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Trends in Land Cover Change in Abandoned Mountain Pastures. A Case Study: Măgura Marga Massif (the Southern Carpathians)

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Abstract

Grazing was the main activity of the inhabitants of the region, so that on an area of only 750 hectares, 16 sheepfolds existed simultaneously. In the last 20 years, mountain pastures were gradually abandoned a fact which led to some changes in land cover, mainly close to timberline. The aim of this paper is to identify general trend of land cover change using change – detection methods based on Landsat TM imagery for 1988 – 2011 time interval. Detailed analysis based on field research and high resolution air photos was also made for the areas with highest land cover changes. The analysis of the historical maps allowed a better understanding of the land cover transformations in the last 70 years. The results showed that the general trend in pastures area for the last 23 years is the biomass gain. Even if this phenomenon has a low and medium magnitude, it is a dominant one, appearing on more than 88% of the pastures area. Moderate intensity changes are explained due to the relatively short time interval since pastures were abandoned. Major changes occurred in some areas: on the southern slopes, because of the specific topoclimate, in areas where the anthropogenic timberline was lowered at very low altitudes and in the areas near the spruce timberline. There are also areas where there are no obvious changes of the timberline. These occur more frequently on the northern and western slopes, near the beech forest timberline. In the study area, the timberline is still anthropogenic, but if the current trend of forest regeneration continues, the timberline will change to a climatic one.

Keywords: *mountain pastures, grazing, timberline, land cover change, Change Vector Analysis (CVA), remote sensing, Măgura Marga Massif, the Southern Carpathians*

Rezumat. Tendințe ale modificării acoperirii terenurilor în cadrul pășunilor montane abandonate. Studiu de caz: Masivul Măgura Marga (Carpații Meridionali)

Păstoritul a fost principala activitate a locuitorilor din regiune astfel încât, pe o suprafață de numai 750 de hectare, au existat simultan 16 stâne. In ultimii 20 ani se constată o abandonare treptată a pășunilor montane care a dus la apariția unor modificări ale acoperirii terenurilor, observate în principal în apropierea limitei superioare a pădurii. Scopul lucrări este identificarea tendinței generale de modificare a acoperirii terenului prin metoda change-detection utilizând imagini satelitare Landsat TM pentru intervalul de timp 1988 - 2011. Deasemenea, o analiză detaliată bazată pe cercetări de teren și aerofotograme de înaltă rezoluție spațială a fost făcută în arealele unde s-au detectat modificări importante. Analiza hărților istorice a permis înțelegerea transformărilor survenite în acoperirea terenurilor în ultimii 70 de ani. Rezultatele demonstrează că procesul de creștere a biomasei vegetale este o tendință generală pentru ultimii 23 de ani. Fenomenul este dominant pe mai bine de 88% din suprafață. Intensitatea mică a transformărilor se datorează în principal intervalului de timp relativ scurt de când pășunile au fost treptat abandonate. Modificări majore apar pe versanții cu expoziție sudică datorită topoclimatului specific versanților însoriți, în arealele în care limita superioară a pădurii a fost în trecut mult coborâtă altitudinal prin defrișare, precum și în vecinătatea limitei superioare a pădurilor de molid. S-au observat și areale în care nu apar modificări evidente ale limitei superioare a pădurii, cu frecvență mai mare pe versanții nordici și vestici, în apropierea limitei superioare a pădurilor de fag. Limita superioară a pădurii este încă una antropică dar, în cazul în care se va meține tendința actuală de regenerare a pădurii, aceasta va evolua spre o limită climatică.

Cuvinte-cheie: *pășuni montane, păstorit, limita superioară a pădurii, acoperirea terenurilor, Change Vector Analysis (CVA), teledetecție, Măgura Marga, Carpații Meridionali*

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Introduction

One of the most important human activities in the mountain environment is grazing. Grazing influences the vegetal community evolution in areas where it is practiced, as well as the cessation of long-term grazing due to the secondary succession.

