Forest cartography using Landsat imagery, for studying deforestation over three catchments from Apuseni mountains, Romania

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Abstract: - This paper is describing the development and application of a methodology that can be used to obtain spatial and statistical data which can allow the deforestation assessment, and not least it can provide the necessary support in assessing the deforestation influence upon runoff. Remote sensing and cartography, used to develop a method for obtaining spatial data regarding the land cover and especially regarding forest surfaces, allows better analysis of the processes involving forest removal, namely deforestation. The methodology is involving the usage of multitemporal - multispectral Landsat imagery and forestry data for an area represented by three catchments located in the Apuseni Mountains, Romania. By using the data sources, a unique spectral library has been constructed with unique land cover classes. This library was used for all considered project imagery. The obtained data was processed after that in a GIS environment in order to obtain the spatial distribution and numerical data that could highlight the deforestation process. The results were then used to indicate the magnitude of forest cover changes which occurred on almost 22% from one of the catchments area.

Key-Words: - Remote Sensing, cartography, GIS, Landsat imagery, spectral library, forestry data, deforestation assessment, Apuseni, Romania.

1 Introduction

Forest cover cartography and remote sensing is a critical measurement needed to extend a field-level understanding of ecological, hydrological, and biogeochemical processes to broader spatial and temporal scales in dry land systems. It is also critical for regional-scale monitoring of forest area changes relevant to land management practices in these regions [11]. Satellite data sets have allowed more standardized depictions of Earth's surface with the goal of creating repeatable map products and baselines for historical analyses. Satellite imagery with weak spatial and spectral resolution is not always capable to produce accurate data regarding the species and type of vegetation surface. This can be improved by using high spatial resolution satellite imagery with a more complete electro-magnetic spectrum [6]. However, satellite imagery give a great significance in the measuring of changes that take place in the forest vegetation, mineral or water surfaces. The obtained results are independent processes that caused those changes, if there is any.

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The real motivation of the present project is represented by the fact that deforestation has a negative impact over the runoff and not only. After a torrential rain event occurred, entire villages, bridges and roads are flooded [4]. Forests can slow down torrents by diminishing their destructive force and, subsequently they can play a major role in the hydrological cycle. When it comes to the rainfall, water is accumulated in different ways in the forested areas as compared to the dry and barren areas.

Considering the above mentioned statements we intended to develop a methodology that can be used to study the past and recent evolution of forest area from three catchments situated in the Apuseni region, Romania, by using old and contemporary data implemented and evaluated with the latest cartographic methods.

The area of Apuseni Mountains is an important area of Transylvania region and is a subdivision of the South-Eastern side of the Carpathians Mountains in Europe (NW of Romania). They are studded by an important hydrological network which has an important ecological role and an important role in energy production.

The area proposed for this study is an area represented by three catchments that are found within the Apuseni Mountains. These catchments are represented by: Răcătău (103 Km^2), Beli□ (84 Km^2) (located upstream of Poiana Horea village) and Some□ul Cald (99 Km^2) (located upstream of Smida village) (**Fig. 1**).

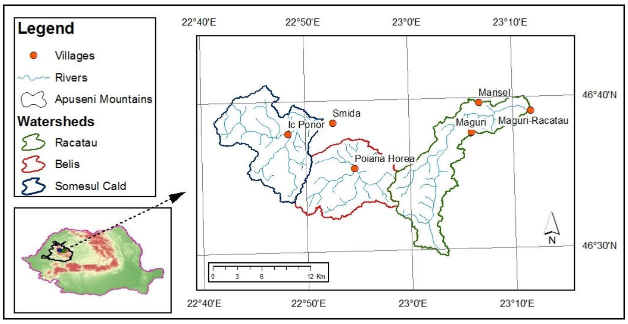

Fig. 1 Study area localisation

The catchments altitude ranges between 675m at the lowest point inside Răcătău to 1759m the highest point from Some□ul Cald catchment. The vegetation inside the area is characterized by coniferous forests represented by spruce and silver fir and small areas with mixed and deciduous forests mostly represented by beech and hornbeam.

