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REMOTE SENSING AND GIS FOR THE FOREST STRUCTURE ASSESSMENT AT THE SMALL BASINS' LEVEL IN THE APUSENI NATURAL PARK

I. HAIDU¹, G. COSTEA²

ABSTRACT. – **Remote Sensing and GIS for the Forest Structure Assessment at the Small Basins' Level in the Apuseni Natural Park.** Land use is an important element when dealing with matters related to solid or liquid flow. The changes registered in the land use can be correlated with the results of balance equations for many small basins. Although these changes are characteristic for the built areas, they are specific to the areas where changes in vegetation structure occurred due to deforestation. Taking into account the environmental factors and other elements that the Apuseni Natural Park promotes (social, landscape, etc.) we were able to highlight, through the use of the new monitoring, analysis and calculation techniques available, the manner in which the forest structure in the park is evolving, at the small watersheds' level. By the use of remote sensing we obtained data for the 1988-2008 land use structure. The resulted data was used as a starting point in the process of developing a GIS model that can deliver data regarding the evolution in the changes at the level of the small watersheds inside the park. This model takes into account both facets of the change process a forest can undergo: afforestation (forest growth over time) and deforestation. Thus, the results obtained have an important significance in establishing the effect of deforestation upon flash-flood formation.

Keywords: *Deforestation, water balance equation, Apuseni Natural Park, Remote sensing, GIS model, small watersheds.*

1. INTRODUCTION

Small basins located in the mountainous area are most likely to have high slopes presenting a high torrential degree. These basins have a high energy of the relief as well as aggressive rainfall patterns that combine and contribute to the run-off formation. Most of these basins are covered by wooden vegetation, which is a part of the forestry fund (O. Iacobescu, 2000).

Forest is one of the shields involved in the interaction process between Earth and water. Deforestation has a negative influence over the runoff. Forests slow down the torrents by diminishing their force, playing therefore an important role in the hydrological cycle. Precipitation water is stored in different manner in the forested areas as compared to dry or almost barren ones. There is no efficient method, mysterious or magical, that allows a total control over the force of water flow (F.A.O., 1967).

The forest, "inadvertently" shares together with the soil, the amount of fallen water storing a part of it in the canopy, another being absorbed by trees and other being eliminated

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through perspiration, etc. Therefore we can infer that in those places where no forest exists, together with certain geomorphological conditions, massive water accumulation is favorable, increasing the flash-flood risk (M. Domnița et al. 2010).

The purpose of the present study, namely the forestry pattern development at the level of small basins, is a topic that can bring reinforcements to the fact that deforestation, most of times practiced at a massive scale, has a large influence over the flash-flood formation.

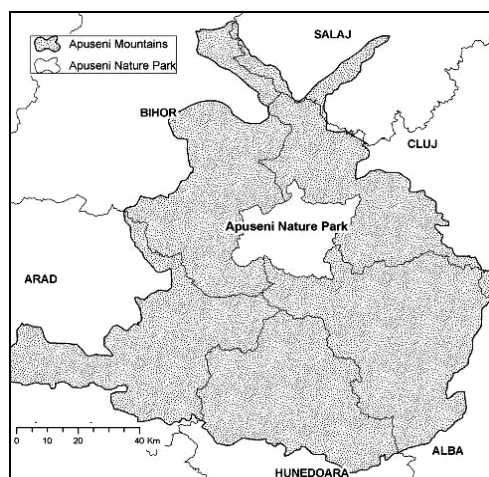


Fig. 1. The localisation of Apuseni Natural Park.

The flash-floods resulted from the water runoff processes reported in the basins of the Apuseni Mountains, led to the choosing of this area for the present study. So that the results of the research topic have a greater importance, the study area was widened in order to match the borders of the Apuseni Natural Park. In this way, the conclusions and results can be given a local character. Located in the heart of Transylvania (Western Romania), at an altitude ranging from 300 to 1800m, the Apuseni Natural Park (approximately 76 000 hectares) constitutes a very interesting subject in what regards the hydrological studies, but also for the social characteristics in the area, its landscape, vegetation and fauna (fig. 1).

