“Babeş-Bolyai” University, Cluj-Napoca, Romania

Faculty of Geography

Department of Physical and Technical Geography

Ph.D. Thesis

- *Summary* -

Using Remote Sensing for deforestation assessment. The deforestation effect over the underlying surface characteristics changes in the upper basins of Someșul Cald and Someșul Rece rivers

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Key-words: *assessment; deforestation; Remote Sensing; effect; underlying surface; upper basins of Someșul Cald and Someșul Rece rivers.*

1. Introduction

Land area with all its features (relief, vegetation, soil, hydrography) influenced or not by human activity, plays an important role in transforming solar energy into heat, in wetting air masses and moving air masses transformation. This active area, underlying at the earth's surface, is in a constant interaction with the atmosphere.

Vegetation through its surface, coverage degree, species, density, height etc. has an important influence on the underlying surface of river basins.

Forest vegetation cover cartography and Remote Sensing is a critical measurement needed to extend a field-level understanding of deforestation process influence on the underlying surface characteristics changes that take place on land at both spatially and temporally scale. It is also a critical issue for regional scale monitoring changes to the wooded areas dealing with territorial planning.

In this way the present study[1] want to propose a complete methodology for assessing deforestations and effects which this process can have over the underlying surface characteristics changes by using the latest methods and data used in Remote Sensing and GIS. The methodology want to offer, especially, spatial results, but as well numerical for making assessments.

This work is divided in nine chapters. By analyzing their sequence we can draw the following steps that are the basis for this study: stating motivation, setting goals and study area description - the state of art regarding the knowledge and methods used in the current research topic, in Romania and abroad - building database - highlighting the link between environmental objects and the electromagnetic spectrum - the selection and the application of imagery processing methods - satellite imagery classification (building the unique spectral library, choosing the supervised classification algorithm, validate obtained data) - deforestation process assessment for the period 1974-2010 - deforestation effects assessments on the underlying surface characteristics variability.

2. Motivation. Research objectives. Study area

The knowledge of study real motivation is an essential element in understanding the result that will be obtained. Given that the study wants also to follow the spatial evolution of the

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analyzed processes, it is also necessary to know the area where these changes take place. The additional details regarding the configuration of the given area can be useful to give to the results a logically sense and significance.

2.1. Motivation

First of all is good to know, that this study don't wish to accuse or to deny the work of certain organs or entrepreneurs related to forestry but simply wants to be a support for forestry management. This is not only because it is a very difficult phase of its existence but especially wants to support actions which can stop deforestations while bringing massive support to the view that deforestations has an impact within both ecosystems and people's lives.

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 (Domniţa et al., 2009). 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, it is accumulated in different ways in the forested areas as compared to the dry and barren areas.

In this way the thesis wants to perform a study over the past and recent evolution of forest areas from three mountainous catchments by using old and contemporary data implemented and evaluated with the latest cartographic methods. Thus, by extracting information from new and old databases and use them for achieving the project objectives, we can say that this is a comprehensive study that can provide a very good view and assessment over the deforestation process and its effects over the underlying surface characteristics changes which are occurring in this area.

2.2. Research objectives

The main objectives of this study are the use of the latest mapping and spatial analysis methods for modeling the evolution of forested areas of three small basins in a mountainous area and the effect of her variability upon underlying surface characteristics. The objectives can be divided in a logical sequence that makes it much easier to understand the purpose of this thesis.

Thus, the first objective was to obtain the database that contain the initial data (scanned maps, satellite imagery, forest stands descriptions, GPS measurements etc.) in a GIS environment. Database will correspond to a period that starts from the 70's and ends in 2010. We have considered the year 1974 as the starting point due to availability of topographic maps and satellite imagery.

The identification of a new methodology which can address and use the database and which can lead to quantitative spatial and digital information (thematic data) for making assessments is an operation used to create new thematic datasets with significant value. Therefore after these operations it is necessary to proceed to the validation step.

With the obtained thematic data we were able to achieve the next goal, which is the most important, namely the deforestation process assessment. This phase of the study involved the usage of GIS modeling algorithms which use the thematic data previously obtained to produce spatial and quantitative data regarding the deforestation process for the considered catchment areas.

The last objective was represented by the assessment on the impact which the deforestation process can have on the underlying surface characteristics changes. This step is supposing the usage of some indicators that can provide valuable information's which are able to characterize the catchment areas regarding the forest surface, terrain configuration, the type or soil texture etc.

2.3. Study area location

To achieve the thesis purpose, which is the study of deforestation process evolution with a role in the runoff three small basins were selected from the upper basins of Someșul Cald and Someșul Rece rivers. When we have done the selection of these three basins we took into account the complexity of the physical-geographical factors, the existence of human settlements and not least the availability of the database.

These catchments were represented by Someșul Cald up-stream of Smida, Beliș up-stream of Poina Horea (both are tributaries to Someșul Cald River) and Răcătău, which is the main tributary for Someșul Rece river (Fig. 2.1, 2.2, 2.3).

As a part of the research work, we have developed a few studies which were published in a few journals and presented at some scientific manifestation (Costea & Haidu, 2010; Haidu & Costea, 2012; Costea et al., 2012). The studies have been developed for the sub-basins areas from Apuseni Nature Park as well.

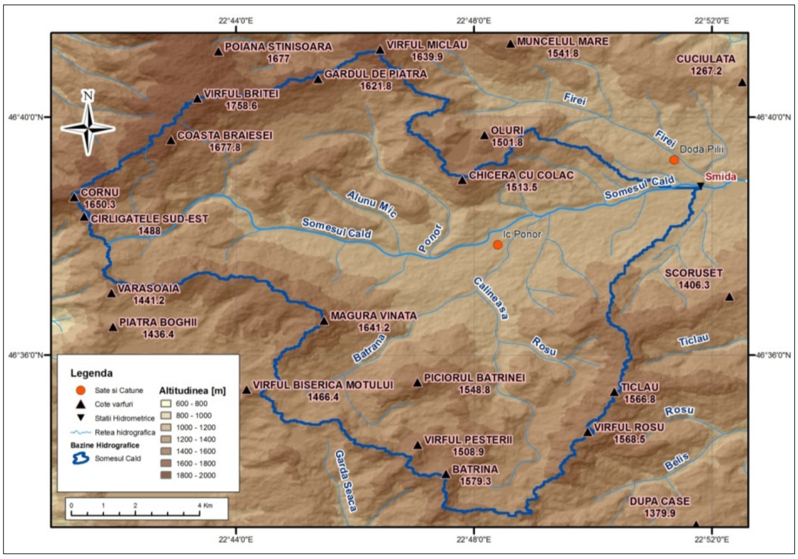

Fig. 2.1 Someşul Cald catchment area.

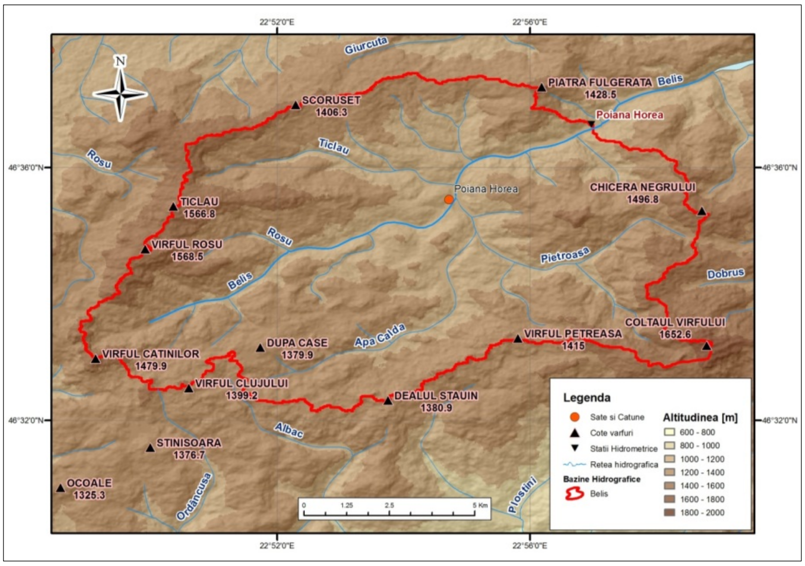

Fig. 2.2 Beliș catchment area.

