REMOTE MONITORING OF ABANDONED GRASSES INVADED BY *Pteridium aquilinum* (L.) Kuhn AND *Cytisus scoparius* (L.) Link

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Abstract

In Romania, grasslands can be seen as a major component of rural development, contributing significantly, through goods and services in the socio-economic sector and environmental protection. However, the grasslands are marked by obvious signs of abandonment. In this context, the aim of the paper is to test vegetation indices for monitoring abandoned grassland areas in Banat, invaded by the species Pteridium aquilinum (L.) Kuhn and Cytisus scoparius. Remote sensing indices were applied in the GIS environment, on high spatial resolution aerial images, among them, Excess Green Index, having the most relevant results. In the case of the analyzed grassland, the values of Excess Green Index show the advanced stage of degradation, signaled especially by the presence on large areas of invasive species Cytisus scoparius and Pteridium aquilinum (L.) Kuhn, but also of different shrub formations. More than 50% of the grassland area may not be used for agricultural purposes.

Keywords: *Cytisus scoparius*, *Pteridium aquilinum*, monitoring, grassland, remote sensing.

INTRODUCTION

In Romania, the grasslands, extended on approx. 20% of the country's territory and approx. 33% of the agricultural area (National Institute of Statistics) can be seen as a major component of rural development contributing significantly, through goods and services, in the economic sector (Durău, 2012; Knowles, 2011), social (Garde *et al*., 2014; Moga *et al*., 2016) and cultural (Bucur, 2014; Zanden *et al*., 2018), closely related to traditional management practices (Öllerer, 2014; Samfira *et al*., 2010).

Although they can be seen as "safe, stable and multifunctional" natural resources in relation to their products and shape, in some cases, grasslands are unjustifiably marked by obvious signs of abandonment, both agronomically and ecologically, a phenomenon often encountered in Europe (Hinojosa *et al*., 2016), but also on large areas in the hill and mountain area of Romanian Banat (Durău, 2014).

Abandonment of pastures often leads to a remarkable damage of them (Cervasio *et al*., 2016), by decreasing biodiversity (Bostan *et al*., 2017), reduction of forage species and a greater abundance of pollen-supplying species (Csergő *et al*., 2013), but one of the "shrill" signals of the presence of the phenomenon, cause and effect, is the spread of the invasive herbaceous species *Pteridium aquilinum* (L.) Kuhn and woody species *Cytisus scoparius*, with large area extension and "sprawling behavior", compared to other species in the grassland vegetation.

Pteridium aquilinum (L.) Kuhn, widespread in the hilly areas of Banat (southwestern Romania), is the economically inefficient invasive species (Cojocariu *et al*., 2016), with rapid "spatio-temporal" evolution (Ponzetta, 2010) and which reduces the usable area of grasslands and implicitly their production.

Scotch broom, *Cytisus scoparius* (L.) Link (Fabaceae), is native to most of Europe (Rosenmeier *et al*., 2013), later being introduced to other parts of the world, including Africa, America and Australia (Potter, 2009), especially in areas with temperate climates. The distribution of the species is less documented in Eastern Europe and implicitly Romania. The species *Cytisus scoparius* has an aggressive invasive character; it multiplies both vegetatively and generatively by seeds; a mature plant can form over 30,000 seeds per plant that remain viable in the soil for about 30 years (Graves *et al*., 2010) and fire does not destroy their germination capacity (Srinivasan *et al*., 2007); the plants regenerate quickly after pruning. Shrubs spread quickly in open areas and often invade abandoned grasslands, forming dense, impenetrable stands (Kang *et al*., 2007; Potter *et al*., 2009).

Therefore, invasive species, although they give a polychrome aspect to the pastoral landscape, they become, by their destructive nature, "enemies assumed" in unison by the members of the scientific communities (Sărăţeanu *et al*., 2008; Sărăţeanu, 2010). As a result, solutions and methods for combating and / or eradicating them have been and are being improved, as efficient, fast and non-destructive as possible for the plants in their vicinity.

As part of the management process of abandoned pastures and implicitly of invasive species, it can be considered the stage of identification and mapping of the areas occupied by them. Given that biological and pratological studies are largely punctual, it is justified to supplement the studies with "spatial" methods and means, capable of analyzing large areas, "remotely", with a minimum of time and effort, in the field, in this context, being about the specific techniques of remote sensing.