2. MATERIALS AND METHODS

To evaluate the changes of the forest patterns at the level of the small basins inside the Apuseni Natural Park, several steps had to be followed, namely: by the means of remote sensing the surfaces covered by forest were delimitedated, and by using GIS modeling and statistical calculation the pattern assessment of the forest located in the small watersheds was achieved.

2. 1. The remote sensing algorithm employed for the forest area surface calculation

The Landsat 5 and Landsat 7 images captured by the Landsat TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus) sensors were used in the process of establishing the land use in the area and particularly the identification of forest areas.

The Thematic Mapper sensor (TM) is an advanced multispectral scanning sensor designed to produce high resolution images. Data coming from this sensor are given simultaneously and transmitted in 7 spectral bands. Bands 1-5 and 7 are images with spatial resolution of 30 m and band 6 is a band with a resolution of 120m (thermal infrared). The ETM+ sensor produces high resolution images as well, which, in addition to the 7-band of the Landsat TM, produces another panchromatic band, band 8 with a 15 m resolution. The thermal infrared resolution is one improved as well, being one of 60m. Using these image sources, a study was conducted for the period 1988-2008. All the images used were taken between July and August, during the luxuriant vegetation period. The images used are of "Level 1" type, meaning that they undergone radiometric and geometric corrections.

Choosing the best band combination to achieve the best possible interpretation of details in the field was the next step. The best band combination is considered the 4-5-3. Since vegetation reflects a lot of light in the near infrared band (band 4, NIR) and the water absorbs almost the entire quantity of light, the contrast between geographical entities leads to a very good distinction of the land / water interface (biodiversityinformatics.amnh.org). Band 5 (Swire, Mid-IR) is a band sensitive to the changes in water content and those in the deciduous vegetation or soil moisture (www.gdsc.nl).

The 4-5-3 combination results in an image clearer than combination 4-3-2 as the bands belonging to the visible spectrum are less (only band 3 – Red exists), hence the recorded blur effect in the false color mode 4-5-3 compared with true color mode (3-2-1) or false color (4-3-2), is lower. It can be observed that the different types of vegetation are much better defined which represents a great benefit for classification.

This band combination emphasizes the phenomenon of light absorption in the infrared wavelength. As a result of the band combination, vegetation with high capacity of light absorption, like forests for example, isolated stands and water bodies with high content are much more emphasized and their differentiation from small vegetation is easier done. In this combination the vegetation appears under the form of red shades. It is noted that where vegetation is abundant and well developed (the forest areas), the color is darker due to the high water content in these elements. When the water content decreases, the band 5 has a larger contribution in the combination, determining lighter colors in the image (band 5 was placed in green filter). Green will be more visible when the vegetation reflects less in NIR (band 4) and more in SWIR (Band 5), as for example in the case of the several types of crops. Uncultivated land types or barren land as well as the inhabited areas will be identified in shades of blue turning grey (as the 3-Red band is placed in the blue filter, emphasizing the gap between ground and vegetation, which is more visible due to the presence of chlorophyll in the leaves) (www.gdsc.nl). Water appears as dark blue to black.

As a classification algorithm, and by having an extended knowledge over the studied area, the supervised classification using ENVI software will be run. By the means of supervised classification, the user can establish a number of classes of his/hers choice and generates the areas of interest for the study. Unsupervised classification doesn't offer this type of possibilities.

Thus, four distinct classes have been chosen for the present study: forest; water surface (water); soil with vegetation (herb); soil without vegetation (soil).

Applying the supervised classification algorithm for each set of images three raster files were obtained, where each represented pixel value is corresponding to land use forms previously defined. An example regarding the park land use structure is the situation from fig. 2, which represents park status in 2008.

2. 2. Forest structure Spatial Analysis at the small watersheds level inside the Apuseni Natural Park area - A GIS model

To achieve the intended purpose of this study we went to the next step, and namely integrating into a GIS database of the results previously obtained classifications. Hence, the obtained raster images were exported to ArcGIS where we extracted the park area covered by forest. The result was obtained under the form of three raster files. An example regarding the forest cover over the Apuseni Natural Park it is showed in fig. 3.