The effects of intense grazing lies in the modification of vegetation structure (Boșcaiu, 1971; Mayer et al., 2009; Parolo et al., 2011) with negative effect on rare, endemic and relict species (Baur et al. 2007). The extension of pastures and the modification of the treeline ecotone and of the timberline are also consequences of grazing (Niculescu, 1965; Boșcaiu, 1971; Nautiyal et al., 2004; Török – Oance et al., 2006; Mihai et al., 2007).

The pastures abandonment, a frequent phenomenon in European countries (MacDonald, 2000; Pavlu, 2005; Golodets, 2010) is also considered a disturbance of the environment (Milchunas et al., 1989). This abandonment appears later in ex communist countries than in other European countries (Kuemmerle et al., 2008). There can be noticed in many countries a decrease of areas covered by pastures and an increase of forest covered ones (Didier, 2001, Kozak et al., 2007; Falcucci et al., 2007). The succession trends after cessation of grazing and pastures abandonment are toward gradual invasion of shrubs and forest recovery on formerly grazed areas. Usually the extension of shrubs is in the detriment of the dominant herbaceous species, like Nardus stricta (Hiller, 2005). The forests invasion into abandoned grasslands is considered in many areas a driver of forest regeneration instead of climatic change (Gehrig-Fasel et al., 2007, Tasser et al., 2007). Increasing timberline related to decrease grazing was also detected in Southern Carpathians (Mihai et al., 2007) and in the Ukrainian Carpathians (Sitko and Troll, 2008).

The aim of this paper is to identify the general trend of land cover change using change – detection methods based on Landsat TM imagery for 1988 – 2011 time interval. We used both NDVI image differencing and Change vector analysis methods.

Study area

Măgura Marga Massif is the highest part of the Bistra Mountains, which are located in the north-western part of the Southern Carpathians (Fig.1). They are a lower subunit of the Țarcu Mountains (Niculescu & Călin, 1990) and reach the maximum altitude of 1502 meters in Măgura Marga Peak. The ridges are gentle and have a high degree of smoothing. They are remnants of Râu Șes and Gornovița old leveled surfaces (Badea et al., 2001).