One of the fundamental principles in remote sensing and spectral science is the ability to measure electromagnetic energy at different wavelengths and different environments. The physical characteristics of the investigated material induce a different, unique spectral behavior, which makes it possible to identify it, by specific methods and means (Gareth, 1999; Mather, 2014). Therefore, similar to the signature of each individual, graphic element by which it is identified, objects and phenomena, depending on the spectral behavior, can be identified by the spectral signature.

The first researchers interested in the spectral properties of plants were Willstatter and Stoll, around 1913 (Mróz *and* Sobieraj, 2004). Subsequently, through numerous scientific researches, experts in the field have discovered how combinations of measured spectral properties reveal specific characteristics of vegetation. Thus, over 150 vegetation indices were "built" in this way, with additional indices, the process being continuously improved.

Given that spectral bands in the near-infrared range are involved in the calculation of vegetation indices, the use of images that do not have them involved the abandonment of the operation. To remove this disadvantage, a series of vegetation indices and "agricultural indices" have been created that can be determined based on RGB images, so with spectral bands only in the visible range (Meyer *and* Neto, 2008; Montalvo *et al*, 2013; Romeo *et al*, 2013).

Woebbecke et al. (1995) proposes the *Excess Green Index*, useful in plant regionalization. The disadvantage of this method of analysis is that the "bright" soil or the pixels with high saturation in green can be the generators of errors in the analysis result (Yang *et al*., 2015).

In the year 2004, Neto et al., quoted by Yang et al., (2015), proposes *Excess green minus excess red*. As in the previous case, the "green" content of the vegetation changes the values of the index *Excess green minus excess red*: they are maximum at a maximum chlorophyll content and decrease in proportion to the quantitative reduction of the respective pigment.

Kataoka et al., (2003), starting from the analysis of the intensity in the RGB images, formulates *Color index of vegetation extraction (CIVE)* in order to improve the "green information" in the images, and Marchant and Onyango, (2002) propose *Vegetative index (VEG)* which differentiates the vegetal formations from the pedological cover. Subsequently, in 2006, Hague and colleagues used this method in vegetation assessment studies (Romeo *et al*., 2013). Guijaro *et al*., (2011) "combine" several vegetation indices, also obtaining detailed relationships and images of the vegetation cover (Yang *et al*., 2015).

As mentioned before, the literature presents numerous vegetation indices that highlight different aspects of geographical, natural or anthropic space, but their suitability in the pastoral space can be demonstrated only by testing, given the particular situations and complexity of vegetation. In this context, the paper aims to test established vegetation indices, applied to aerial images, to monitor abandoned grassland areas in Banat, invaded by the species *Pteridium aquilinum (L.)* Kuhn and *Cytisus scoparius*.

MATERIAL AND METHOD

In the elaboration of the present study, the methodology described in figure 1 was followed.

Study area. In choosing the study area, two aspects were taken into account: the existence of an informational support resulting from previous own research and the location of the pasture in an area with a great biological diversity but with obvious features of under-exploitation, abandonment.

The analyzed area, respectively the grassland area considered in this study, is located in Caraş-Severin County, in the administrative-territorial unit (ATU) Brebu, on a surface of 251.50 ha (figure 2).

