A GLIMPSE OF LIGHT INTERCEPTION PROCESSES IN THE MOUNTAIN GRASSLANDS FROM ȘIRNEA VILLAGE, ROMANIA

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Abstract
Satellite imagery can provide key information regarding the functional characteristics of the vegetation at different spatiotemporal scales based on several synthetic indicators such as fPAR (fraction of absorbed photosynthetically active radiation), albedo, LAI (leaf area index), land cover, NDVI (Normalized Difference Vegetation Index) etc. The paper presents the preliminary results of a vegetation screening performed in Romanian mountain grasslands from Şirnea village using PAR ground measurements and remote sensing synthetic indicators to characterize the Agrostis capillaris grassland type in terms of light interception processes. This initial study contributes to the development of an infrastructural and methodological framework for future research directly applicable to various environmental issues occurring in the Rucăr-Bran Corridor associated with restoration, deforestation, encroachment, die□off, and xerification. A Delta-T Devices Beam Fraction Sensor was used to measure the radiation fluxes in µmol m^{-2} s^{-1} on July 13-14, 2018 in Şirnea village. Sentinel 2A L1C product allowed the calculation of NDVI in ArcGIS 10.3 from Bands 8 (842 nm Near Infrared - NIR) and 4 (665 nm - RED) at 10 m resolution. The LAI was computed using an exponential function with a multiplying factor. MODIS/Terra Leaf Area Index/FPAR 8-Day L4 Global 500 m SIN Grid V006 synthetic image for 12 to 17 July 2018 was used to characterize the vegetation status based on LAI and fPAR. Lower values of both NDVI and LAI were recorded for mowed/grazed areas, and sloped grasslands (LAI = 1.5-2). Higher values corresponded to the intercanopy patches of spruce and shrubs (LAI = 3-5).

Keywords: phytosociological associations, NDVI, leaf area index, fPAR, satellite monitoring

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INTRODUCTION

Many ecosystems are existing in a grassland - forest continuum, where land cover by woody species (trees and shrubs) varies in terms of abundance and dominance (Breshears, 2006). Fluctuations and successions of the two major ecosystem types in mountain areas depend on the capacity of resilience that is influenced by the patterns of energy, water, and biogeochemistry, as well as anthropic actions (Bărbulescu et al., 1991).
Consequently, the land cover is often heterogeneous comprising distinctive herbaceous and forest canopies, but also patches beneath woody plants and the intermediate transition areas and encroachments with mixed canopies (Dunea, 2015). Processes such as light interception and absorption, shading, resources root uptake, versant exposition and slope determining runoff establish the ecological relationships between various patches of phytosociological associations, respectively the interactions among and between composing organisms within their environment (Motcă et al., 1994).
In permanent grasslands, the plants are associated in complex functional groups with which they provide specific grassland typological features regarding the relationships between the species that form the association, as well as between them and the biotope in which they are located.
At the same time, the plants belonging to the phytosociological association substantiate the value of multifunctional utilization consisting on enhanced modalities of use (forage, melliferous, medicinal and aromatic,

biodiversity reservoir, ecological compensation, agro-tourism, landscape) and functional biodiversity improvement (Dincă et al., 2014). From a systematic point of view, the grouping of the species in the canopy gives the possibility of studying them for different characteristics such as botanical traits including interspecific competition, vivacity of species, utilization value, rate of growth and development of associated species, requirements for the ecological factors, the mode of exploitation (grazing, mowingor mixed system), etc.

The number of species in the canopy of various types of mountain grasslands depends on several factors. Among the most important stand the pedoclimatic conditions, the management of grasslands and light regime(Dunea and Dincă, 2014). In this context, the monitoring of the vegetation is a reliable action that can establish the "*health*" status of the ecosystems in the context of climate variability.

Satellite imagery can provide key information regarding the functional characteristics of the vegetation at different spatiotemporal scales based on several synthetic indicators such as fPAR (fraction of absorbed photosynthetically active radiation), albedo, LAI (leaf area index), land cover, NDVI (Normalized Difference Vegetation Index), etc. (Vuolo et al., 2016). Lately, among the most used remote sensing systems and products that can provide such information, are MODIS (Fensholt et al., 2004) and Sentinel (Schauman et al., 2018).