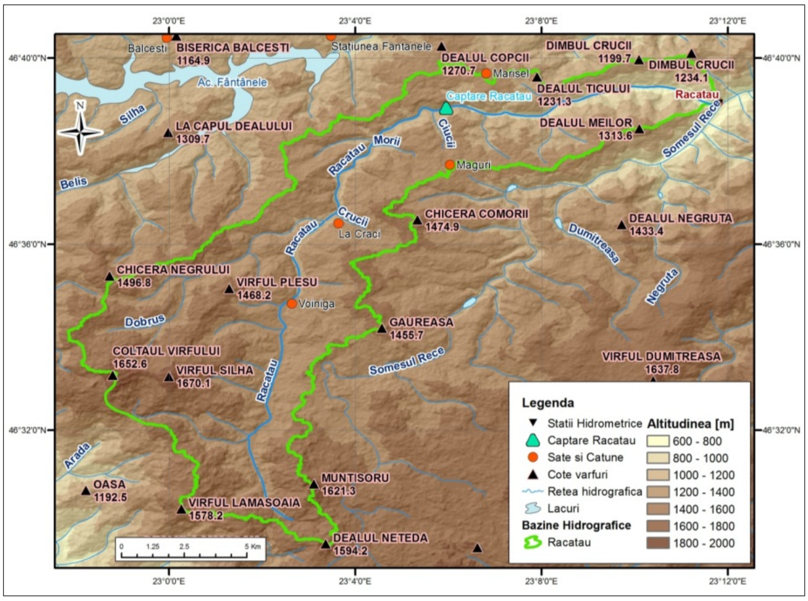

Fig. 2.3 Răcătău catchment area.

3. State-of-art

Deforestation, like a process occurred in the forested area has been the subject of several works. This have involved and still involves developing methodologies needed to materialize the phenomenon observed in the digital data. It can provide a quantitative - spatial point of view over the deforestation evolution at a specific space and time scale. In this way the magnitude and the impact are becoming much easier to study. Thus, a short resume for the studies regarding the deforestation research in Romania and abroad is proper, if we consider the topic of this study.

3.1. Short historical review of methods and data types used in estimating deforestation

There are many studies regarding the deforestation assessments. The same we can talk about the data types and the used methods. At international level many types of data were used from both sensors: active or passive.

At the beginning the damage and deforestation assessment were done by using field observations. Only after some time color and infrared aerial photography were introduced. Today we tend to use data obtained from Remote Sensing fro satellites, radar scanners and other modern data sources (satellite imagery with high spatial resolution, laser scanners etc.).

The first aerial observations (do not be confused with aerial photography) were made on forests since 1860 in USA. In Europe the first experiments with photos were around 1858 around Paris city. The first aerial photography has been made from an airplane around 1909 in France.

Aerial photographs were used for mapping vegetation since 1919, but their development as an important tool used in forestry, coupled with field observations, dates only from 1940. Later that, the ERTS satellites (later called Landsat 1, 2, …, 7) were launched to produce Remote Sensing data. Other known satellites are the satellites with optical sensors like SPOT, ERS, ASTER, IRS, IKONOS, NOAA, TERRA and radar satellites like RADARSAT and JERS (both provide optical and radar data).

LIDAR technique, developed in the last 15 years, is one of the newest approaches for assessing forest structure. Since LIDAR is able to penetrate the top layer of the tree crowns, scientists were able to get the vertical texture of the forest – things that no other scientific instrument can't provide. In the future people are intending to make LIDAR to perform forest inventory and biomass measurements, which will improve the maps resolution (www.eoearth.org; http://www.agu.org).

3.2. Undertaken deforestation assessment studies in Europe

In Europe the deforestations and especially forest clearances are dated from an early period which is found between the ancient and early modernism. In this Northern part of the planet was imposed a program of sustainable forest development. Deforestations are more evident in the southern part of the globe, in the tropics. Here, because of the fact that the states located in this area want to develop their economy, the forest loggings are very high (http://www.eco-act.typepad.com).

Many studies have been undertake, especially in Europe, to assess the changes that have occurred at the land cover level and in particularly on the disappearance of forest land. From these studies the most known are those made in Ireland, one of the richest countries in Europe in terms of land area covered by forest (Brown, 2009; Kankaanpää & Timothy, 2004); the studies from the “black triangle” area which is a part from a territory of three countries: Germany, Czech Republic, Poland (http://www.fao.org; Ardö, 1998; Schardt et al., 1993). These studies have been used satellite imagery, especially Landsat.

One of the biggest projects for Europe in terms of land use and changes detection that occur in a certain period of time is the "Corine Land Cover" project. This is a project that includes all European countries. The project is using data from digital sources like satellite imagery (Landsat, SPOT HRV) and cartographic sources, like land use maps, topographic maps or even forest maps. The data resulted after interpretation is provided at 1:100.000 scale. The smallest unit mapped is about 25 ha and the changes occurring in the studied period are reported only when they occurred on a minimum 5 ha area. So far data have been obtained for the period 1990 - 2000 - 2006 (http:// www.eea.europa.eu).

Studies which are using airborne radar data sets are those like the one performed by Keil et al. (1993) under the MAC Europe 1991 project, which uses radar data to assess forest areas in the Harz Mountains, Germany. Data used in this study is AIRSAR data type (multifrequency-polarimetric data) recorded in 1991 by JPL aircraft. This was an evaluation mission of the forests in terms of forest type, age classes, crown density, separating coniferous from deciduous trees, and damages recorded in the forest cover (deforestation, trees breaks etc.).

LIDAR technique was used for example in Europe to assess the structure of Pinus sylvestris stands in an area of Spain. Using this data it was possible to delineate areas of pine stands. Each polygon obtained was validated with field data information by considering the composition and structure of each stand. This is more a statistical study that seeks to highlight which validation method is better and gives the smallest errors in the case that we want to use LIDAR data for forest stands inventory (Pascual et al., 2008).

Studies which have used high-resolution satellite imagery are the studies made by Comaniciu & Meer (2002) or Chehata et al., (2011). They are using IKONS and Formosat-2 imagery.

3.3. Short history about forestry management in Romania

In our country in the early XX century forests occupied approximately 35-40% of the country surface. Their surface has been gradually reduced as a result of irrational exploitation, area disposal and deforestation. The forest area has come to fall from about 9 million ha to 6.3 million ha in late 1974 (Damian, 1978).

If at the beginning of capitalism, the forest economy was guided by the principles of sustained cuts soon this principle was abandoned or replaced by the maximum profitability. Consequently, the forest culture issues were sidelined. In this way less investment were made in this domain and maximum profit was obtained from exploitation.

The forest logging intensity reaches a maximum between the two world wars - in 1930 it exceeded with 60% the growth from the accessible forests. It was the moment when the companies with foreign capital have left naked many watersheds (Vrancea, Aries, Lotru, Ampoi, Sebeş and so on). They left prey whole areas to water erosion and they unbalanced the forest structure regarding the age classes. The operation was high even in the period from 1949 to 1964 (Damian, 1978).