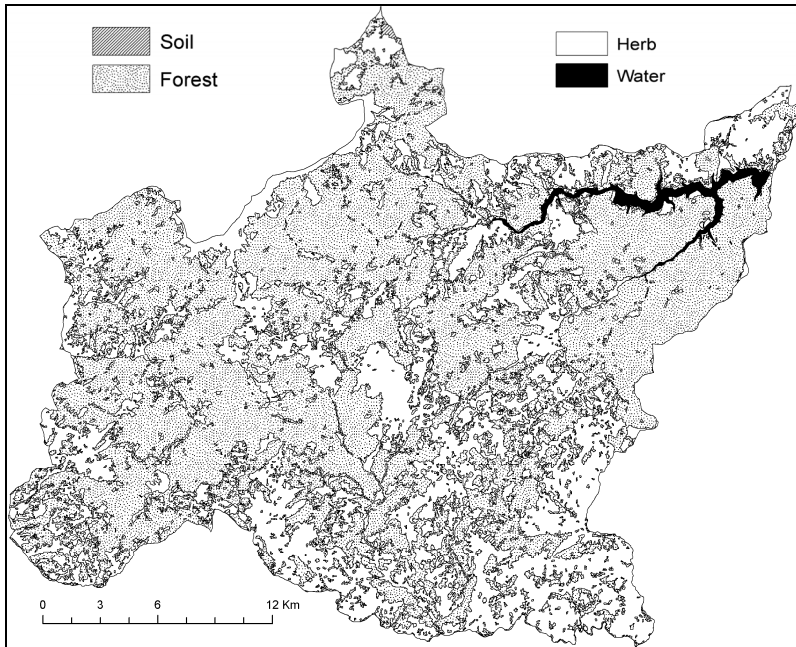


Fig. 2. “Maximum Likelihood” supervised classification method result
Land use structure in 2008.

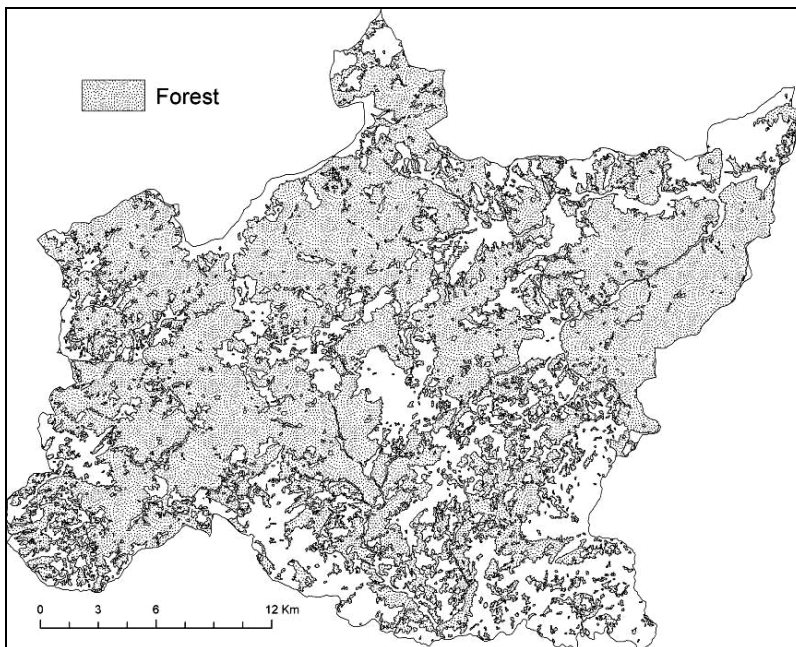


Fig. 3. Forested area in the Apuseni Natural Park in 2008 - raster file.