The aim of the paper is to present the preliminary results of a vegetation screening performed in Romanian mountain area from Șirnea villageusing PAR ground measurements and remote sensing synthetic indicators to characterize the *Agrostis capillaris*grassland type in terms of light interception processes.

This initial study contributes to the development of an infrastructural and methodological framework for future research directly applicable to various environmental issues occurring in the Rucăr-Bran Corridor, Romania, associated with restoration, deforestation, encroachment, die- off,and xerification.

MATERIAL AND METHODS

The study area is located in the North of Fundata administrative territory, at Șirnea village (WGS-84 coordinates: 45,95 N and 26,05 E - 1100-1350 m altitude), and is characterized by the prevalence of mountain grasslands (fig.1).

Vegetation. In this area, there are fourmajor zonal grassland types (fig. 2) as follows: mesophilic*Agrostis capillaris* on flat surfaces, meso-xerophilic*Agrostis capillaris* on slopes, *Festuca rubra* and *Agrostis capillaris,* and *Festuca rubra and Nardus stricta*(Dunea et al., 2017).

Fig.1 Location of the studied grasslands from Șirnea village, Fundata administrative area, Romania

Climate. The general circulation of air masses that occur in the predominant northeast-southwest direction determines the unfolding of the climatic elements. The variety of the landforms, the increase of the altitude in the corridor, in the double sense, from the peripheries to the Giuvala-Fundata watershed and from the axis of the corridor to the slopes, up to about 1400-1500 m, generates vertical gradients in decreasing of temperature, increasing of the amount of precipitation, cloudiness and atmospheric pressure. The canopies, especially the ones of the forest vegetation, together with the different exposure of the slopes, the depression basins, etc. establish sensitive variations in the corridor topo-climate.

The climate, comforting and tonic for human activities, is characterized by milder winters compared to the surrounding mountain peaks, with relatively warm summers and longer, warmer and dryer autumns.

The temperature regime is characterized by average annual values of 4-6 °C (4.4 °C at Fundata), while the temperature is decreasing obviously with the altitude (fig. 3). In some depressions, there are frequent thermal inversions, which in addition to the lowered temperatures, frequently cause valley fogs, early and late mists, and soil frosting. At Fundata, the multiannual average number of days without frost is 139.

Atmospheric precipitation increases with altitude, from the peripheral regions of the corridor to the Giuvala Pass. The average multiannual rainfall recorded at Fundata reaches 1020.9 mm. The absolute maximum rainfall was recorded on June 19, 1924, when the value was 306 mm in 24 hours (one of the highestpluviometric value ever recorded in Romania).

The average length of the snow layer is ~200 days at Fundata, while at the weather stations outside the corridor, e.g. Câmpulung and Brașovthere are 121 and 144 dayson average, respectively. At Fundata the snow layer is usually present from the middle of November until the first decade of April.

Generally, the wind is the most unstable meteorological element being influenced by the general atmospheric circulation, local topography and other factors. The peculiarities of the corridor and surrounding mountains determine that the main wind direction at Fundata is relatively even distributed between the northeast (41.7%) and southwest (42.6%).

Fundata platform has the most uniform climate in the entire corridor, favoring the growth of herbaceous and woody vegetation, grazing and even the potato cultivation.

Fig.2 Pictures taken at Ciocanu village, Fundata on 13 july 2018 showing the cloud cover and *Agrostis capillaris* plants in flowering

Ground measurements. A Delta-T Devices Beam Fraction Sensor was used to measure the radiation fluxes in µmol m^{-2} s^{-1} on July 13-14, 2018 in a representative unshaded point from Șirnea village. The sensor was connected to a field laptop for data logging at a rate of 10 seconds (fig. 3).

Fig.3 Photosynthetically Active Radiation measurements at Fundata

Satellite data. Since the ground screening was performed on 13 and 14 July 2018, a corresponding satellite image was searched for this datewith minimal cloud coverage. The only available image was provided by Sentinel 2A namely Sentinel_L1C_T35TLL_A015963_20180713T092029 and was downloaded from the ESA server (https://scihub.copernicus.eu/) being geometrically corrected with top-of-atmosphere (TOA) reflectance.