Once with change of political regime and as a result of massive deforestation from the mentioned period conservation and development program has been developed for the period 1976-2010. The program was adopted by Law no. 2 from 15 April 1976. Through this program are established for the first time, long-term management measures, with very favorable consequences in forest management and economy (Programul național pentru conservarea și dezvoltarea fondului forestier în perioada 1976-2010).

For the knowledge of forest resources, the transition to a scientifically-based management of forests and establishment of forest capacity, during the period 1948 - 1956 forest planning have been developed for all forests. Our country is the worlds first fully equipped with forest management plans which are reviewed from 10 to 10 years. From 5 to 5 years they are used to develop the national forest inventory (Legea nr. 2 din 15 aprilie 1976).

3.4. Studies and research methods for Romanian forest evolution

In Romania topographic plans were initially used for forest inventory. After a while, aerial photographs were introduced. The first aerial photographs in Romania were obtained in 1910-1914 and the last ones dates from 2005 (Popescu, 2009). Recently in some forest research stations high-resolution satellite images, like Formosat-2 and digital photogrammetric processes were used, but only for forest inventory. The same is the case of LIDAR data (http://www.madr.ro, proiectul PS 851).

Studies which have also used Landsat imagery to highlight changes in forest structure are the ones made by Olofsson et al. 2011, Kuemmerle et al. 2009, Knorn et al. 2012. For the chosen study area *Costea & Haidu (2010)* have tried to do a deforestation assessment for the sub-basin areas.

Other studies evaluating deforestations were those where data from Corine Land Cover project has been used *(Kozak et al., 2006; Dutcă & Abrudan, 2010)*.

4. Building the project database

The database used in this study is based on both cartographic sources classic and digital. To describe and to define a geographical area there is necessary to have a database that contains with elements with x, y, z known coordinates. Combined with other data, a mapping database can be used to represent a variable distribution within a studied region.

4.1. Cartographic database

Regarding the classical cartographic database, on paper, necessary in the study, a database consisting from the following was obtained:

- Water cadaster maps, scale 1:100000, which were used in the first phase for locating and delineating the studied catchments.
- Soil maps, scale 1:200000, for obtaining information's regarding the soil type and texture for obtaining different coefficients.
- Topographic maps, scale 1:25000, were used to obtain, in digital format, all information's necessary regarding the catchments configuration.
- Forestry maps scale 1:20000, reproduce the forest surface was obtained by using the topographic plans at a scale of 1:10000. The aerial photography was made in 1962, and the cartography in 1966-1976.

4.2. The alphanumeric database and the secondary data sources

Alphanumeric data entry is required for various stages of the study. Information must be extracted almost always from an analogic source, electronic or not (depending on availability). Often it is necessary to introduce them manually. In this way we can create data which is describing various forest bodies. Thus, we obtained virtually auxiliary attribute used to obtain new information.

To summarize the data regarding the forest stands we have built a Forest Information System that stored the information. An example of such system is the system carried out by Haidu & Costea (2009) for U.P. I Ijar which is an adjacent area to the study area.

To identify other types of land cover I used old and new photos. In this way I was able to construct high precision sample surfaces for calibration and spectral library construction and not least for validating results obtained from satellite imagery classification.

4.3. Digital database

Digital databases are the last data sources in the field of GIS spatial analysis and modeling. From the multitude of existing data we purchased, realized and used the followings: Landsat satellite imagery (http://earthexplorer.usgs.gov); GPS measurements; ASTER DEM v2 (http://asterweb.jpl.nasa.gov).

4.4. Spatial and temporal resolution. Sensor choice

Acquisition of satellite images is one of the most important phases of a remote sensing based project. This step is important because the final results are affected by the project input data quality. A cloudless image with maximum visibility can be considered a very good source. Second, is very important to keep in mind the purpose for which we use the satellite imagery because there are several types of images and sensors that have different spectral and spatial characteristics.

4.4.1. Remote Sensing platforms and sensor types

Using a wider definition of Remote Sensing, we can say that there are many platforms on which it can be build or mount a Remote Sensing sensor. The discussions in this chapter have summarized the trading platforms and sensors used in cartography and in the most popular GIS applications. Satellites and airplanes collect data and imagery used in GIS. Sensor developed in these platforms incorporates film or digital cameras, light detectors, LIDAR systems, radar (SAR), multispectral and hyperspectral scanners. Many of these tools can also be mounted on terrestrial platforms such as trucks, tractors, tanks etc. Balloons or helicopters can also be used as platforms.

From the most popular sensors we mention: MSS, TM, ETM+ (Landsat), AVHRR (NOAA), HRV, HRVIR (SPOT, Spot Image), MODIS (Terra), ASTER (NASA, Terra), IKONOS (GeoEye).

4.4.2. Spatial and temporal resolution. Specifications

To better understand the multitude of satellites and to argue the choice a chapter regarding the technical specifications was necessary. This chapter is presenting useful information’s on the most used sensors in environmental applications, especially on vegetation, and if they are active or passive.

Landsat has been taken into account due to its accessibility, cost (free) and considered period (1974-2010). Landsat satellites are carrying space passive sensors that do not emit radiation toward the Earth. Instead they capture the electromagnetic radiation emitted by the Earth's surface. LANDSAT-1 was the world's first Earth observation satellite (EOS), launched by the United States in 1972. It is recognized for its ability to observe the earth far from space. Its excellent set of capabilities emphasized the importance of state-of-the-art remote sensing. Following LANDSAT-1, LANDSAT-2, 3, 4, 5, and 7 were launched. LANDSAT-7 is currently operating as a primary satellite.

LANDSAT-5 was equipped with a multispectral scanner (MSS) and thematic mapper (TM). MSS is an optical sensor designed to observe solar radiation, which is reflected from the Earth's surface in four different spectral bands, using a combination of the optical system and the sensor. TM is a more advanced version of the observation equipment used in the MSS, which observes the Earth's surface in seven spectral bands that range from visible to thermal infrared regions (Table no. 4.1).

Tabelul nr. 4.1 *Technical data for Landsat MSS, TM and ETM+ sensors*

Landsat MSS			**Landsat TM**			**Landsat ETM+**		
Multispectral Scanner			**Thematic Mapper**			**Enhanced Thematic Mapper +**		
Channel	**Wavelength [nm]**	**Spatial Resolution [m]**	**Channel**	**Wavelength [nm]**	**Spatial Resolution [m]**	**Channel**	**Wavelength [nm]**	**Spatial Resolution [m]**
			Blue (1)	450-520	30	Blue	450-515	30
Green (4)	500-600	60	Green (2)	520-620	30	Green	525-615	30
Red (5)	600-700	60	Red (3)	630-690	30	Red	630-690	30
NIR (6)	700-800	60	NIR (4)	760-900	30	NIR	750-900	30
NIR (7)	800-1100	60	SWIR1 (5)	1550-1750	30	SWIR1	1550-1750	30
			TIR (6)	1040-1250	120	TIR	1040-1250	60
			SWIR2 (7)	2080-2350	30	SWIR2	2090-2350	30
						PAN	500-900	15
Altitude	907-915 km		705 km			705 km		
Scene size	185 x 185 km		185 x 185 km			185 x 185 km		

The Landsat database can be accessed for free from the internet: http://earthexplorer.usgs.gov. In the Landsat database there were identified some imagery for the studied area (Tabel no. 4.2).