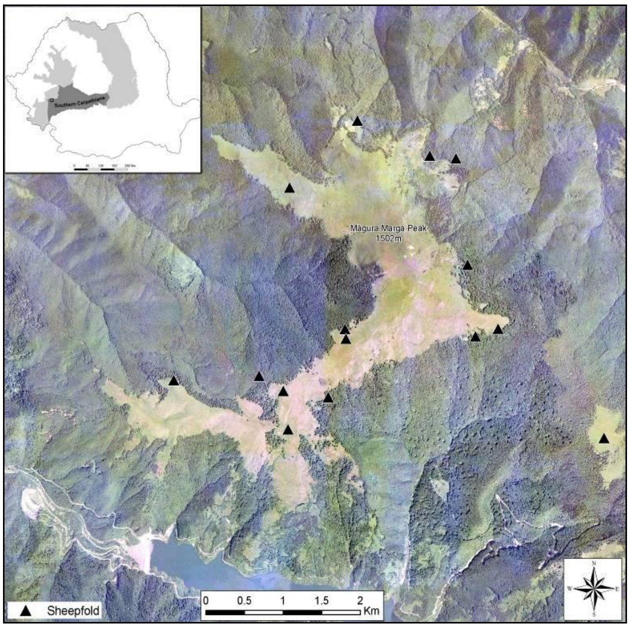

Fig. 1 Location of the study area

The beach forests (*Fagus sylvatica*) cover the largest area but, in some places, there are mixed forests where fir (*Abies alba*) or spruce (*Picea abies*) are the dominant tree species. There are several glades which have been used mainly in the past as hay meadows or pastures. The timberline is anthropogenic (Boşcaiu, 1971, Török - Oance and Török - Oance, 2005) and is located at altitudes ranging between 600 m to 1100 m. Above timberline, there are mountain pastures, which were extended mainly following deforestation. The vegetation consists of grasses where Nardus stricta and Festuca rubra are the dominant species. The shrub vegetation is also present over large areas. The dominant species are: Vaccinium myrtillus, Vaccinium vitis-idaea and Juniperus sibirica. The mountain pastures formed an anthropogenic ”pseudo–subalpine” level (Boșcaiu, 1971). Măgura Marga Massif was the main place for sheep grazing for the peasants from nearby villages: Marga, Măru and Voislova. Sixteen sheepfolds existed on the mountain pastures in the same time, near the timberline. Gradually, grazing was abandoned as a consequence of the economic, social and political transformations during last 20 years.

Materials and methods

Data

For change – detection we have used two Landsat TM imagery (path 185 and row 028) from different years, but for the same season: 29 August 1988, 29 August 2011, respectively (images courtesy of the U.S. Geological Survey). Further, the 1988 scene will be named time-one (T1) scene and the 2011 scene will be named as time-two (T2) scene.

We used paper maps from different time periods for a better evaluation of the land use/land cover changes. We used topographic maps al 1:20000 scale - Măru (1953) and Bucova (1940) map sheets - (maps courtesy of geo-spatial.org) and topographic maps at 1:25000 scale color from 1984.

SPOT HRS Digital Terrain Model (DEM), 30 m horizontal resolution, was used for both morphometric analysis and for the mitigation of the topographic effect. Detailed analysis was made based on GPS data and color air photo from 2005 (0.5 meters resolution).

Since the NDVI values are closely related to rainfall, we used average monthly precipitation data for both considered periods: August 1988, August 2011, respectively. Data were recorded at the Cuntu meteorological station (1460 m), at only 15 km distance in straight line from the Magura Marga Massif.

Image processing, change–detection and spatial analysis were done in IDRISI Andes and ArcGIS 9.3. software.

Pre-processing

Change analysis requires some preliminary data processing. Both Landsat TM scenes are geometrically and terrain corrected (L1T product type).

Radiometric normalization of the input data was made using image regression. Linear regressions were performed for each pair of bands considering the bands from T1 as independent variables. The resulted equations were used to produce adjusted time-one images (Eastman, 2009).

The shading induced by relief in a mountainous area is a source of error in the analysis and interpretation of satellite images (Millette et al., 1995). Both images are acquired early in the morning (image from 1988 at 8:30:00 and the one from 2011 at 09:03:37), when the effect of shadowing can be extreme. So, it was necessary first to eliminate of the topographic effect. We used the modeling illumination based on the DEM for the mitigation of the topographic effect (Eastman, 2009). Hillshade function was used to obtain the illumination model from SPOT HRS DEM. We used the same values of the sun elevation and sun azimuth with those from the acquisition of the Landsat scenes. This model was used to calibrate each band in order to remove the topographic effect.

NDVI changes

One of the most commonly normalized indexes used to analyze vegetation is Normalized Difference Vegetation Index (NDVI) (Rouse et al., 1974). It is calculated as the difference between NIR and RED bands normalized by the sum of those bands (Equation 1).

$$NDVI = (NIR – Red) / (NIR + Red) \quad (1)$$

Theoretically, NDVI values are ranging from -1 to 1. Usually, negative values represent water, values around zero represent bare soil and values over 0 represent green vegetation. The NDVI images were compared using statistical tests. For the detection of NDVI changes, we applied the image-differencing method.

Analysis of summary statistics of NDVI values showed that both extreme values and averages are higher in 2011 than in 1988 (Table 1).

Period	Min.	Max.	Mean	SD
29.08. 1988	0.1504	0.7446	0.5009	0.1381
29.08. 2011	0.2445	0.8962	0.6109	0.0904

SD = standard deviation

Statistical comparison of the two data sets, performed with Wilcoxon matched-pairs test, showed that there exists a highly significant statistical difference ($p < 0.0001$).