In order to structure the parks' surface according to the existing small watersheds, ASTER data was used (20m spatial resolution). This type of data led to the processing of the DEM. The use of the ArcHydro extension led to the vector structure (polygon) of the small watersheds (areas under 5 km²) to be created (fig. 4).

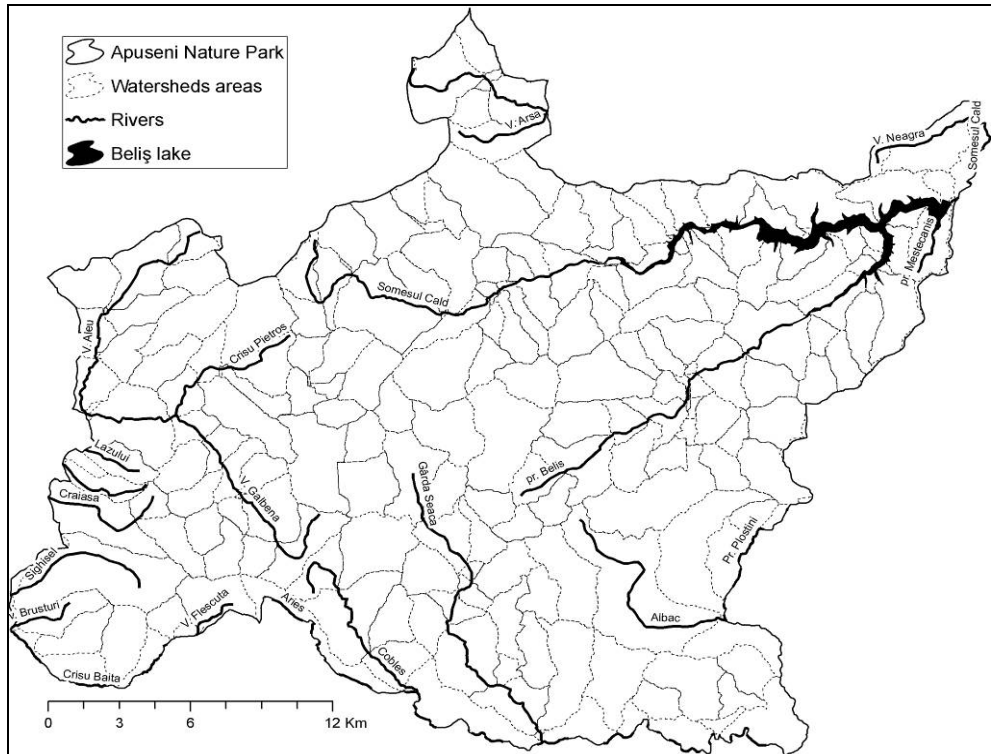


Fig. 4. The small watersheds areas from the Apuseni Natural Park.

A first analysis of forest pattern in the park was made for the a 12 year period (1988-2000). This period should be taken into account when interpreting the data obtained from the classification as there may appear positive results due to the stand existing in 1988 which could have spread in the 12 year period. The stand areas weren't detected unfortunately, as in 1988 the stand vegetation wasn't as lush as to allow its identification on satellite images. Such changes are considered as positive, while those resulting from deforestation are perceived as negative changes. The same principle was applied for the 2000-2008 period as well.

The Raster Calculator tool from the Spatial Analyst extension of the ArcGIS software was used in order to determine the degree of the forest fund evolution between 1988-2008. The result consists in raster data types displaying the values belonging to these changes (fig. 5).

Using this data the structure and evolution of small watershed during 1988-2008 was studied. The study implied the use of the ArcGIS software in order to build a computational model, integrated in ArcToolbox as a standalone tool. This model uses as input the vector layer corresponding to the small watersheds and the raster data previously obtained.