Tabelul nr. 4.2 *Landsat imagery database used*

Capture date	Sensor type
20 August 1981	MSS
29 August 1988	TM
22 August 2000	ETM+
26 August 2010	TM

5. The link between environmental objects and the electromagnetic spectrum

The agitation of the charged particles that are present in all matter causes all Earth objects to emit electromagnetic radiation. The objects emit this energy, but can also transmit, absorb, and reflect it. The sun is one of the main natural sources of the electromagnetic energy on Earth (http://www.state.nj.us). Thus, it is important to know how each element from this interaction is influenced by one other.

5.1. The electromagnetic spectrum

The electromagnetic spectrum is the continuum of energy that ranges from nanometers to meters in wavelength, travels at the speed of light and propagates through a vacuum such as outer space. All matter radiates a range of electromagnetic energy such that the peak intensity shifts toward progressively shorter wavelengths as the temperature of the matter increases. Fig. 5.1 shows the EM spectrum, which is divided on the basis of wavelength into regions. The EM spectrum ranges from the very short wavelengths of the gamma-ray region (measured in fractions of nanometers) to the long wavelengths of the radio region (measured in meters).

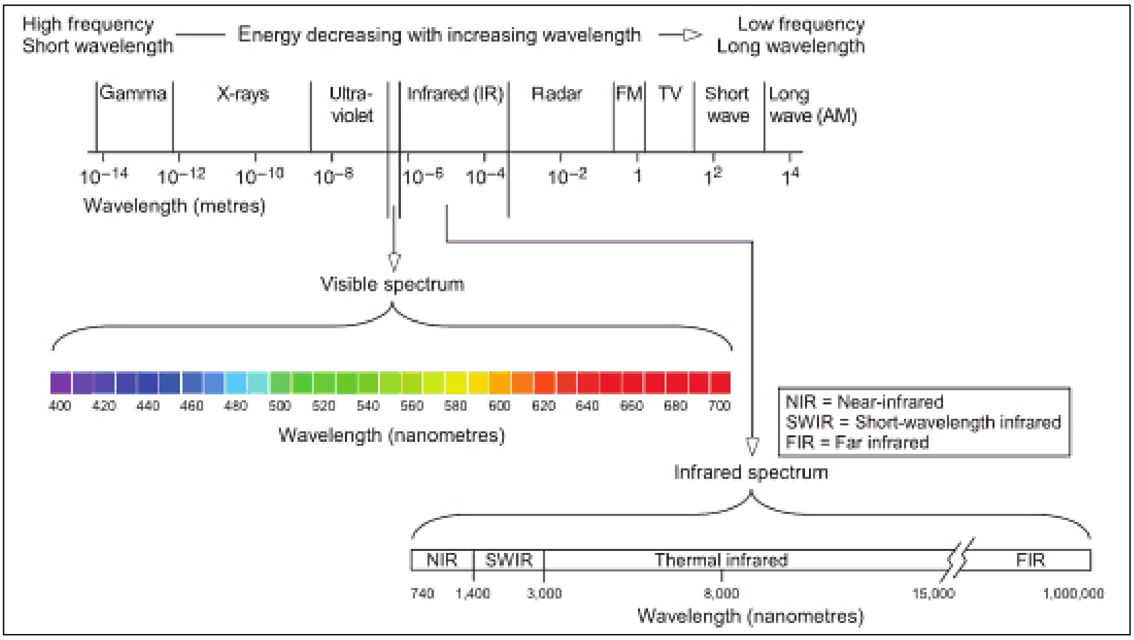

Fig. 5.1 Electromagnetic spectrum (Purkis & Klemas, 2011).

Any combination of electromagnetic waves that impress the human eye retina, defines a color which can be darker or brighter, depending on the component wavelengths intensity. The visible spectrum is represented by the electromagnetic waves that can be detected by the human eye. Visible spectrum is found in nature as a rainbow. The shorter wavelength lying outside the visible spectrum is the Ultraviolet (UV) and the longest is the Infrared (IR). Although not directly perceived by humans, ultraviolet waves can cause some materials to emit visible light and infrared waves which can be detected by some equipment (cameras and sensors) and converted into visible light (http://cobra.rdsor.ro).

5.1.2. Electromagnetic radiation and his interaction with Earth's atmosphere

Electromagnetic radiation has the role of carrying the information in remote sensing. Technical systems are based on the behavior of incident radiation on the earth's surface. Most applications are using the incident solar radiation. The natural illumination is one of the passive remote sensing scanners characteristics (Popescu, 2009). During interactions between electromagnetic radiation and matter, mass and energy are conserved according to basic physical principles. Therefore, the incident radiation can only be: transmitted, absorbed, emitted, scattered, and reflected (Fig. 5.2).

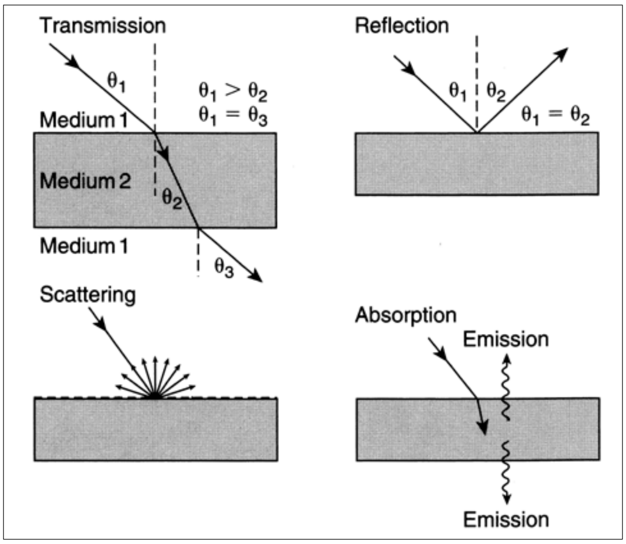

Fig. 5.2 Fundamental electromagnetic interactions with matter (Avery & Berlin, 1992).

Emission, scattering, and reflection are called surface phenomena because these interactions are determined primarily by properties of the surface, such as color and roughness. Transmission and absorption are called volume phenomena because they are determined by the internal characteristics of matter, such as density and conductivity. The incident energy is representing the sum of these phenomena (5.1).

$$i_\lambda = r_\lambda + \tau_\lambda + \alpha_\lambda \tag{5.1}$$

where:

i_λ - incident energy;

r_λ - absorbed energy;

τ_λ - transmitted energy;

α_λ - reflected energy.

The particular combination of surface and volume interactions with any particular material depends on both the wavelength of the electromagnetic radiation and the specific properties of that material. These interactions between matter and electromagnetic waves are recorded on remote sensing images, from which one may interpret the characteristics of matter (Sabins, 2007).

Reflectance is a property of the observed material and is a dimensionless quantity. Value is between 0 and 100 if we use the percent expression or between 0 and 1. Reflectance is not measured directly in remote sensing, it must be determined indirectly (Peddle et al., 2001).

The objects illuminated by the Sun respond differently to the same spectral region. For example, in the infrared difference between deciduous forest and pine can be observed. In the visible spectrum the difference between them is made by the isolated tree crowns. Color is a differentiation element only at certain periods of the year like in spring and autumn in the temperate zone.

Each object and phenomenon in the field has a characteristic spectral response personality. This defines the spectral signature that differs from one object to another, even if the image perceived by the human eye has the same color. For example, the apple crown response is identical at first sight with the plum but the difference can be observed more in the outside of the visible spectrum, in the infrared channel.

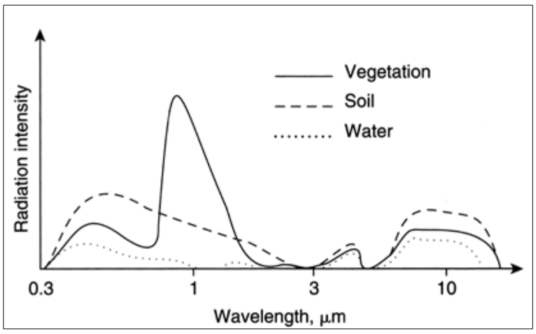

Fig. 5.3 Reflectance intensity (Avery & Berlin, 1992).