The database used in the study is containing forestry data and Landsat imagery. Forestry data is represented by maps and inventory tables which were available for the years 1986, 1996 and 2006. The Landsat imagery was obtained for:

- 29 Aug. 1988 (TM);
- 22 Aug. 2000 (ETM+);
- 26 Aug. 2010 (TM).

The Landsat imagery is of good quality, which means that no clouds or haze can be found over the studied area. The imagery set was obtained for almost the same date from the vegetation season. With the database defined the next methodology was applied.

2 Methodology description

The methodology used for the study is a methodology which has included several steps for achieving the expected results. Thinking about the available database our intention was to perform a supervised classification in order to extract thematic data from Landsat imagery. From the multitude of supervised classification algorithms the Spectral Angle Mapper (SAM) has been chosen. This choice was made because we have successfully created a set of samples that allowed us to create a unique spectral library that can be used to classify all imagery set. And not least because of the advantages of this algorithm. The SAM algorithm has been run for the standard reflectance calibrated imagery [19, 1, 9].

2.1 Spectral Library creation

The Spectral Library is a set of classes or endmember spectrum to be referred during feature extraction process from hyperspectral or multispectral data. It can be further explained as a collection of spectral plots which is being compiled so that it can be used as a reference in information extraction from multispectral or hyperspectral data [8, 14]. Usually they are containing endmember spectra for the chosen classification scheme. The spectral libraries are usually built by compiling information from three sources:

- spectra collected during field campaigns;
- spectra built from laboratory analyses;
- spectra collected from image analyses (as training areas average spectra) [8].

For this study we have chosen the third method. The imagery from 1988 was used for calibrating endmember spectra. In this way we have identified by using the imagery database and forestry maps a few forest stands that didn't change their structure during the period 1988-2010. We have used this stands to construct unique forest training areas. For accuracy reasons the forest class has been separated into coniferous, deciduous and mixed. For the rest of the classes old and new photos and field trip data have been used to identify features. In order to assure the uniqueness of the spectral library a training area separability test has been done by using the calibration imagery. The results are represented in **Table 1**.

Table 1 Training areas separability test

	Training areas	1	2	3	4	5	6	7
1	Deciduous F.	0.00						
2	Coniferous F.	2.00	0.00					
3	Mixed F.	2.00	2.00	0.00				
4	Herbaceous Up.	2.00	2.00	1.97	0.00			
5	Barren land	2.00	2.00	2.00	2.00	0.00		
6	Pasture	2.00	2.00	2.00	2.00	2.00	0.00	
7	Water	2.00	2.00	2.00	2.00	2.00	2.00	0.00

*(0 = no separability; 2 = very good separability)

The Spectral library was constructed after that by using the average spectra collected from the training areas. At the end, the spectral library is containing a collection of unique spectra which are corresponding to the following classes:

- Water bodies;
- Forest land (Coniferous, Deciduous, Mixed);
- Herbaceous uplands;
- Pastures;
- Barren lands.

2.2 Spectral Angle Mapper (SAM)

The Spectral Angle Mapper (SAM) is one of the leading classification methods. It is a geometrical, physically-based spectral classification that uses an *n*-dimensional angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra, treating them as vectors in a space with dimensionality equal to the number of bands.

SAM classification assumes reflectance data [7]. However, the error introduced by using radiance data is probably (in most cases) not prohibitively large because the origin will still be near zero (even if it is not at zero) [17]. We have done a test for the test image calibrated in radiance, but because the radiance is affected by the quantity of incoming solar radiation and topography [10] the accuracy results after visual investigation show multiple errors. The advantages using SAM are:

- it is not affected by solar illumination factors, because the angle between the two vectors is independent of the vectors length;
- it is an easy and rapid method for mapping the spectral similarity of image spectra to reference spectra;
- it is also a very powerful classification method because it represses the influence of shading effects to accentuate the target reflectance characteristics;
- it does not require any assumptions on the statistical distributions of input data in performing classification, as is done in parametric methods, such as the Maximum Likelihood classifier [5].

Considering this the SAM algorithm was run for all imagery database. This was possible by using the ENVI software [17].