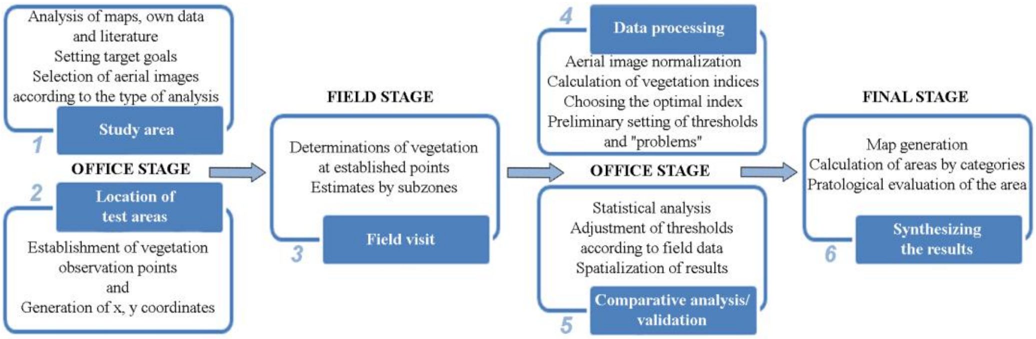


Figure 1. Working methodology

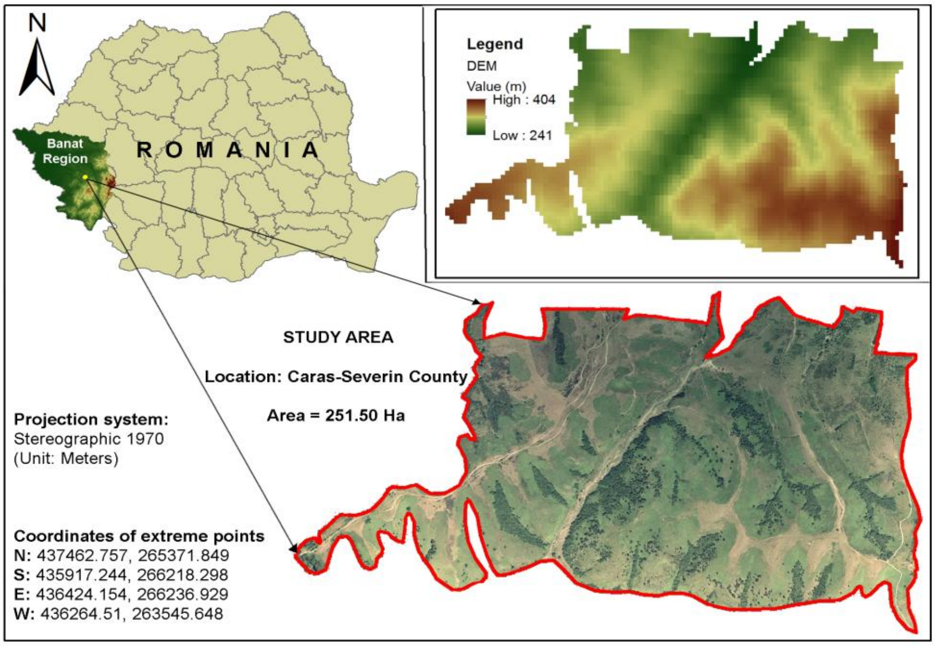


Figure 2. Location of the study area
(processing after OCPI, European Environment Agency, www.geospatial.org)

From the point of view of vegetation, the territory belongs to the sky level – *The oak sublevel* - As. *Quercetum farnetto-ceris* (Rudski, 1949, quoted by Doniţă *et al*., 2005). The woody vegetation is well represented by massive forests, predominated by *Quercus* species: *Quercus robur*, *Q. petraea* (sessile oak), *Q. cerris* (Turkey oak), *Q. frainetto* (Hungarian oak), beside *Carpinus betulus* (hornbeam), *Alnus glutinosa* (black alder), *Corylus avellana* (hazel), etc., and in the higher areas beech is also present (*Fagus sylvatica*). The analyzed grassland is characterized by altitudes between 241-404 m and the slope inclination between 0-23°, respectively 0-43%, this being located in the hilly area of Banat.

Location of test areas. In order to support the opportunity to use vegetation indices considered in the pratological studies, test areas were placed in the field to validate the results.

Each observation point was marked with GPS coordinates. In the test areas, the targeted aspects were determined, included in five categories of interest: clean grassland, areas covered with *Pteridium aquilinum* (L.) Kuhn, areas covered with *Cytisus scoparius*, shrubs and other surfaces.

During the numerous field visits, we had discussions with the inhabitants of the commune to identify the reasons for abandoning this area of grasslands.

Data processing (aerial images) and comparative analysis. Considering the fact that the vegetation studies in the field are punctual, for the spatialization of the information and the filling of the informational "gaps", five vegetation indices were selected, their determination being based on the orthophotoplan from the area of interest.

Calculation methodology is that described by Romeo et al. (2013): the image used (orthophotoplan RGB) is normalized according to the relations (1) and (2) (table 1); four vegetation indices are calculated, based on the relationships (3), (4), (5) and (6), and subsequently, the resulting indices are combined according to the relation (7) (table 2).