Reflected wave intensity (power) modified by the atmosphere between the ground and the sensor is called radiance (L_λ). Radiance is what the sensor measures and it may be very different from the ground reflected intensity because of haze and other substances which scatter light (Lachowski et al., 1995). Radiance has specific units and is typically quoted in watts per steradian per square meter per nanometer ($W*sr^{-1}*m^{-2}*nm^{-1}$). In Fig. 5.3 it can be seen the spectral signature of the main environmental features: soil, water, vegetation.

5.2. Image preprocessing

Preprocessing of satellite imagery prior to image classification and change detection is essential. Preprocessing commonly comprises a series of sequential operations, including atmospheric correction or normalization, image registration, geometric correction, and masking (e.g., for clouds, water, irrelevant features) (Coppin & Bauer, 1996).

Because this study will only use Landsat imagery, we will customize the above mentioned operations only for this type of data.

The Landsat data is provided in DN values (digital numbers) at different preprocessing levels. Most scenes are Level 1T type, which means that the image has been already corrected radiometrically, geometrically and also orthorectified. Basically we have an image ready to use. But it is interesting to know how these images reached this level and also it is useful to know what steps we need to follow to have a Level 1T image.

5.2.1. Image preprocessing basic operations

Landsat has classified his products according to the image preprocessing level. Level 0 is the first level and is presented as RAW format. For Landsat TM this kind of images is corresponding to the Level 0, and in case of Landsat ETM + to Level 0R. RAW image format is a characteristic format which is saying that no modification has occurred. This image is used before applying the radiometric and geometric correction. The image contains unaltered information, that is used in the correction process, and a file generated by Landsat with calibration parameters (metadata). In this case only pixel shifting phenomenon correction has been applied. In this way all the pixels from the image dataset are well aligned. The processes for obtaining Level 0R products are reversible.

Level 1R images are corrected radiometric Level 0R images. Before this step, corrections like banding, destriping, and scan correlated shift are made. Radiometric corrections are not reversible. After the radiometric correction pixels values are corresponding to the absolute radiance.

Level 1G imagery are Level 0R imagery with radiometric and geometric processes. Geometric rectification of the imagery resamples or changes of the pixel grid are the operation suffered by the imagery in order to fit the map projection or another reference image. This becomes especially important when scene to scene comparisons of individual pixels in applications such as change detection are being sought.

Orthorectified Level 0R images are becoming Level 1T. Through this operation objects can be better identified, because it eliminates relief distortions effect. This operation is performed by using a digital elevation model. Geodetic precision of Level 1T imagery depends on ground control points (GCP) and DEM resolution (http://landsathandbook.gsfc.nasa.gov).

5.2.2. Image calibration: DN to Radiance

During 1G product rendered image pixels are converted to units of absolute radiance. The following equation is used to convert DN's in a 1G product, back to radiance units is:

$$L_\lambda = G_{rescale} * Q_{CAL} + B_{rescale} \quad (5.2)$$

this is also expressed as:

$$L_\lambda = \left(\left(LMAX_\lambda - LMIN_\lambda\right) / \left(Q_{CALMAX} - Q_{CALMIN}\right)\right) * \left(Q_{CAL} - Q_{CALMIN}\right) + LMIN_\lambda \quad (5.3)$$

where:

L_λ = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * μm);

Grescale = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm)/DN;

Brescale = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm);

QCAL = the quantized calibrated pixel value in DN;

$LMIN_\lambda$ = the spectral radiance that is scaled to QCALMIN in watts/ (meter squared * ster * μm);

$LMAX_\lambda$ = the spectral radiance that is scaled to QCALMAX in watts/ (meter squared * ster * μm);

QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN_\lambda$) in DN;

= 1 for LPGS products (LPGS = Level-1 Product Generation System);

= 1 for NLAPS products processed after 4/4/2004;

= 0 for NLAPS products processed before 4/5/2004;

(NLAPS = National Landsat Archive Production System);

QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX_\lambda$) in DN = 255.

For running the (5.5) formula we can use the ENVI software which already has incorporated this algorithm (http://www.exelisvis.com).

5.2.3. Radiance to reflectance calibration

The normalization of satellite imagery takes into account the combined, measurable reflectance’s of the atmosphere, aerosol scattering and absorption, and the earth’s surface (Kim & Elman, 1990). It is the volatility of the atmosphere which can introduce variation between the reflectance values or digital numbers (DN’s) of satellite imagery acquired at different times. Although the effects of the atmosphere upon remotely sensed data are not considered errors, since they are part of the signal received by the sensing device, consideration of these effects is important. The goal conveniently should be that following image preprocessing, all images should appear as if they were acquired from the same sensor (http://www.cast.uark.edu).

For relatively clear Landsat scenes, a reduction in between-scene variability can be achieved through normalization for solar irradiance by converting spectral radiance, calculated above, to planetary reflectance or albedo. This combined surface and atmospheric reflectance of the Earth is computed with the following formula (5.5) (Chander & Markham, 2003):

$$\rho_p = \frac{\pi * L_\lambda * d^2}{ESUN_\lambda * \cos\theta_s} \tag{5.6}$$

where:

ρ_p - Unitless planetary reflectance;

L_λ - Spectral radiance at the sensor's aperture;

d - Earth-Sun distance in astronomical units;

$ESUN_\lambda$ - Mean solar exoatmospheric irradiance;

θ_s - Solar zenith angle in degrees.

5.2.4. Atmospheric correction

The objective of atmospheric correction is to retrieve the surface reflectance (that characterizes the surface properties, material physical property) from remotely sensed imagery by removing the atmospheric effects.

To compensate for atmospheric effects, properties such as the amount of water vapor, distribution of aerosols, and scene visibility must be known. Because direct measurements of these atmospheric properties are rarely available, there are techniques that infer them from their imprint on hyperspectral radiance data. These properties are then used to constrain highly accurate models of atmospheric radiation transfer to produce an estimate of the true surface reflectance (http://www.exelisvis.com).

6. Imagery analysis methods for vegetation cover changes assessment

The notion of "spectral signature", in remote sensing, covers an area in which complex phenomena are involved. All environment objects reflect and emit energy flow in the form of electromagnetic radiation. The relative variation of the reflected or emitted energy as a wavelength function is what we might call "the spectral signature" of the considered object. Thus for a given object, in a given state, a unique spectrum must correspond. This spectrum can be used to identify the object and his status. For a satellite that makes measurements in a number of spectral bands, the spectral signature of an object correspond to different radiometric levels recorded in each band (Guyot, 1989).

Spectral signature varies depending on vegetation season (is the case of hardwoods which have leaves only a few months per year), the moment of anthropic elements capture (crops status, buildings under construction etc.), the location of object in the field and date/time stamp (which provide azimuth and Sun elevation).

6.1. Minerals and soils spectral signature interpretation

The shape of the minerals reflectance spectrum is due to the existence of many absorption bands which result from two different types of processes: electronic transitions and ionic vibrations (Guyot, 1989).

The electrons transitions from one energy level to another are related to metal anions. They produce large spectral bands that appear mainly in the ultraviolet. Their number is decreasing when the wavelength is increasing. Practically the bands limit resulted from electronic transitions is around 1.1μm.

6.2. Vegetation spectral signature interpretation

All the leaves spectrums of small plants or forest tree species (including coniferous needles) have the same form, the differences occur only in the amplitudes. Three spectral regions can be distinguished: The visible, the near infrared (NIR), The Mid-infrared.