Image differencing was used for change detection of the NDVI. We have decreased the older image (1988) from the new one (2011). Positive values indicate areas where NDVI was stronger in 2011 than in 1988, while the negative values indicate those areas in which the NDVI is lower. NDVI data from difference image are normally distributed, so we used as the threshold between "no changes" and "changes" two standard deviations from mean. We

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also considered three standard deviations as threshold between "changes" and “major changes”.

Change Vector Analysis

CVA is a method for detecting changes using more than one spectral image pairs. If relevant spectral features are used as input data instead of original data, the result of CVA could be more useful, allowing a better interpretation (Johnson and Kasischke, 1998). Because the analysis was focused on land cover changes, we used the brightness and greenest components derived by Tasseled Cap Transformation as input data, components considered to be better biophysical indicators than spectral bands (Siwe & Koch, 2008).

Tasseled Cap Transformation (Kauth & Thomas, 1976, cited by Mather, 2004) is a special case of principal components analysis which produces four new components: brightness, greenness, yellowness, and nonesuch. The brightness is associated with bare soil and rocks or built-up areas and the greenness is associated with green vegetation. The brightness and greenest components contained about 95% of the total variability of the data (Lillesand & Kiefer, 2000).

To asses the vegetation changes, we used as input data for CVA two pairs of images: the brightness and the greenest tasseled cap components at T1 and T2. CVA method produces two output change components: the magnitude of change and the direction of change. The magnitude measure is the Euclidean distance computed in the n-dimensional space, between the location of the T1 pixels to the location of the corresponding T2 pixels.

Direction of change is represented by the vector direction in n dimensional space between the two moments, T1 and T2. It is expressed in degrees from 0 to 360 in a clockwise direction (Fig. 2). The direction of change shows the type of changes (Eastman, 2009).

Magnitude of changes ranged between 0.016 and 178.08, with an average value of 48.874. We established four grades of change intensity (no change, low, medium and high), based on magnitude data histogram analysis and field data.

The direction of vectors is the result of the combination of positive or negative changes in the spectral bands analyzed. There can be distinguished 2n types of changes, where n is the number of bands (Lorena et al., 2002). Thus we could distinguish four types of changes: biomass loss (increase in brightness and increase in greenness), biomass gain (decrease in brightness and increase in greenness), burned areas, water or forest regrowth (decrease in brightness and decrease in greenness) and deforestation (increase in brightness and decrease in greenness) (Fig. 2). The direction image was reclassified in the above mentioned change categories. In the area where pastures occur, the biomass gain is the dominant change.

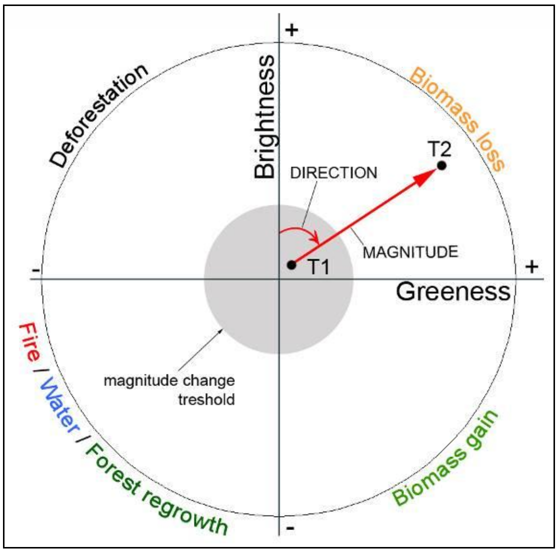

Fig. 2 Representation of the magnitude, direction and the resultant change direction classes in 2 band radiometric change space (brightness and greenness tasseled caps)

Visual analysis of historical maps and air photos, related with field data, allowed the understanding of changes detected by CVA. The analysis regarded especially areas with the greatest magnitude of change and with direction of change between 90 and 180 degrees, which represents biomass gain. The analyzed maps are from periods of time when grazing was practiced with different intensities: the early communist period (1953), at the end of the communist period (1984) and after this period (2005).