The five vegetation indices were analyzed in order to establish the "suitability" of each in the specific conditions of the area of interest, thus being designated the "optimal index".

In the analysis, value ranges were established for the five categories: areas used as grassland (roads, trees, gaps, etc.), "clean" grassland, areas covered by the invasive grass species *Pteridium aquilinum* (L.) Kuhn, areas covered by the invasive wood species *Cytisus scoparius* and the category "shrubs", in which we included all species of shrubs (except *Cytisus scoparius* shrubs) and young shoots from woody species as a result of a long lack of maintenance work, the grassland not being grazed or mowed.

The percentage estimates made in the field were statistically compared with the results obtained by processing the vegetation index, thus testing the efficiency and compliance of that index.

Table 1

Normalization of the RGB image (orthophotoplan in the study area) (Gée *et al*., 2008, Romeo *et al*., 2013)

$$r = \frac{R_0}{R_0 + G_0 + B_0};\quad g = \frac{G_0}{R_0 + G_0 + B_0};\quad b = \frac{B_0}{R_0 + G_0 + B_0};$$

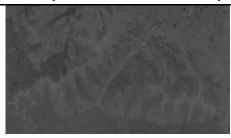
Relation (1)

Where: R, G, B are the three normalized component bands, ranging from 0 to 1 and are obtained as follows:

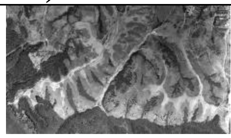
$$R_0 = \frac{R}{R_{max}};\ G_0 = \frac{G}{G_{max}};R_0 = \frac{R}{R_{max}};\ B_0 = \frac{B}{B_{max}};$$

Relation (2)

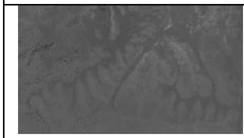
Where Rmax = Gmax = Bmax = 255 for 24-bit color images.



r



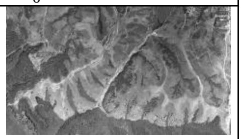
R_0



g

G_0

b



B_0

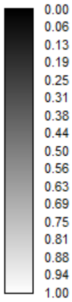


Table 2

Calculation of vegetation indices

Vegetation indices	Calculation formulas
Excess green (Ribeiro, Fernández-Quintanilla, Barroso, & García-Alegre, 2005; Woebbecke, Meyer, von Bargen, & Mortensen, 1995, quoted by Romeo et al., 2013)	$ExG = 2g - r - b$ Relation (3)
Excess green minus excess red (Neto, 2004, quoted by Romeo et al., 2013)	$ExGR = ExG - 1.4r - g$ Relation (4)
Color index of vegetation extraction (Kataoka, Kaneko, Okamoto, & Hata, 2003, quoted by Romeo et al, 2013)	$CIVE = 0.441r - 0.811g + 0.385b + 18.78745$ Relation (5)
Vegetative index (Hague, Tillet and Wheeler (2006, quoted by Romeo et al., 2013):	$VEG = \frac{g}{r^a b^{1-a}}$ Relation (6) where, a = 0,667, value established following the researches of the cited author.
Combination of indices – Guijarro et al. (2011), quoted by Romeo et al., 2013	$COM = w_{ExG}ExG + w_{ExGR}ExGR + w_{CIVE}CIVE + w_{VEG}VEG$ Relation (7) where wExG, wCIVE and wVEG are weights for each index, representing the relative importance of the index. Guijarro et al. (2011) provide the values for the four weights participating in the combination, which are the following: wExG = 0.25, wExGR = 0.30wCIVE = 0.33 and wVEG = 0.12.

The Cluster Analysis was performed based on Paired Group Algorithm and Correlation Similarity Measure. Method of relative differences (https://www.expii.com/t/what-is-relative-difference-4251).

Absolute deviation = Calculated Value – Predicted Value.

Statistical analysis was performed using the statistical software program PAST version 2.17

$$AA = \frac{(Calculated\ Indices - Predicted\ Indices) \times Predicted\ Indices}{100} \quad \text{Relation (8)*}$$

*https://stats.mom.gov.sg/SL/Pages/Absolute-vs-Relative-Change-Concepts-and-Definitions.aspx

The final stage. The result obtained, materialized by the land cover map, is exploited for two major purposes: the calculation and location of the areas related to each category of land use and as a support in the evaluation of the two invasive species identified.