NDVI was computed in ArcGIS 10.3 from Bands 8 (842 nm Near Infrared - NIR) and 4 (665 nm - RED)at 10 m resolution according to the following equation:

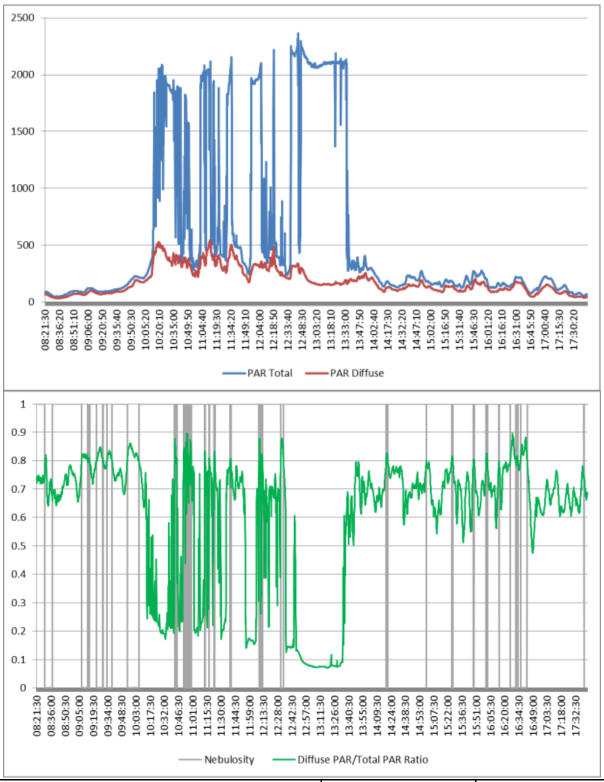
$$\text{Normalized Difference Vegetation Index (NDVI)} = \frac{\text{Band 8} - \text{Band 4}}{\text{Band 8} + \text{Band 4}}$$

After obtaining the NDVI raster, the leaf area index (LAI) was computed using an exponential function with a multiplying factor. Furthermore, MODIS/Terra Leaf Area Index/FPAR 8-Day L4 Global 500m SIN Grid V006 synthetic image for 12 to 17 July 2018 (CloudCover: 8) was used to characterize the vegetation status based on LAI and fPAR.

The shape of the grasslands from Șirnea was vectorized and overlapped on the images.

RESULTS AND DISCUSSION

The preliminary tests performed at Șirnea village provided the fluctuations of PAR at ground level highly influenced by the cloud cover and upper fast air currents that displaced the clouds rapidly. Figure 4 presents this pattern for 13 July 2018 showing the periods with clouds (overcast conditions) when the diffuse radiation was close to the total one, while in clear sky conditions the total PAR reached values above 1500 μmol m^{-2} s^{-1}. The maximum value was 2366.3, while the lowest was 43.9, and the average of 570 μmol m^{-2} s^{-1}. The diffuse radiation was more constant having a coefficient of variation of 63.2 % and an average of 180.6 μmol m^{-2} s^{-1}. The maximum of diffuse PAR was 542, while the minimum reached 31.7 μmol m^{-2} s^{-1}. Figure 4 also shows the nebulosity and the diffuse/total PAR ratio.

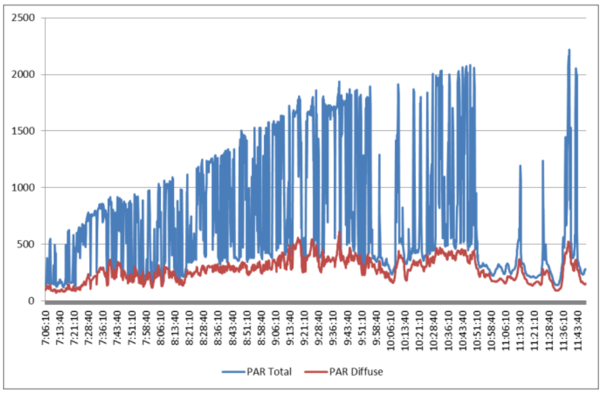


Average	570.0	180.6
Median	213.6	148.9
Standard deviation	718.5	114.2
Coeff. of Variation (%)	126.1	63.2
Minimum	43.9	31.7
Maximum	2366.3	542.0
Range	2322.4	510.3
Skewness	1.4	1.0
Kurtosis	0.3	0.2