Factors that may influence the vegetation spectral response are:

- vegetation anatomy and phenological stage (flowering, fructification, etc.);
- vegetation age;
- vegetation water content status in the moment of image capture;
- minerals deficiency;
- parasites attacks;
- soil background reflection.

6.3. Water bodies spectral signature interpretation

In nature the water exists in all three states of aggregation: liquid, gas (water vapor) and solid (ice and snow). Clean water is colorless in thin layers, but takes on a bluish color - green in layers thicker than 6 cm. In special circumstances, when the water contains different dissolved substances the color can change to: weak yellow, yellow, brown, milky, red, and blue. In these cases in the water there may be iron oxide, manganese compounds, humic acids, organic matter or chlorophyll. We should not omit any artificial influence of pollutants. This is a present reality in most water bodies from populated areas with economic activity (http://www.scrigroup.com).

7. Imagery analysis methods for vegetation cover changes assessment

In order to complete imagery analysis and cover change assessment the diagram from Fig. 7.1 has been followed. The focus of vegetation detection by remote sensing has shifted to the interpretation of satellite imagery. Images in digital format allow for numerical processing and analysis and the application of multivariate classification methods to the data (http://www.geog.ubc.ca). Image classification is the process used to produce thematic maps from imagery.

The themes can range, for example, from categories such as soil, vegetation, and surface water in a general description of a rural area, to different types of soil, vegetation, and water depth or clarity for a more detailed description. It is implied in the construction of a thematic map from remote sensing imagery that the categories selected for the map are distinguishable in the image data. As described before, a number of factors can cause confusion among spectral signatures, including topography, shadowing, atmospheric variability, sensor calibration changes, and class mixing within the GIFOV (Ground Instantaneous Field of View). Although some of these effects can be modeled, some cannot (with any reasonable amount of effort), and so they must be treated simply as statistical variability (Schowengerdt, 2007).

Traditionally, thematic classification of an image involves several steps:

- Feature extraction,
- Training,
- Labeling.

The end result is a transformation of the numerical image data into descriptive data that categorize different surface materials or conditions. By virtue of the labeling process, we have presumably converted the data into a form that has informational value (Schowengerdt, 2007).

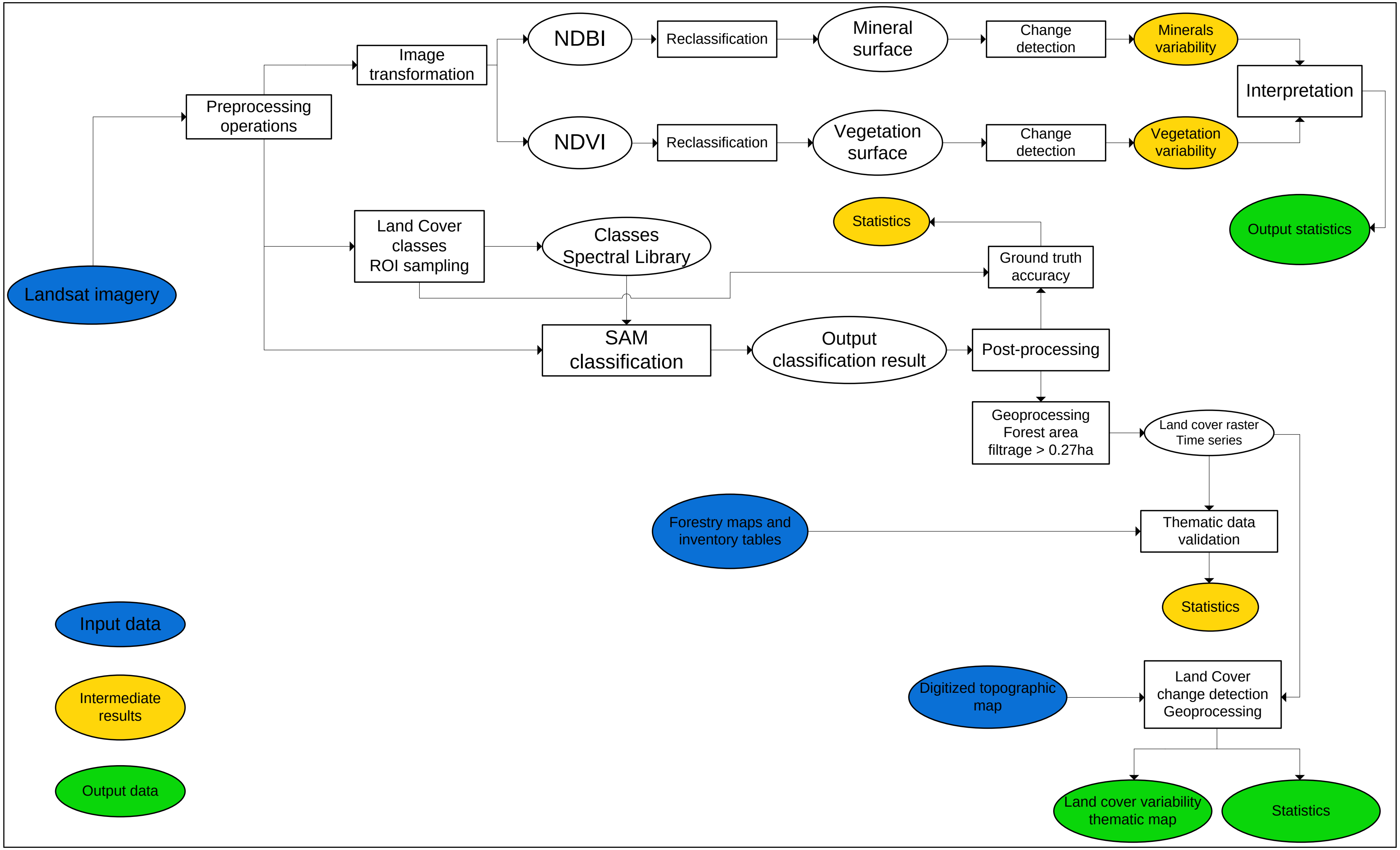

Fig. 7.1 Imagery analysis and cover change assessment flowchart.

7.1. Image transformation by using spectral indices

Spectral transformations alter the spectral space (defined by the DN multispectral vector, where spatial dependence is not explicit); and spatial transformations alter the image space (DN(x, y), where the spatial dependence is explicit). Many of these transformed spaces are useful for thematic classification, and are collectively called feature spaces in that context. Various features can be described if we can derive them from the spectral space. These derived spaces do not add new information to the image, but rather redistribute the original information into a more useful form (Schowengerdt, 2007). So by using the spectral indices we can convert spectral reflectance (Chander & Markham, 2003) into biophysical information that can be interpreted directly by us, the users.

7.1.1. Using spectral indices for estimating vegetal cover changes

The intention was to use for the first phase two spectral indices to estimate changes in the vegetation and mineral cover that occur in three watersheds in the study period. The indices are: NDBI (Zha et al., 2003) and NDVI (Tucker, 1979).

7.1.2. Using the NDBI index for estimating changes in mineral surfaces

The NDBI index (Normalized Difference Built-up Index) was designed to achieve the separation between the urban areas and mineral objects from the rest of the features on an image. Practical, to obtain the separation of vegetation and water surfaces from the minerals. NDBI index is using mid-infrared (TM5) and near-IR (TM4) bands (6.1). This is a fast method for mapping the minerals with satisfactory results.