Used materials:

- documents, cadastral maps in analog format (at a scale of 1: 10000) and digital (.dwg.) taken from the archive of the town hall of Brebu commune, necessary for the identification and delimitation of the grassland areas;
- thematic maps (limit of administrative-territorial units of Romania, limit of physical-geographical units), graphic data created by the National Agency for Cadastre and Real Estate Advertising, published on the INSPIRE Geoportal of Romania and on the Open Data Portal of the Romanian Government, available free of charge on the website;
- Digital Elevation Model (DEM) with spatial resolution at 25 m, Produced using Copernicus data and information funded by the European Union - EU-DEM layers; owned by the Directorate - General for Enterprise and Industry (DG-ENTR) and the European Commission, owned by the European Environment Agency (EEA), available on the website;
- the orthophotoplan with the spatial resolution of 0.5 m taken from the Archive of the Office of Cadastre and Real Estate Advertising Timiş.

The softwares used for preprocessing, processing and data analysis were Idrisi Selva, ArcGIS 10.2.1 and AutoCADMap 3D 2012.

RESULTS AND DISCUSSION

In Romania, in recent years, there has been a gradual abandonment of hill and mountain grasslands (Török - Oance R *and* Török - Oance M, 2012), which led to changes in the coverage of these lands, observed mainly near the upper limit of the forest. This situation is also found in the case of the study area, where the analysis of cartographic materials, but especially the "visits" in the field, show, on the one hand, biological diversity, on the surface of the grassland considered to be present, from small species of the grassy carpet to the trees, and on the other hand, the soil not covered by vegetation, roads and "gaps" inside the vegetation formations, shaded by an accentuated abandonment phenomenon, signaled at first sight by the excessive presence of invasive species *Pteridium aquilinum* (L.) Kuhn and *Cytisus scoparius*.

Selection and validation of the best index for grassland analysis

Being an inhomogeneous area in terms of phyto-ecology, but also in terms of land use, field studies, on a one-off basis, can be completed and replaced, with automated methods, "remotely" (Cojocariu *et al*, 2017; Dusseux *et al*, 2014; Kuzucu *and* Balcik, 2017; Tiwari *et al*, 2017; Ustuner *et al*., 2014). In this context, the vegetation indices are suitable to be used (Meyer and Neto, 2008; Romeo et al, 2013), indices based on the principle that plants have a much higher "green" content compared to the soil or other components of the environment.

Field determinations attest the inhomogeneity of the vegetation. Thus, the areas with specific grassland vegetation have been reduced in favor of large, compact fern areas (*Pteridium aquilinum* L. Kuhn). Other surfaces have been replaced by isolated trees and shrubs in clumps. The invasive character of the shrub species *Cytisus scoparius* (Parker, 2000) implies a dramatic increase in the analyzed grassland.

Following the computerized testing of the vegetation indices determined for the considered grassland, the best result was obtained in the case of Excess Green Index (figure 3), so that we selected it in order to achieve the proposed purpose, respectively identification of the invasive species, both as presence and as distribution in relation to other species.

In the study area, the values of the ***Excess Green Index*** (EXG) range between -1, in the case of areas not covered by vegetation, and 2, where the vegetation is "excessively green" (figure 3).

To identify the land use categories and implicitly the different plant species, especially the two invasive species, the EXG values were grouped, according to the number of classes previously established. Initially, the assignment of values to different classes was done by visual analysis and based on data from previous studies. Subsequently, by processing the data obtained from the field, the “real” values were adjusted, corresponding to each element followed.

In the validation of the results obtained by the EXG calculation, the data collected from the field, from the test areas, had a significant weight, but also by the “visual” and imagistic estimates, on the entire area of interest. Based on them, for each subzone was determined the share of each land use category and the invasive vegetation composed of the two targeted species. A similar procedure was applied to the EXG image, by reclassification and raster-vector conversion being possible the calculation of the surfaces and percentages belonging to each analyzed component, in each subzone.

The degree of similarity/ correlation between the two data types was established by cluster analysis (figure 4).