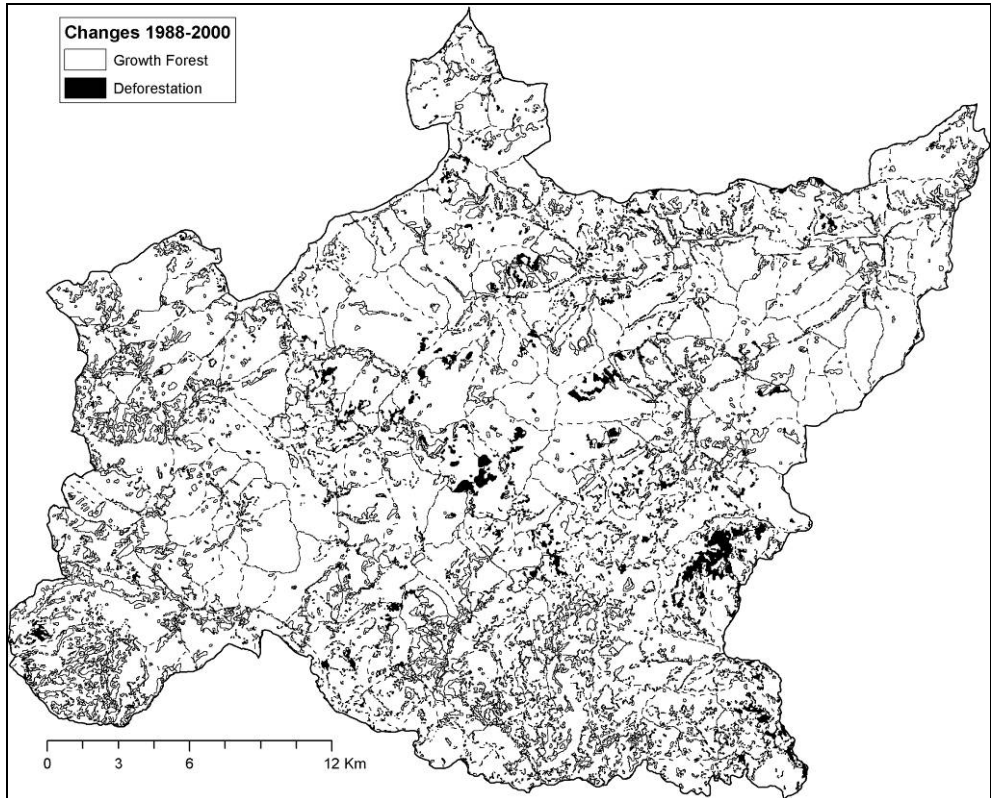


Fig. 5. Spatial changes of the forested structure in the Apuseni Natural Park from 1988 to 2000.

The GIS model, based on the spatial analysis done with Zonal Statistics (an ArcGIS extension) that takes into account simultaneously 2 values of a raster with a single band, which performs joins of data and calculations for each period introduced.

3. RESULTS

The application of all the afore mentioned steps and the use of the GIS integrated calculation model, led to the obtaining of data that facilitate an easier interpretation of the forest structure at the level of each watershed.

Following the interpretation of results we could represent as graphic the structure of forested area corresponding to the small watersheds from the Apuseni Natural Park for the studied period.

Fig. 6 is graphically representing the evolution of the park for the period 1988-2008. Similar maps were made for the periods 1988-2000 and 2000-2008 respectively.