Results and discussions

Change detection method applied to spectral features used in the analysis of vegetation (NDVI and tasseled caps) showed that, for the considered period, there is a general trend of increasing plant biomass in abandoned pastures areas. NDVI analysis showed important changes of this index in two main areas (Fig. 3). The first one is located in the southern part of the area, along the Bistra Mărului valley, related with the construction of the Poiana Mărului reservoir, which was finished in 1990. There are two dominant trends here: the high decreasing of the NDVI due to increased surface water and the high increases in NDVI at the west of the reservoir were vegetation recovered the area affected in 1988 by construction works.

The second area overlaps pastures and is characterized by medium to high increase of NDVI. The largest areas where NDVI increased are in the north where the number of sheepfolds, now abandoned, is higher. In the south, the location of these areas is near the limit of the forest, which was lowered by clearing up to about 600 m altitude.

Since there is a direct correlation among rainfall and NDVI (Wang et al, 2003; Cui & Shi, 2010), we checked if the increase of NDVI is somehow caused by this climatic factor. The rainfall data recorded at Cuntu meteorological station showed that monthly average value recorded for August 2011 (15.8 mm) is much lower than average rainfall in the same month of 1988 (43.6 mm). The year 2011 was a very dry one, so that NDVI increase is not caused by precipitation.