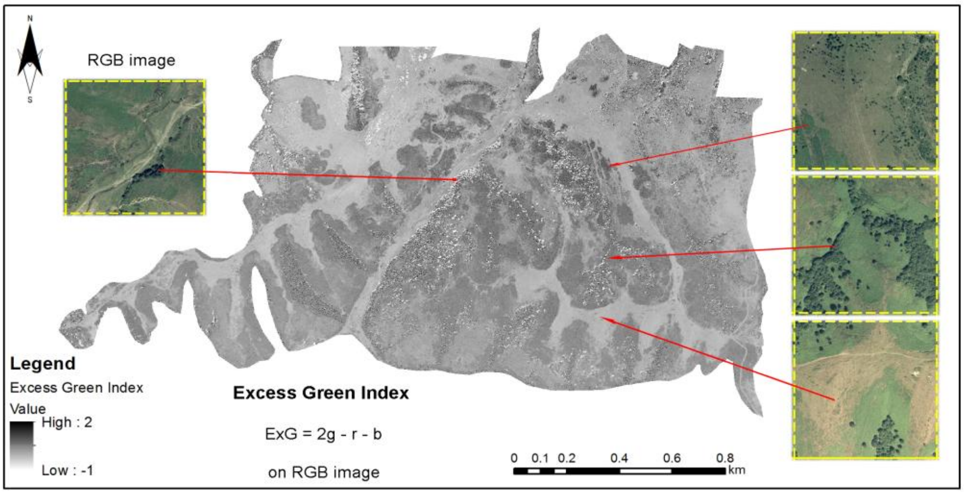
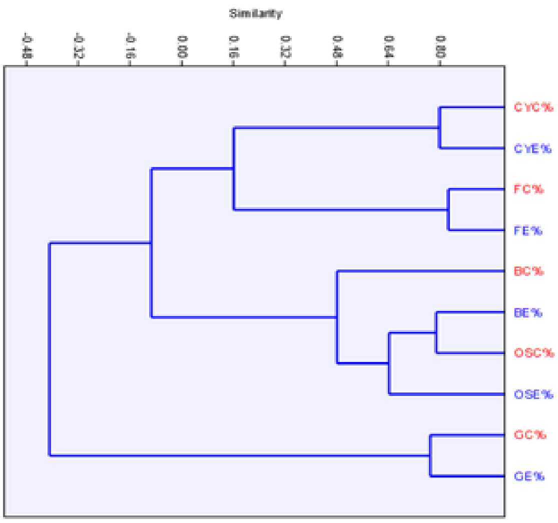


Figure. 3 Excess Green Index values in the grassland analyzed (processing after OCPI)