Fig. 4 Time series of PAR recorded at ground level on 13 July 2018 and statistical results

Overcast conditions were characterized by values below 500 μmol m^{-2} s^{-1} and when the clouds were displaced in the area, the PAR was fast dropping towards this threshold.

The same pattern was observed in the next day (14 July) but more obviously due to a denser cloud cover and faster air currents. It was a shorter time series that reached a maximum value of 2219.8 and a minimum of 121.5 with an average of 716.9μmol m^{-2} s^{-1}. The coefficients of variations were lower for both total and diffuse PAR compared to the previous day. PAR quantum at canopy level depends on LAI (Dunea and Moise, 2008).



Average	716.9	272.2
Median	492.6	269.8
Standard deviation	532.7	102.4
Coeff. of Variation (%)	74.3	37.6
Minimum	121.5	72.0
Maximum	2219.8	609.1
Range	2098.3	537.1
Skewness	1.0	0.2
Kurtosis	-0.2	-0.4

Fig. 5 Time series of PAR recorded at ground level on 14 July 2018 and statistical results

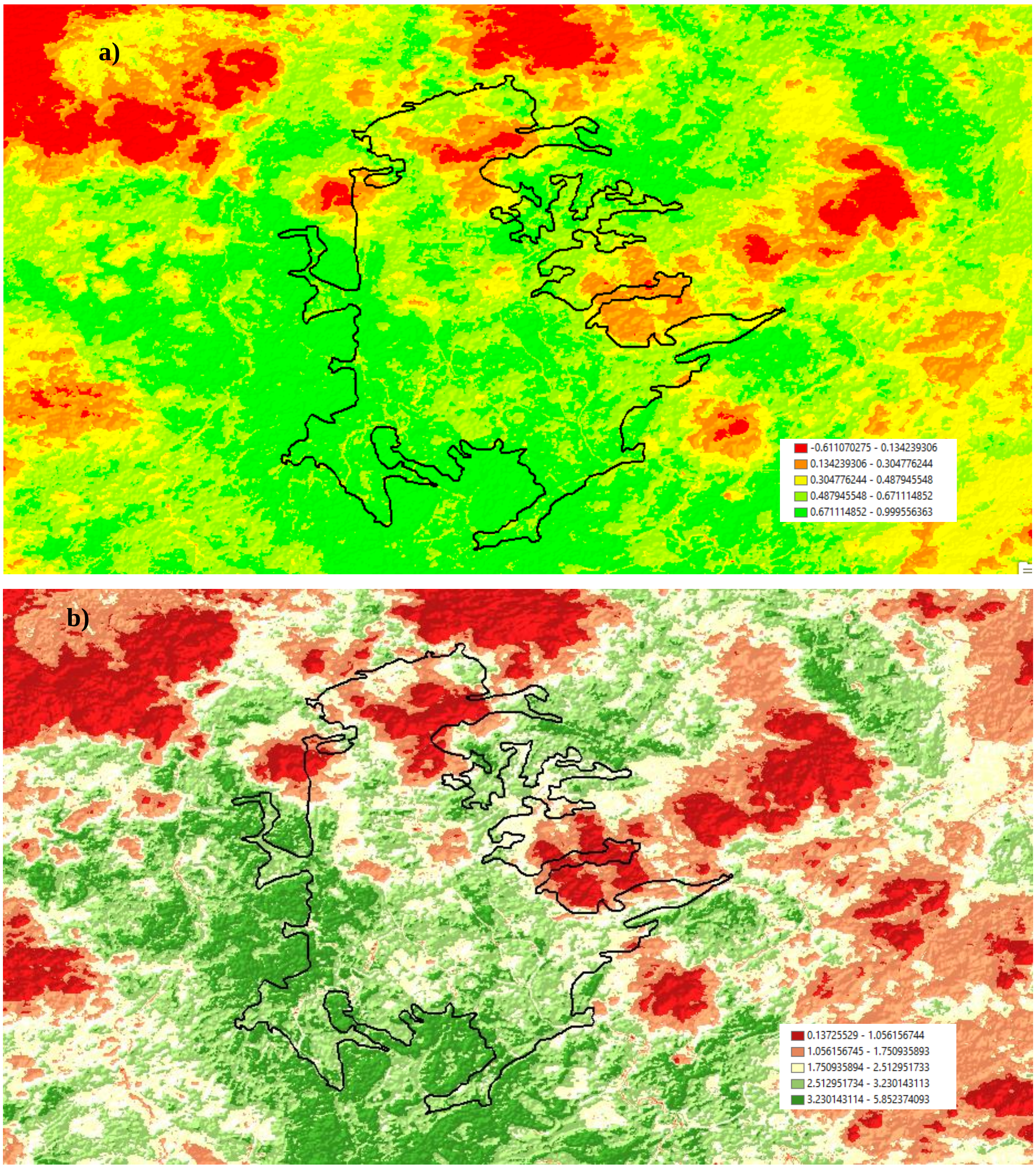


Fig. 6.NDVI (a) and LAI (b) indicators computed using a Sentinel 2A image acquired on 13 July 2019