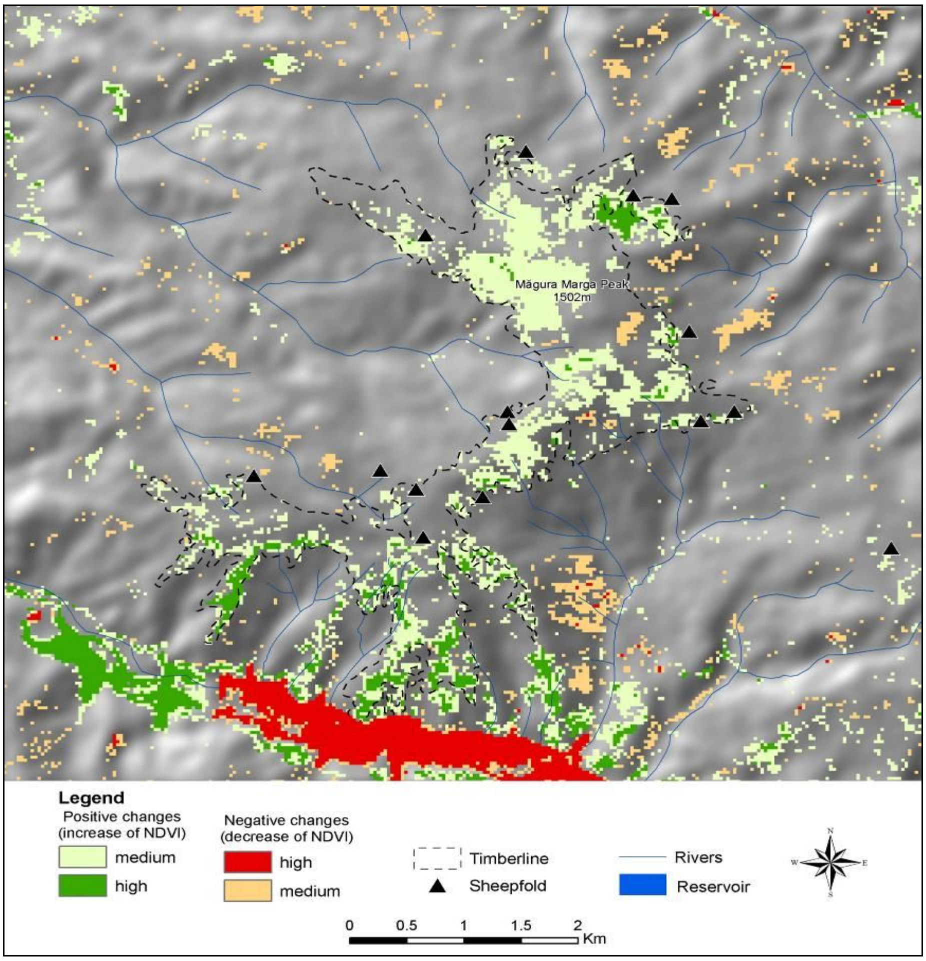

Fig. 3 NDVI changes for 1988 – 2011 period

VCA highlighted a predominance of plant biomass growth in the area used as pasture (Fig. 4). Even though the most common biomass increases have small and medium magnitudes, this is a general phenomenon that affects over 88% of the pasture area. There is a growth of scrub vegetation consisting of Vaccinium myrtillus and Vaccinium vitis-idaea and in some areas at higher altitudes, the advancing of Juniperus sibirica shrubs was observed. This phenomenon is common in abandoned pastures (Schulz & Leininger 1991; Coughenour 1991; Dullinger et al., 2003). The highest changes occur in some areas eastwards and southeastwards of Măgura Marga Peak, near the upper limit of a small patch of spruce forest. Here, there is a higher advancement of spruce seedlings and shrubs which leads to regeneration of treeline. In contrast to this area, the smallest changes of timberline occurred in the deciduous forest areas, a phenomenon also observed in Ukrainian Carpathians (Sitko & Troll, 2008) (Fig. 4), except for the abandoned pastures on the southern slopes and also the pastures within glades, where we noticed the regrowth of the trees and seedlings, a fact confirmed too by the large increase of NDVI. (Fig. 3 and Fig. 4) This phenomenon is specific for the areas where timberline is artificially created. (Holtmeier, 2007).

We detected that the land cover change is related to slopes exposure to solar radiation. On the southern slopes, the forest regeneration and the shrubs growth is more intense than on the northern slopes. This is due to specific topoclimate of the southern slopes, characterized by higher temperatures and earlier melting of snow cover, compared to northern slopes. The regeneration of vegetation is directly related with a favorable thermal regime (Holtmeier, 2007).

Another explanation is that because of this particular climate, the forests from the southern slopes have been cleared and the pastures were extended far in the forest domain, up to altitudes of 580-800 m. With the abandonment or reduced use of pastures at present, the forest began to recover its former territories.

The cartographic analysis of maps from different time periods is complementary to change detection method. So we could understand the land cover evolution for a longer period of time (1940 – 2011). On topographic maps from the 1940-1953 period, there were no patches of forest or isolated trees near the timberline, which shows high intensity of pasture use. On 1984 topographical maps, isolated trees and some forest patches are represented above timberline. The succession trend of the vegetation after cessation of grazing and pastures abandonment could be easily observed on the air photos from 2005 (Fig. 5, Fig. 6, Fig. 7).

The field observation showed that in the proximity of the sheepfolds, the vegetation differs significantly from that of surrounding areas. The nitrates and phosphorus accumulation in soil modified the physical and chemical properties of the soil. As a result, the grasslands were replaced by azonal vegetation with *Rumex alpinus, Urtica dioica* and *Poa annua*. This vegetation is very persistent and occurs even in areas where the grazing has been stopped for many decades.

