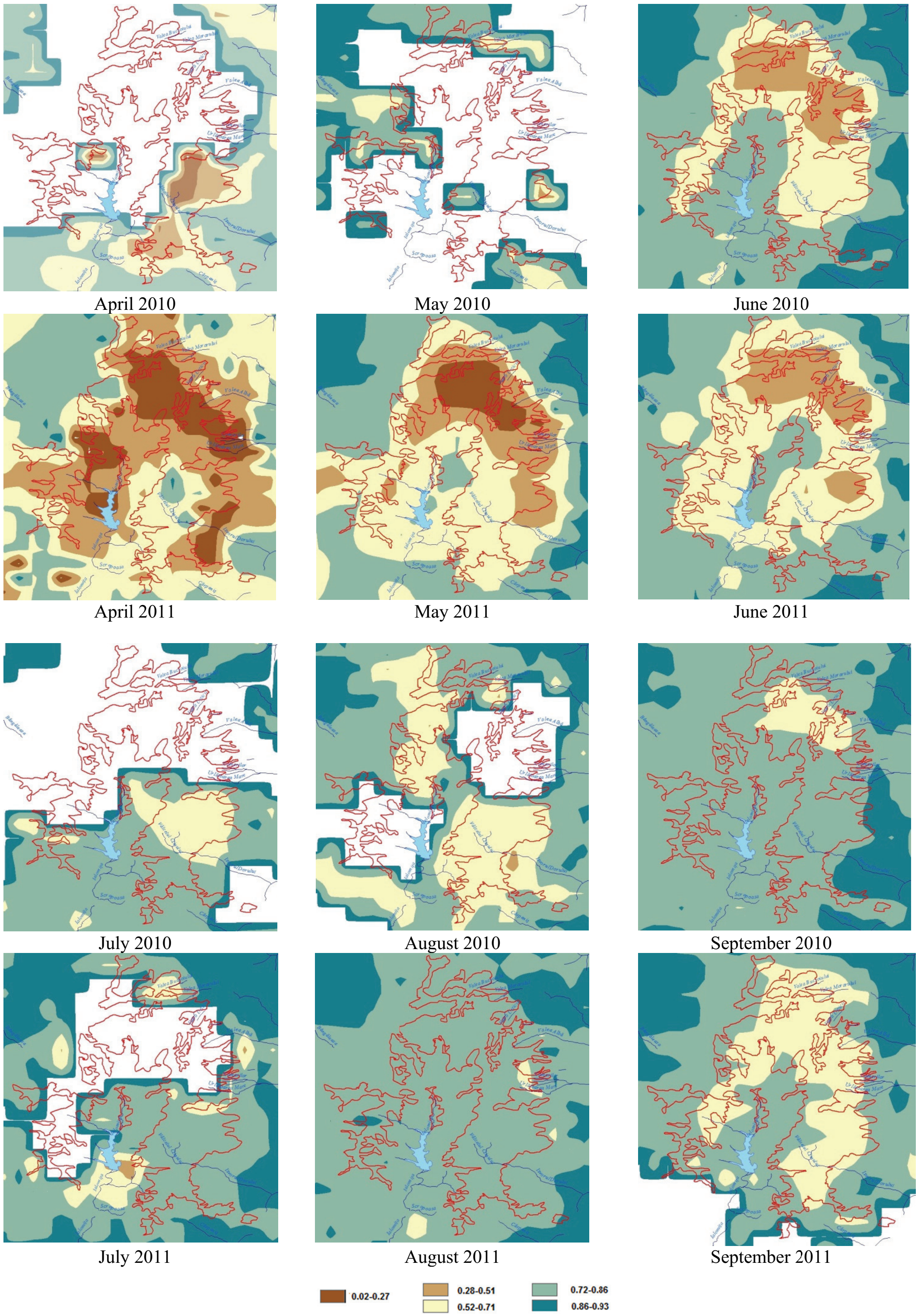

Figure 4. NDVI extracted from S10 MERIS 10-days composite images, courtesy of the CVB project produced by VITO

Table 1. Descriptive statistics of the NDVI results obtained from S10 MERIS composite images

Month	Count	Minimum	Maximum	Sum	Mean	Std. deviation
April 2010	28	0.04	0.77	11.05	0.39	0.20
April 2011	97	0.05	0.84	36.15	0.37	0.18
May 2010	27	0.38	0.93	20.60	0.76	0.14
May 2011	97	0.13	0.81	49.47	0.51	0.18
June 2010	97	0.36	0.87	57.56	0.59	0.12
June 2011	97	0.34	0.84	58.63	0.60	0.13
July 2010	41	0.59	0.88	29.43	0.72	0.08
July 2011	49	0.64	0.88	38.14	0.78	0.05
August 2010	60	0.49	0.88	40.69	0.68	0.10
August 2011	97	0.68	0.86	74.64	0.77	0.03
September 2010	97	0.61	0.84	71.16	0.73	0.05
September 2011	95	0.54	0.81	64.33	0.68	0.06

Table 1 highlights useful information regarding NDVI temporal distribution for each year. We have computed NDVI weighted averages based on available pixels for each month of the studied years as follows: 0.38 in March, 0.54 in April, 0.60 in June, 0.75 in July, 0.74 in August, and 0.71 in September. The lowest NDVI values were recorded in the northern part of Bucegi Natural Park, while the southern grasslands presented higher values correlated with earlier start of vegetation growth. From the grassland typology point of view, *Oxytropis-Elynion* (OXE) association had the lowest NDVI values as compared to other types, being alpine grasslands located at higher altitudes. Future assessments will be necessary to determine better NDVI thresholds for each grasslands type of Bucegi Natural Park using larger intervals of time and by employing images from other sensors such as AVHRR, SPOT-5 and PROBA-V (from October 2013).

CONCLUSIONS

NDVI has a significant relationship to many grassland ecosystem parameters such as vegetation presence, net primary productivity, and photosynthetic efficiency, which can provide information concerning the ecological status and changes due to grazing impact, or can facilitate a rational grazing management. The observed NDVI chronology was in agreement with canopy growth phenology.

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