The results of this process are represented by three rasters representing the land cover classes for 1988, 2000 and 2010. The results have been statistically tested regarding the accuracy by using training areas as ground truth data. The obtained overall accuracy is 98.51% for 1988; 95.52% for 2000 and 93.28% for 2010. The overall accuracy is a very simple measure of accuracy [3]. The resulted value is computed by dividing the total number of correctly classified pixels by the total number of reference pixels. In this way Kappa coefficient is providing a better view over the classification accuracy. The coefficient is a statistical measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier [2]. In our case the values of Kappa coefficient is somewhat lower than the overall accuracy. Differences in these two measures are to be expected because each value incorporates different forms of information from the error matrix. The overall accuracy only includes the data along the major diagonal and excludes the errors of omission and commission. The values obtained for the Kappa coefficient are: 0.98 for 1988; 0.94 for 2000 and 0.91 for 2010. As we can see all the values, even the overall accuracy, are in 10% tolerance which means that we have a good spread of classification results around the considered period.

3 Results

Deforestation assessment using the land cover data obtained after the classification is possible only if these layers present veracity.

3.1 Land cover data validation

Validation is an estimation process focusing on the accuracy of remote sensing products. This assessment usually is achieved not on the whole map but on a statistically significant sample extracted from it [13].

Ground-truth information often referred to as "reference data," involves the collection of measurements or observations about objects, areas or phenomena that are being remotely sensed. This ground-truth information can be used by geographers to aid them in the interpretations, analysis and validation of the remotely sensed data [15].

Among many ground-oriented data sources are field observations, in situ spectral measurements, aerial reconnaissance and photography, descriptive reports and inventory tallies, and maps [18].

In this study ground truth data has been collected for forest type classes from forestry maps and inventory tables. Three stands that did not change over the time, which were also used to obtain training areas, have been chosen to be the ground truth data for our resulted thematic map. For the rest of the features we have used auxiliary data from forest maps, old and new field photographs, field inspections (for pasture, bare land, herbaceous upland and water).

The forest validation areas are represented by three forest stand which are configured like in the following: 1. 100% deciduous; 2. 100% coniferous and 3. 60% / 40% coniferous/deciduous for the mixed forests.

The validation process has involved a zonal statistic procedure which was possible by using the ArcGIS Desktop software [16]. The results for the resulted thematic data are presented in the following tables.

Table 2 Ground truth validation for 1988

Val.ar. \ L.C.	1	2	3	4	5	6	7	Total
1	**78.6**	0.0	0.0	0.0	0.0	10.7	10.7	100.0
2	0.0	**100.0**	0.0	0.0	0.0	0.0	0.0	100.0
3	0.0	0.0	**100.0**	0.0	0.0	0.0	0.0	100.0
4	0.0	0.0	0.0	**100.0**	0.0	0.0	0.0	100.0
5	9.1	0.0	0.0	0.0	**90.9**	0.0	0.0	100.0
6	11.3	0.0	0.0	0.0	9.4	**79.3**	0.0	100.0
7	0.6	0.0	0.0	0.0	0.3	0.0	**99.1**	100.0

Table 3 Ground truth validation for 2000

Val. ar. \ L.C.	1	2	3	4	5	6	7	Total
1	**91.1**	0.0	0.0	0.0	0.0	1.8	7.1	100.0
2	0.0	**100.0**	0.0	0.0	0.0	0.0	0.0	100.0
3	0.0	0.0	**100.0**	0.0	0.0	0.0	0.0	100.0
4	0.0	33.3	0.0	**61.1**	5.6	0.0	0.0	100.0
5	0.0	0.0	0.0	36.4	**63.6**	0.0	0.0	100.0
6	26.4	0.0	0.0	0.0	7.6	**62.3**	3.8	100.0
7	0.9	0.0	0.0	0.0	0.0	0.0	**99.1**	100.0