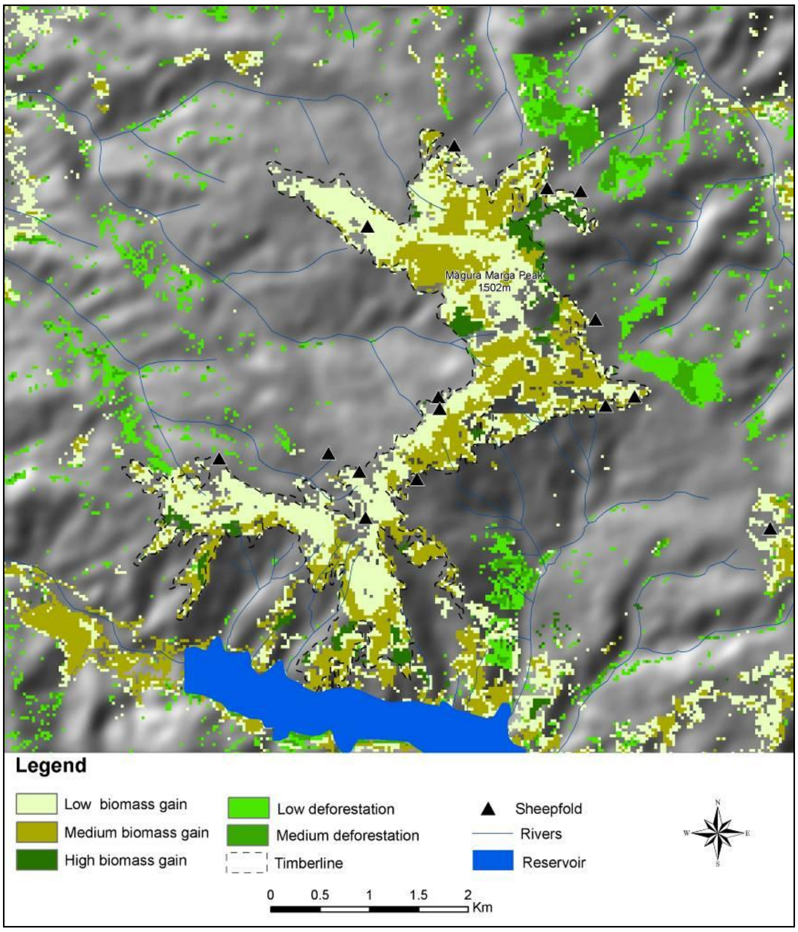

Fig. 4 Gain and losses in vegetal biomass between 1988 - 2011 detected by CVA

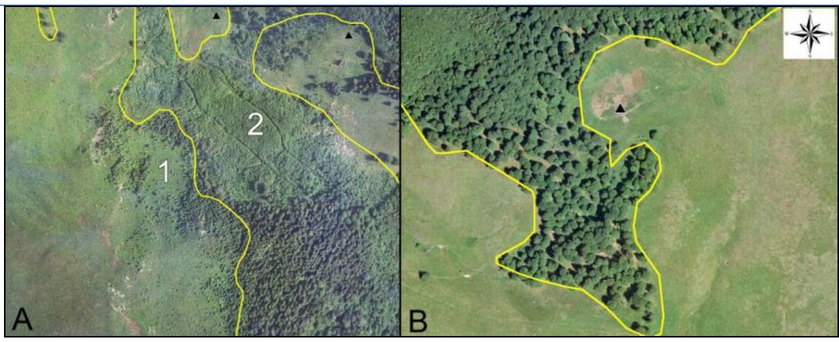

Fig. 5 Comparison between timberline in 1984 (yellow line) and 2005 (air photo). A: Treeline advance above the coniferous timberline (1) and forest regrowth in deforested area (2); **B**: Beech forest timberline. Almost no changes can be detected in this time interval

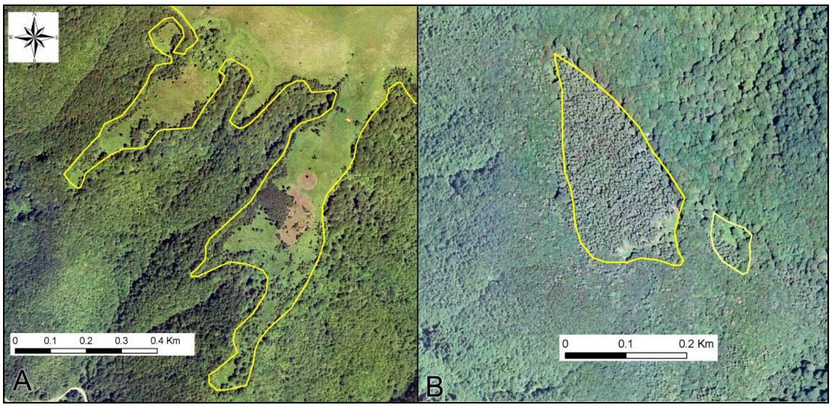

Fig. 6 Comparison between timberline in 1984 (yellow line) and 2005 (air photo)