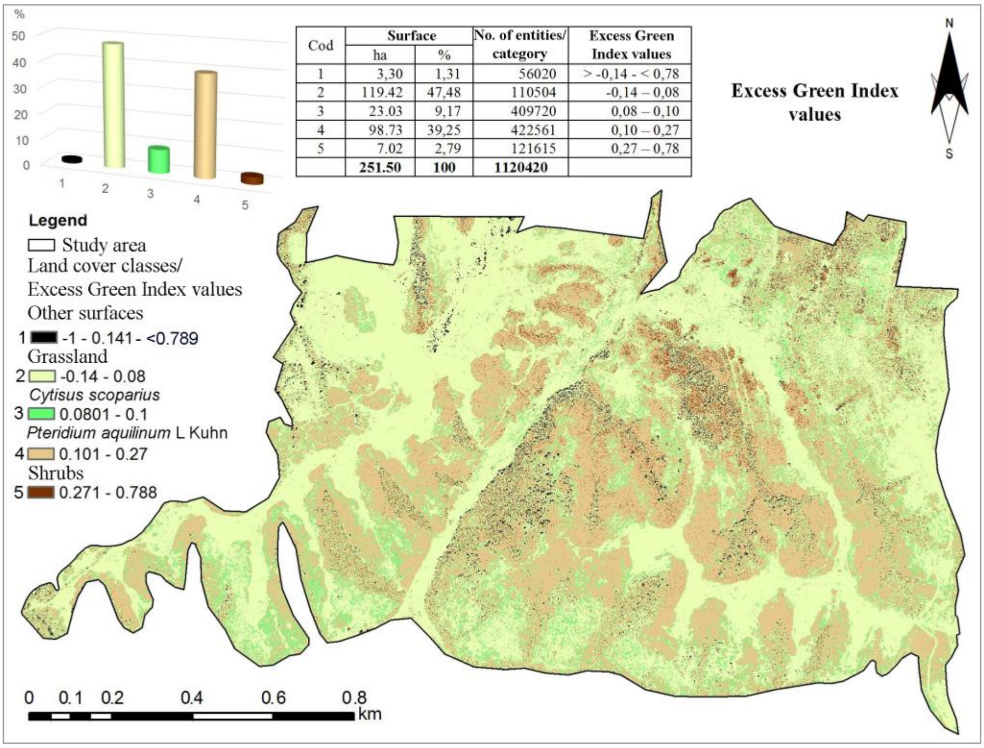


Legend: G – Grassland, OS – Other Surfaces, B –Bushes, F – *Pteridium aquilinum* (L.) Kuhn, CY – *Cytisus scoparius*, C- Calculated, E - Estimated

Figure. 4 Comparative analysis estimated values (land) - calculated values (EXG)

A correlation coefficient of 0.9091 was established between the data collected from the field and the calculations performed on the basis of EXG, which suggests minor differences and therefore validates the possibility of using EXG values in this type of analysis.

After validating the EXG results and finalizing the variation intervals, the overall picture was outlined: the area of interest was represented per land use categories, in the case of vegetation formations being identified the "target species", respectively *Cytisus scoparius* and *Pteridium aquilinum* (L.) Kuhn (figure 5).



Cod	Surface		No. of entities/ category	Excess Green Index values
	ha	%		
1	3,30	1,31	56020	> -0,14 - < 0,78
2	119.42	47,48	110504	-0,14 – 0,08
3	23.03	9,17	409720	0,08 – 0,10
4	98.73	39,25	422561	0,10 – 0,27
5	7.02	2,79	121615	0,27 – 0,78
	251.50	**100**	**1120420**	

Figure. 5 Distribution of vegetation formations and land use categories according to the Excess Green Index values

Vegetation formations and land use categories

It was shown that the useful area of the analyzed grassland amounts to 119.42 ha, respectively 47.48% of the total area (Figure 5).

Of the total surface of the grassland, 39.25% is covered by the species *Pteridium aquilinum* (L.) Kuhn, and 9.17% belongs to the shrub species *Cytisus scoparius*, both being formations with a strong invasive character.

The vegetal cover of the analyzed grassland surfaces is dominated by mesoxerophilous species with associations of *Agrostis tenuis* and *Festuca valesiaca*, dominant, and locally islands of *Chrysopogon gryllus*, *Poa pratensis* and *Botriochloa ischaemum*. In relation to the types of dominant grasslands, there are other facies or groups of associations on smaller areas built of mesophilic and mesoxerophilic or mesohygrophilous species, characteristic of forest-steppe areas: *Lotus corniculatus, Medicago falcata, Onobrychis arenaria, Trifolium campestre, Coronilla varia, Dorycnium herbaceum, Achillea millefolium, Galium verum, Euphorbia cyparissias, Thymus marschallianus, Potentilla argentea, Daucus carota, Centaurea micranthos, Leontodon autumnalis, Chrysanthemum leucantheum, Asperula cynanchica, Scabiosa ochroleuca, Rhinanthus glaber, Carex distans, Cichorium intybus, Carduus acanthoides, Eryngium campestre, Cirsium vulgare, Carduus nutans, Hieracium pilosella, Gypsophila muralis, Plantago lanceolata, Sanquisorba minor, Prunella grandiflora, Juncus conglomeratus, Juncus effusus, Luzula campestris.*

As a consequence of the abandonment of grasslands, the fern covers an area of 98.73 ha of the total grassland area (figure 5). *Pteridium aquilinum* (L.) Kuhn forms a belt at the edge of the forest, capitalizing on acid and humid soils (Cox *et al*., 2008). In the analyzed grassland, the fern creates a dense, compact cover in which no other species appear; maybe only in the marginal areas that it has not yet managed to "master". The idea is supported in other papers that report that leaves and rhizomes prevent seed germination and other plant growth (Ngubane *et al*., 2014).

Due to the fact that the fern is not consumed by animals, and it even causes their poisoning (Senyanzobe *et al*, 2016) and because the explosive growth leads to the reduction of native species, most of the works in the field refer to eradication solutions: herbicide and repeated mowing, followed by sowing with species of the grassland flora in the restored areas (Cervasio *et al*., 2016). In this case, an inventory of its distribution is particularly useful in order to intervene.