Table 4 Ground truth validation for 2010

Val. ar. \ L.C.	1	2	3	4	5	6	7	Total
1	**79.5**	0.0	0.0	0.0	0.0	16.1	4.5	100.0
2	0.0	**100.0**	0.0	0.0	0.0	0.0	0.0	100.0
3	0.0	0.0	**100.0**	0.0	0.0	0.0	0.0	100.0
4	11.1	0.0	0.0	**55.6**	33.3	0.0	0.0	100.0
5	9.1	0.0	0.0	0.0	**90.9**	0.0	0.0	100.0
6	1.9	0.0	0.0	0.0	0.0	**98.1**	0.0	100.0
7	9.8	0.0	0.0	0.3	0.3	0.0	**89.6**	100.0

** 1 = Deciduous F.; 2 = Barren land; 3 = Water; 4 = Pasture; 5 = Herbaceous Upland; 6 = Mixed F.; 7 = Coniferous F.*

There are many factors that we have to consider when interpreting the truth of a thematic map obtained by applying remote sensing techniques. Such factors are the day of the year/month in the vegetation season, losing of forest consistency, big deforestations, plants water content, inventory table data precision, imagery light conditions etc.

Considering all this factors the interpretation of the ground truth statistics data can be made. We can see that in all tables (**Table 2**, **3**, **4**), for all the years, the deciduous and coniferous forests are well defined, but the high species variability of the mixed forest sample is causing the spreading over the classes. This is happening more in 2000. The variability can be also due to the fact that the imagery from 2000 (ETM+) was taken in water stress conditions, and also because there is a very low number of possibilities to have a mixed forest stand close to 50/50 as a ground truth sample. But again a truth in the percentage spreading over the classes can be a proof of the thematic data precision. For the rest of the samples only the herbaceous upland is raising some problems because of strong reflectance properties of the high-dense herbaceous vegetation, but in a normal percentage regarding the accuracy. This can be also due to the dispersion over the area of some threes that cannot be classified as forest and are hard to spot on.

3.2 Deforestation assessment

Evaluation of the static attributes of land cover (types, amount, and arrangement) and the dynamic attributes (types and rates of change) on thematic data may allow the types of change to be regionalized and the approximate sources of change to be identified or inferred. These changes, in turn, influence management and policy decision making. Satellite imagery extracted data enable direct observation of the land surface at repetitive intervals and therefore allow mapping of the extent and monitoring and assessment of processes like change detection and deforestation [20].

In our case, this is an example that have the intention, for the first, to obtain the land cover variability over the studied area. No more studies have been developed before this one for the studied area which is considering such a long period of time. Regarding the forest areas, they have to meet the Romanian forestry law which is saying that we have to consider surfaces as forests if trees are covering a minimum surface of 0.25ha and they have minimum 5m height at maturity in situ [12]. There was no stand in the validation dataset that has trees under 5m. In our study a minimum of 0.27ha has been adopted because of imagery spatial resolution. For this reason a geoprocessing model was built to remove the surfaces under 0.27ha.

In order to compute the change detection a geoprocessing algorithm has been also created and used. The algorithm is using like input parameters the filtered thematic data obtained from satellite imagery.

Thus, we have classified the changes at the forest level as deforestation for the situation when the forest surface has changed in other cover type and reforestation/afforestation when the forest has been replanted or the forest has restored his growing vigor and consistency, in this way the pixels appeared as forest area on Landsat imagery (**Fig. 2**, **3**).

By using the data obtained from land cover change we were able to compute statistics (**Fig. 4**, **5**) and to make spatial assessments for the deforestation process.