A: Advance of trees, seedlings and shrubs on the southern slopes pastures; **B**: Glades used in the past as pastures and hay meadows, invaded in present by seedlings and shrubs

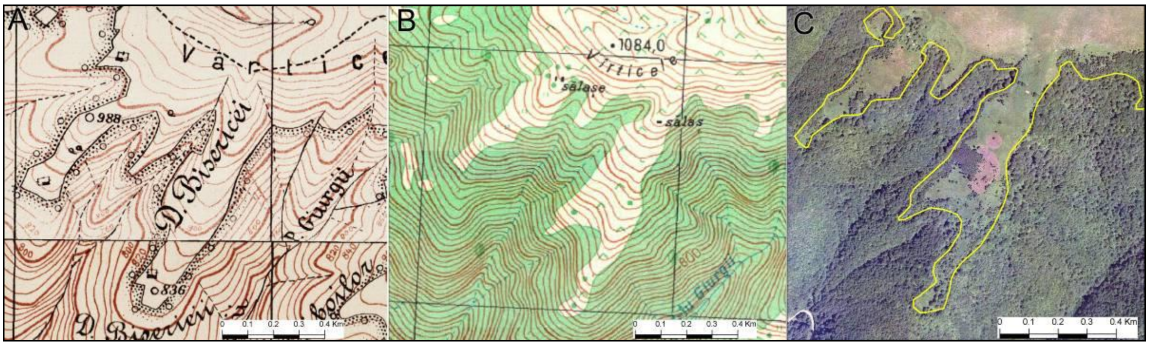

Fig. 7 Timberline of the same area in different period of times: A, topographical map at scale 1:20000 (1953); B, topographical map at scale 1:25000 (1984) - isolated trees or small forest

Conclusion

The analyzed area is one where grazing was practiced extensively until 20 years ago. Mountain pastures in the study area form a "pseudo-subalpine" domain because they have been largely extended by forest clearing and burning of the shrubs. The timberline is anthropogenic and is far lowered on the southern slopes, to below 600 m altitude.

Both NDVI image differencing method and VCA showed that, for 1988 – 2011 time interval, the general trend in abandoned pastures is the vegetal biomass gain. In contrast to other methods of change detection, CVA provides both quantitative information on product changes (magnitude of change) and especially qualitative information (direction of change). Moreover, CVA has the ability to detect biomass changes even in the same category of land cover. Field data are absolutely necessary for correct interpretation of the analysis results. This study is the first attempt to detect vegetation changes using VCA method for the Romanian Carpathians.

The predominance of plant biomass growth with low and medium magnitudes is the dominant process in the abandoned pastures. At southern slopes and in areas where the anthropogenic timberline was lowered at very low altitudes, this process is more intense. In contrast to this areas, the smallest changes of timberline occurred in the deciduous forest areas, on the northern and western slopes.

We could notice both change in the grassland vegetation structure, where dominant species, like Nardus stricta, has been replaced by scrubs on large areas, and the regeneration of the forest vegetation. We detected also the treeline ecotone regeneration near the fir timberline. Near the sheepfolds, the vegetation is azonal and persisted even if the grazing has been stopped for many decades.

Although in the Southern Carpathians there is an obvious trend of the temperature to increase, because of the very low altitudes of the timberline in the study area, the forest recovery is not a consequence of the climatic change. Favorable thermal regime can be considered to be an additional factor. In the future, if the current trend of forest regeneration continues, the timberline will change to a climatic one.

Better results should be obtained by using satellite images with very high resolution. In further studies, it will be established representative test areas for the monitoring of the vegetation changes.

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