In the open grasslands, in addition to shoots or shrubs remaining to the deforested wood species, there are also shrubs: *Crataegus monogyna* (hawthorn), *Rubus ssp.* (blackberry), *Rosa ssp.* (dog-rose), *Prunus spinosa* (blackthorn), *Ligustrum vulgare* (wild privet), *Cornus sanguinea* (dogwood), *Sambucus nigra*, spread in clusters or isolated individuals and invading the grassland in a proportion of 2.79% of the total.

In the analyzed grassland, there is also an exaggerated spread of the shrub species *Cytisus scoparius* (figure 5). It is found in the form of isolated individuals, gathered as bouquets, but the dense, closed surfaces are worrying. The species lives on plateaus, but also on sunny slopes and as such does not compete with the fern. Mature plants are 2 - 3.5 m tall, have a long perennity and bloom in spring, in May and June. Madhusudan P. Srinivasan (2011) reports that age was positively correlated with plant circumference and height in *Cytisus scoparius.* Studies on the growth and development of the species *Cytisus scoparius* have been developed also in other works (Paynter *et al*, 2003; Sheppardet *et al*, 2002) in order to monitor and control the species, but without approaching their distribution in abandoned grasslands and the negative impact on pastoral agriculture.

Implications of abandonment. Causes

Grassland degradation, a complex concept that involves physical changes in pedological conditions, biodiversity and productivity, has both socio-economic implications, compared to the initial state of reference (Andrade *et al*., 2015).

In the grassland considered a case study, abandonment began in the early 1990s, with the change of political regime, from communism to capitalism.

The abandonment of this grassland surface cannot be attributed to the orographic and/or climatic factors, or to the lack of infrastructure. In this case, the human component is responsible, with direct implications in the degradation of grasslands, by the depopulation phenomenon, specific to the Western area of Romania, defined, on the one hand, by the negative natural demographic balance, and on the other hand, by ample migratory phenomena (Raboca H *and* Raboca N, 2014; National Institute of Statistics).

According to the inhabitants of the area, another "local" cause of grassland degradation, generally in Caraş-Severin County and in particular, in the study area, is their "immediate economic undervaluation": the active population commutes or migrates to the poles of attraction of the area, considering the agricultural activities as unprofitable or with insufficient incomes.

Thus, after the cessation of agro-pastoral practices, in the analyzed grassland, there is a tendency of vegetation succession, the specialized plant species tending to disappear in favor of the most competitive ones, the invasive species causing grassland degradation.

In the last 30 years, by the unhindered increase in the density and height of the bushes of *Cytisus scoparius* and *Pteridium aquilinum* (L.) Kuhn, the native grassland vegetation had no chance in the "fight" for light and food. In the absence of minimal cleaning work, non-use with animals, the area usable as grassland has been significantly reduced. As such, the cessation of traditional grassland management has led to the widespread spread of the two invasive species, *Pteridium aquilinum* (L.) Kuhn and *Cytisus scoparius,* in addition to other species of trees, shrubs and shoots

CONCLUSIONS

The result obtained by applying vegetation indices may be affected, in some cases, by meteorological conditions, given that the images are taken from open spaces. Also, the stage of plant development, nutritional deficiency or soil in different colors, etc., always complicates the correct interpretation of the results of these methods based on indices from the visible spectral range. However, compared to other vegetation indices tested, the use of Excess Green Index values in the analysis of vegetation formations and land use had optimal results, confirmed by the comparison between the data collected in the field, and can be used successfully in future studies.

In the case of the analyzed grassland, the values of Excess Green Index show the advanced stage of its degradation, signaled especially by the presence on extensive areas of the invasive species *Cytisus scoparius* and *Pteridium aquilinum* (L.) Kuhn, but also of different shrub formations. In this context, more than 50% of the grassland area cannot be used for agricultural purposes.

The use of remote sensing methods and techniques, in our particular case - of vegetation indices, in pratological research gives at least three major advantages: significant reduction of the field stage by automated estimates, spatialization of scientific data and information, which allows processing with other cartographic and statistical data and their completion, but also the possibility to visualize the results, including for the "unseen" areas in the field.

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