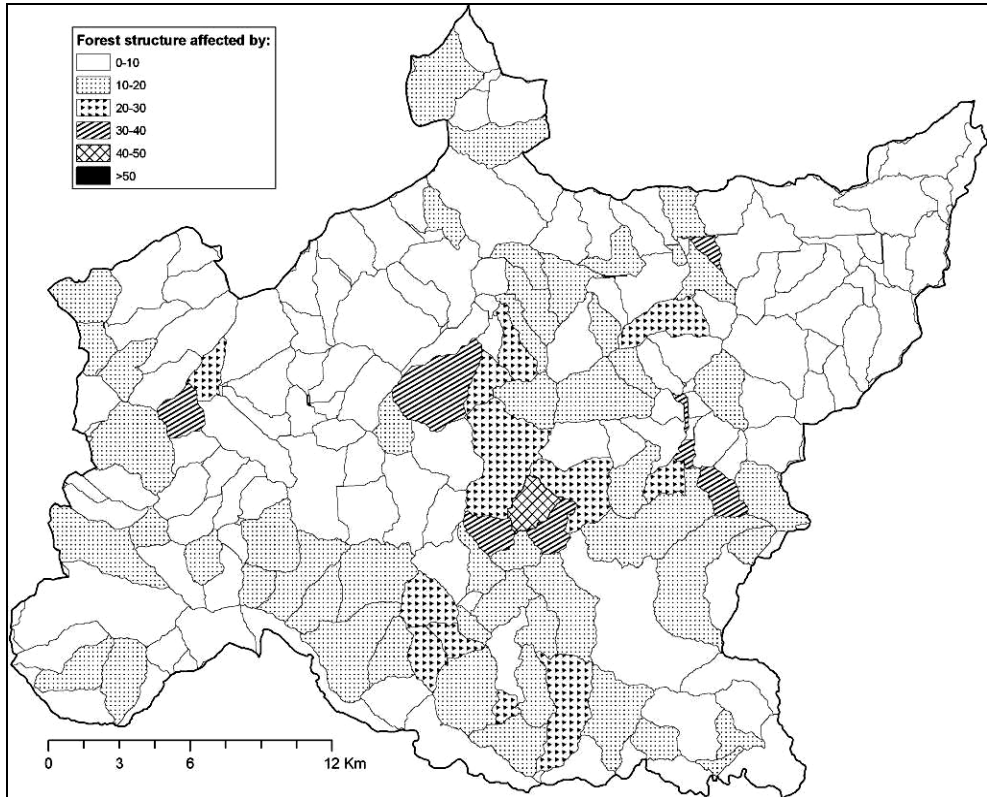


Fig. 6. Evolution of the forest structure corresponding to Apuseni Natural Park small watersheds for the period 1988-2008.

4. CONCLUSIONS

The present study has as purpose the local-scale assessment of the evolution registered in forested areas covering the small watersheds of the Apuseni Natural Park. In addition it tries to highlight the methods that can be used in order to achieve such an assessment.

By interpreting the results, for the 1988-2000 period, the forested cover in the small basins from the Apuseni Natural Park has not changed significantly, and the pattern suggests a cohesive forest structure, with small variations occurring in the highly populated areas, namely on the banks of the Albac and Beliș rivers (the SE of the park area), where deforestation reached here 15-16%.

The 2000-2008 period represented high interest for the authors of the presents study due to several reasons. The main reason was the report of several flash-floods that occurred after the year 2000. The second reason would be the returning of the forestry fund parcels to the presumed rightfully owners, as new laws have been passed regarding this matter. During this

time period, nevertheless, the patterns of the forested areas in the small watersheds have undergone massive deforestation. Hence, on the Beliș River, deforestation registered about 50% and on the other watersheds (the sub watersheds located in the West of the Park area, on the Crișul Pietros River, as well as those in the East and Center of the Park, in between the Albac River and the outlet of the Someșul Cald River at the Beliș Lake) major differences have been registered as compared to the 1988-200 period. This factor led to the apparition of the frequent floods registered since 2000. Furthermore it shows as well that the decision of giving certain rights to “old owners” over the forest stands is not a very good one.

The study over the period of 1988-2008 is justified, as it will reveal more accurately those watersheds that are facing problems in what regards the forested area pattern. It was found that in certain small watersheds, the forest structure was changed up to 50 %, sometimes 80% even (the case of the Beliș river, at the center of the Apuseni Natural Park) (fig. 6). As shown, the data the study based itself, is up to date. Therefore the results regarding the evolution of the forest structure in the small basins from the Apuseni Natural Park, become more useful and of real interest.

Land use changes, especially when dealing with deforestation, are important from the hydrologic perspective when they lead to an increase or to a decrease of the solid and liquid flow (O. Iacobescu, 2000). Although these changes are characteristically to the built areas, they are also specific to the areas affected by deforestation, especially when land use changes in the river basins having a high energy of the relief. The increase of the deforested area has the same resulting effect in this case, less obvious maybe, but very significant for the runoff process.

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