Landsat TM and ETM+ are used in this case because they have a finer spectral resolution than Landsat MSS. From Table no. 4.1 we can see that Landsat MSS infrared spectrum is not matching very well the Landsat TM/ETM+ infrared spectrum, especially in the $SWIR_1$ zone where the minerals have a stronger reflectance. This band is missing. By processing the imagery dataset, NDBI index variability has been obtained for the period 1988-2010. For this step we used the ENVI remote sensing software and the ArcGIS Desktop GIS software. The results are spatialised in 7.2, 7.3.

It can be notice that the most affected watershed by mineralization process is Răcătău. In this area the mineralization process according to NDBI values occurred at an average rate of 4% from watershed area. The largest mineralization area according to NDBI is occurring during the period 1988-2000 around the small villages like Voiniga, situated in the center of Răcătău watershed, Măguri and Mărişel situated in the north area of Răcătău watershed. The process is also persistent in the next period, 2000-2010 with almost the same ratio, but more in the south of Voiniga.

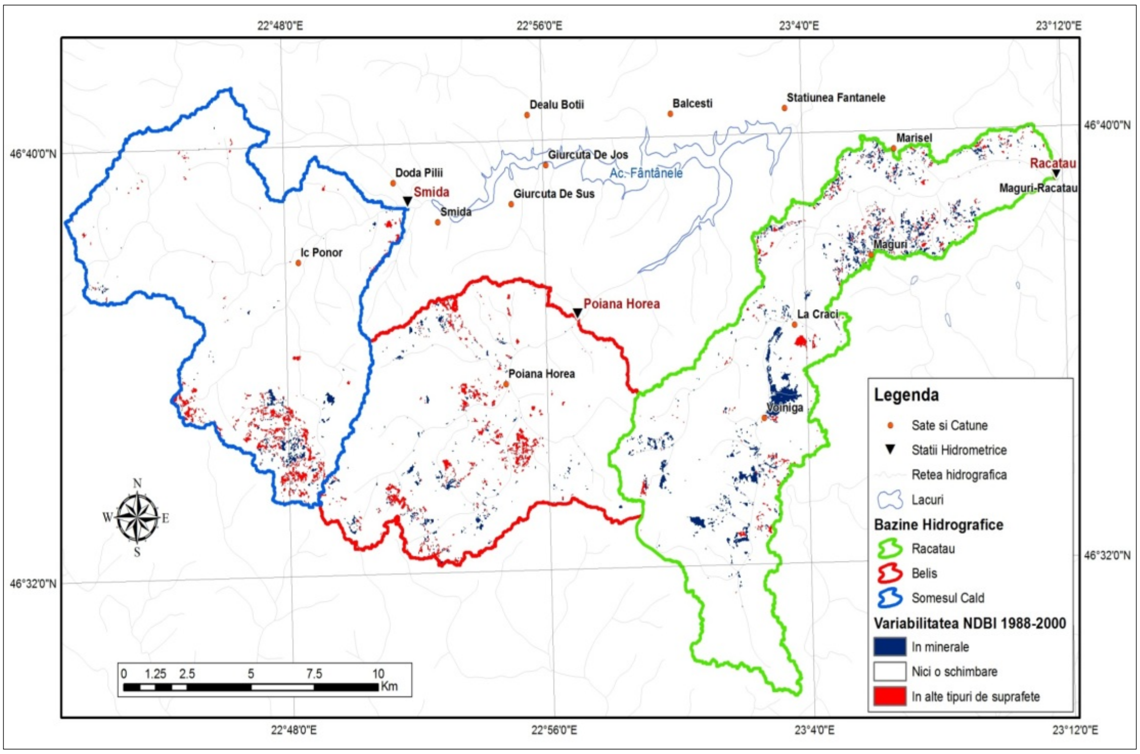

Fig. 7.2 Mineralisation process variability according to NDBI index values (1988-2000).

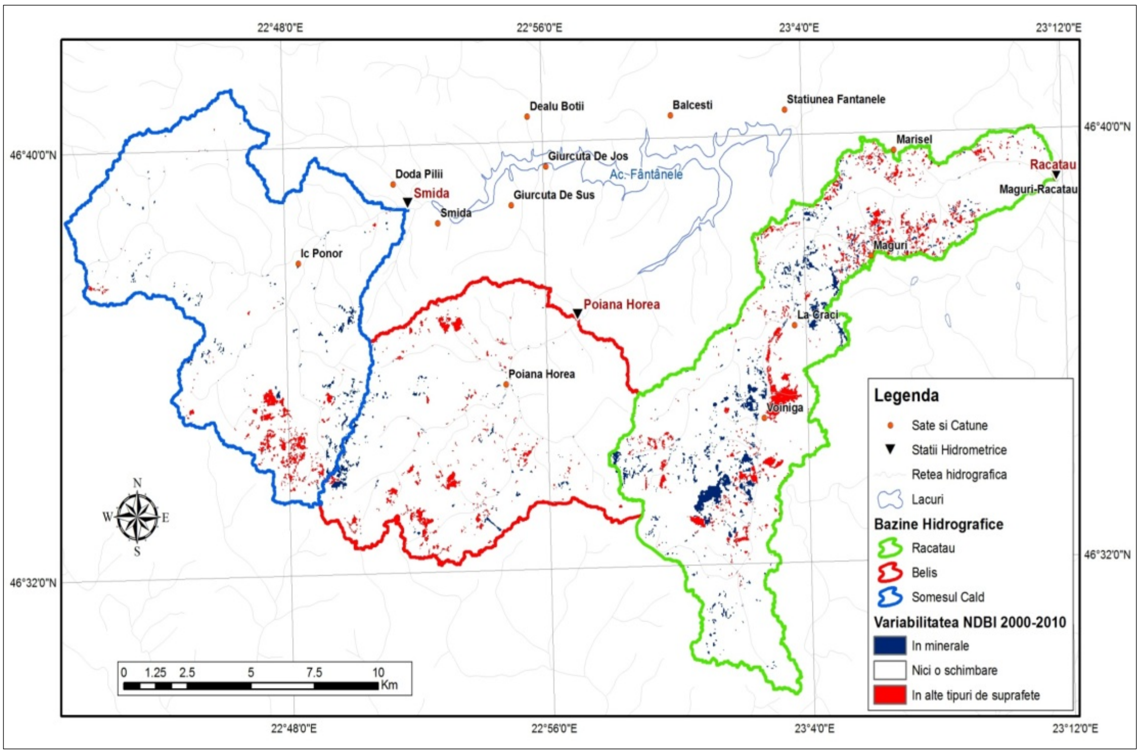

Fig. 7.3 Mineralization process variability according to NDBI index values NDBI (2000-2010).

7.1.3. Using the NDVI index for estimating changes in vegetation surfaces

The NDVI index (Normalized Difference Vegetation Index, Tucker, 1979) it is the most known and used index in the world. NDVI is an index that provides a standardized method of comparing vegetation greenness between satellite images. The index is using the near infrared and the red band.

The results after applying the thresholds were imported in ArcGIS software and processed to obtain the differences and the spatial variability of NDVI during the period 1981-2010. In the case of Landsat MSS imagery (1981) before the threshold operation a resample pixel operation has to be done. We have resampled the NDVI image from 60m to 30m in order to match the other rasters. NDVI spatial variability is presented in Fig. 7.4, 7.5 and 7.6.

An important aspect to note is that using NDVI index assumes no highlighting for deforestation process. NDVI and NDBI emphasize that there is variability at the vegetation level in general, regardless the type, tree or grass. If it is to follow the variability of NDVI and NDBI we can see that the two values obtained are validated by each other both spatially and numerical values. Another very important aspect is that to determine mineral and vegetable areas histogram thresholds were used, which allowed manipulation of histograms. Thus we believe that accuracy has suffered, and the variability referred to this study (deforestation) can not be estimated. For this it is necessary to extract thematic data to assess the forest surface variability.