The data processing of the Sentinel 2A image (fig. 6) provided the NDVI and LAI for the studied area. Red and orange (NDVI), and red and crimson (LAI), are unusable information because they correspond to cloud cover and buildings.

Lower values of both NDVI and LAI were recorded for mowed/grazed areas, and sloped grasslands (LAI = 1.5-2). Higher values corresponded to the intercanopy patches of spruce and shrubs (LAI = 3-5).

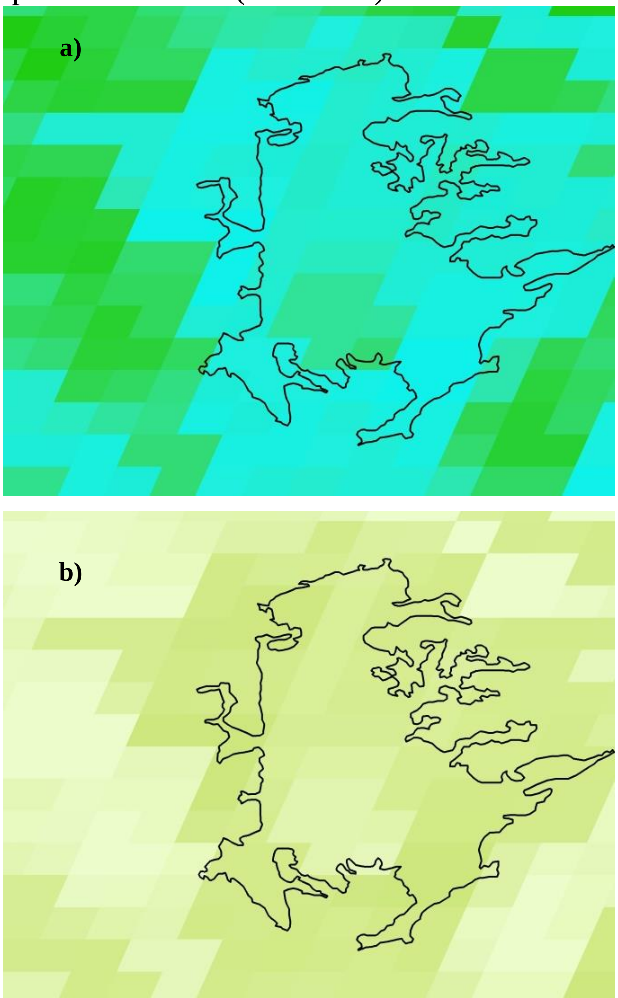


Fig. 7 MODIS/Terra data for fPAR(a) and Leaf Area Index (b) for 8-Day synthetic image for 12 to 17 July 2018

On the Sentinel 2ALAIimage acquired on 13 July, the roads are clearly identified. The eastern cloud formation was pictured from ground in figure 2. The lowest NDVI and LAI appear in the south-southwest area, which is Ciocanu village that concentrates numerous buildings and mowed grasslands. The same result was established based on the MODIS fPAR and LAI (fig. 7). Ciocanu area had lower values than the grasslands located at Șirnea (center and north areas).