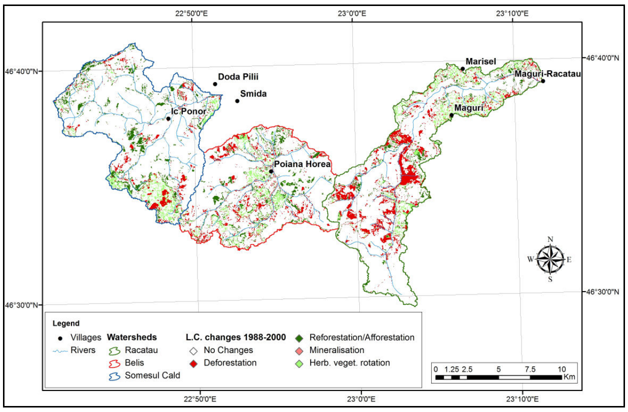

Fig. 2 Land Cover change 1988-2000

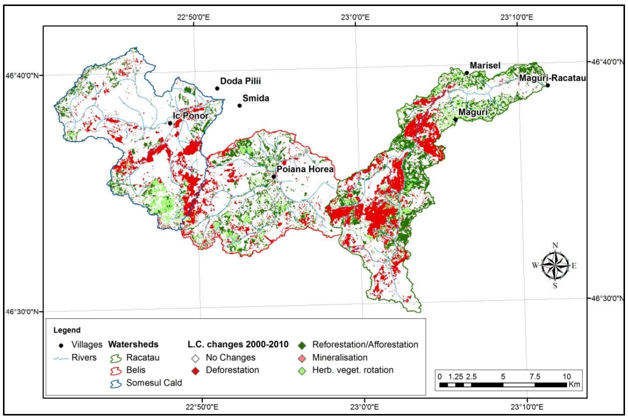

Fig. 3 Land Cover change 2000-2010

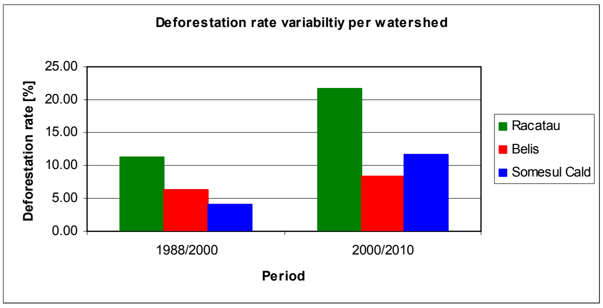

Fig. 4 Deforestation process intensity

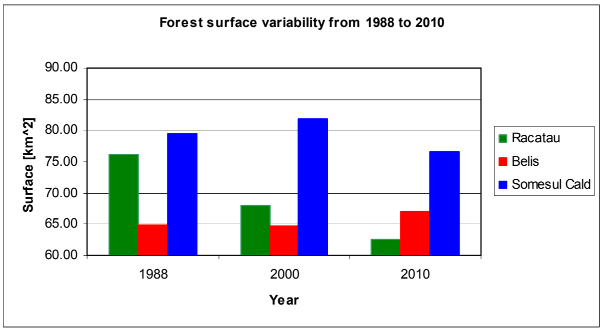

Fig. 5 Forest surface variability

The deforestation process which is occurring in the study area is affecting with a higher rate two catchments as we can see in **Fig. 4**. Răcătău and Some□ul Cald are the most affected. The higher rate of deforestation occurred in Răcătău is affecting in 2010 almost 21-22% of the catchment area. Beli□ has a lower deforestation rate, almost a constant rate. The graphic from **Fig. 4** is taking in account only the deforestation process without considering the reforestation/afforestation process.

We can use the forested area as a prove for the deforestation process variability. It can be notice that in **Fig. 5,** after 1988, for various reasons the forest surface has suffered a variability. For Răcătău and Some□ul Cald watersheds the variability was greater because big forest surface has been removed.

It can be seen that deforestation in the period 2000-2010 for Beli□ catchment was lowered compared to the others. This can be because of the applied forestry protection measures. They are reflected in the existence of a higher forest surface at the end of the period, in 2010 (**Fig. 5**).

4 Conclusion

Accuracy, reliability, reproducibility and robustness of an used methodology is demonstrated by the fact that it corresponds to the use for which it was provided. This was demonstrated by validating the results obtained after running the classification algorithm. The method gave good results even under weather change conditions. Although the vegetation lost much of its vigour in the 2000 image, due to drought conditions, the method is still able to extract with highly precision the land cover data. In this way, the analyzed process of deforestation is enjoying as well an increased accuracy and the presented results are in accordance with the truth.

Deforestation study in the catchments of Răcătău, Beli□ and Some□ul Cald rivers during the period 1988-2010 is a unique study in terms of used methodology and forest cover area variability over the years. Regarding the deforestation process values we can say that higher rates like the one occurred in the Răcătău catchment area should be absent or reduced.

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