Conclusions

The current study is a preliminary test that provided some interesting insights within the light interception and reflectance processes occurring in the mountain grasslands. This initial step pointed out the necessity of using a more complex system for determining canopy radiative processes i.e., a canopy analyzer and the developing of data fusion and downscaling methods to fill the spatiotemporal gaps determined by the cloud cover and temporal resolution of a specific satellite mission. Moreover, the utilization of MODIS images does not provide fine scale resolution making difficult to discriminate between phytosociological associations and thus the establishing of the grassland typology and associated vegetation indicators.

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REFERENCES

[1] Bărbulescu C., Puia I., Motcă Gh., Moisiuc Al., Cultura pajistilor si a plantelor furajere, Editura Didactica si Pedagogica, Bucuresti, 1991.

[2] Breshears D.D., The grassland–forest continuum: trends in ecosystem properties for woody plant mosaics?Frontiers in Ecology and the Environment,Volume 4, Issue2, 96-104, 2006.

[3] Dincă, N., Barbu, I., Dunea, D., An inventory of floristic composition in permanent grasslands of Rucăr-Bran Corridor: application and perspectives of melliferous potential, Scientific Papers-Series A, Agronomy 57, 157-162, 2014.

[4] Dunea D., Dincă N., Radulescu C., Mihaescu C., et al., Response of solar radiation bioconversion on *Medicago sativa* L. silage potential, Romanian Journal of Physics Volume 63, Number 5-6, 2018.

[5] Dunea D., Tanislav D., Stoica A., Bretcan P., Muratoreanu G. et al., Eco-Pract: a project for developing the research competences of students regarding the monitoring of floristic composition in mountain grasslands, Journal of Science and Arts, 1, 225-238, 2018.
[6] Dunea D., Bioconversion efficiency in grass-legume forage systems, LAP Lambert Academic Publishing, Germany, Saarbrucken, ISBN 978-3-659-79200-7, 256 pag., 2015.
[7] Dunea D., Dincă N., Contributions to the Development of a Crop Growth Model for Assessing Grass-Legumes Interactions, Bulletin USAMV CN series Agriculture, 72(2), 388-396, 2015.
[8] Dunea D., Frăsin L.B.N., Dincă N., Ecophysiological Responses of White Clover-Hybrid Ryegrass Mixture to Foliar Fertilisation,Notulae Botanicae Horti Agrobotanici Cluj-Napoca 43 (1), 173-178,2015.
[9] Dunea D., Dincă N., Improving land utilization using intensive grass-clover mixtures in forage production systems, Romanian Agricultural Research, 31, 2014.
[10] Dunea D., Moise V., Artificial neural networks as support for leaf area modelling in crop canopies, New Aspects of computers, Proceedings of the 12th WSEAS International Conference on Computers, 440-446, 2008.
[11] Fensholt R., Sandholt I., Rasmussen M.S., Evaluation of MODIS LAI, fAPAR and the relation between fAPAR and NDVI in a semi-arid environment using in situ measurements. Remote Sensing of Environment 91: 490-507, 2004.
[12] Motcă Gh., Oancea I, Geamanu Lidia Ivona, Pajistile Romaniei, Editura tehnica Agricola, Bucuresti, 1994.
[13] Schauman S. et al., Characterisation of Functional-Trait Dynamics at High Spatial Resolution in a Mediterranean Forest from Sentinel-2 and Ground-Truth Data, Remote Sens., 10(12), 1874, 2018.
[14] Vuolo F., Żółtak M., Pipitone C., Zappa L., Wenng, H. et al., Data service platform for Sentinel-2 surface reflectance and value-added products: System use and examples. Remote Sens., 8, 938, 2016.