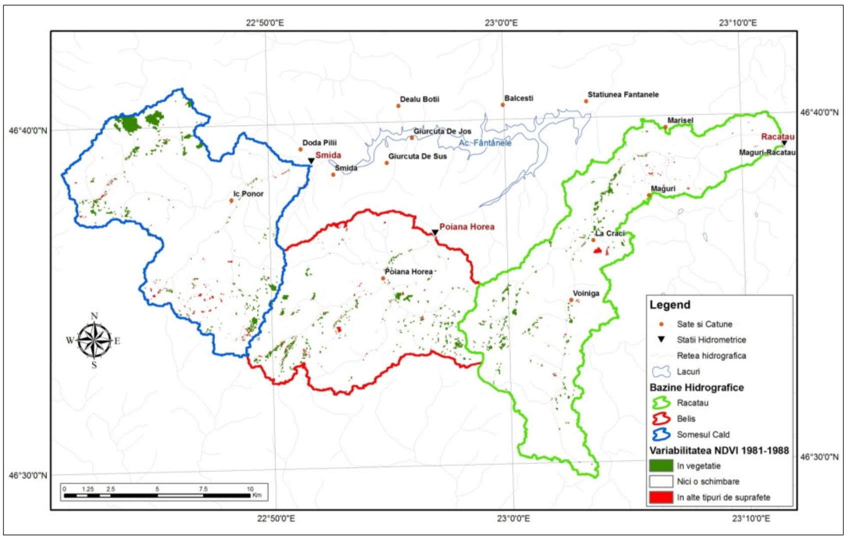

Fig. 7.4 NDVI variability for the period 1981-1988.

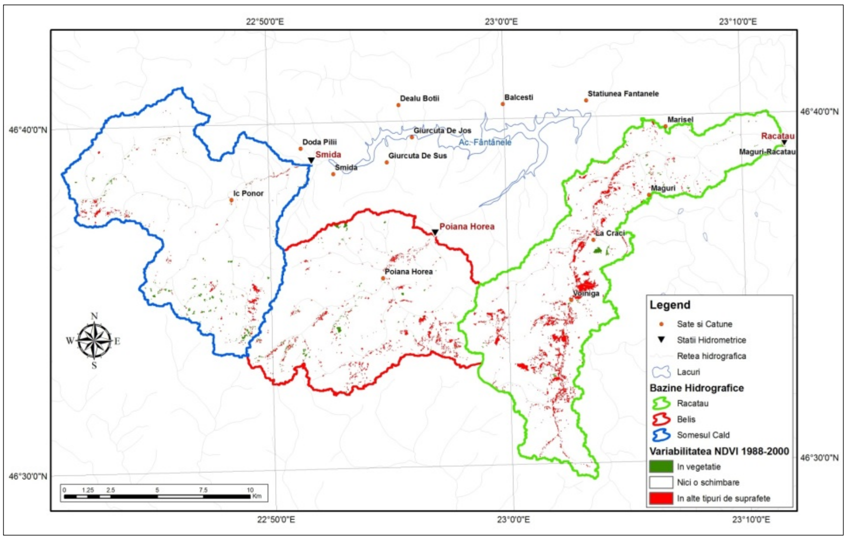

Fig. 7.5 NDVI variability for the period 1988-2000.

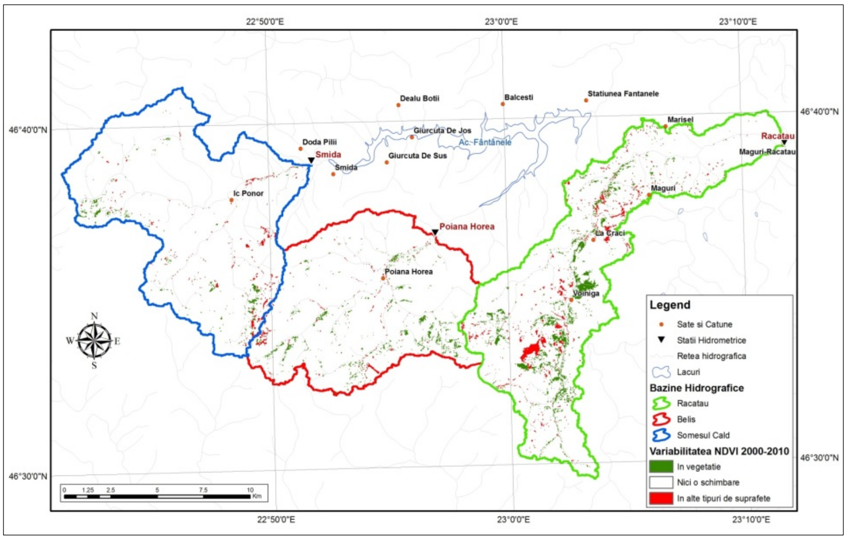

Fig. 7.6 NDVI variability for the period 2000-2010.

8. Thematic data extraction for deforestation assessment

The real world entities are so complex that they should be classified into object classes with some similarity through thematic data modeling in a spatial database. The objects in a spatial database are defined as representations of real world entities with associated attributes. Generally, geospatial data have three major components: position, attributes and time. Attributes are often termed "thematic data" or "non-spatial data”, which are linked with spatial data or geometric data. An attribute has a defined characteristic of entity in the real world. Attribute can be categorized as normal, ordinal, numerical, conditional and other characteristics. Attribute values are often listed in attribute tables which will establish relationships between the attributes and spatial data such as point, line and area objects, and also among the attributes (http://stlab.iis.u-tokyo.ac.jp).

8.1. What it is a thematic map?

This sub-chapter is intended to clarify what means a thematic map, to what it can be used and what features can be represented on this kind of map to show a particular theme connected with a specific geographical area.

8.2. What do we need? Land cover or Land use?

In many instances, the terms Land Use and Land Cover tend to be exchangeable. However there are differences. Land use refers to how land is used by humans. In other words it refers to the economic use to which land is put. For example is the land being used for commercial purposes (stores, office buildings, apartments, etc.) or for industrial purposes (factories, assembly plants)? Or is the land being used for recreational or agricultural purposes? (http://www.fao.org; http: //www. cara.psu.edu).

Considering the difference between this two terms usage and the analyzed phenomena we decided that land cover data is necessary in order to complete the purpose of the project. So, thus been said, the type of the surface has to be obtained.

8.3. Remote sensing methodology for thematic data extraction

It is possible to analyze remotely sensed data of the earth and extract useful thematic information. Notice that data are transformed into information. One of the most often used methods of information extraction is multispectral classification. This procedure assumes that imagery of a specific geographic area is collected in multiple regions of the electromagnetic spectrum and that the images are in good registration (Jensen, 1986). The overall objective of image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes.

Normally, multispectral data is used to perform the classification. The process of multispectral classification may be performed using either of two methods: supervised or unsupervised.

8.4. Supervised classification

To perform a supervised classification certain steps must be followed (Jensen, 1986). These steps are: adopting classification scheme; selecting sampling areas; statistics must be extracted from the sampling spectral data; a proper classification algorithm must be selected; classification result must be tested for accuracy; the obtained data must be validated with ground truth data.

8.4.1. The classification scheme

The categories of interest must be carefully selected and defined to successfully perform digital image classification. It is important for the analyst to realize, however, that there is a fundamental difference between what will call „information classes” and „spectra classes” (Jensen et al., 1983; Campbell, 1983). Information classes are those that man defines. Conversely, spectral classes are those that are inherent in the remote sensor data and must be identified and labeled by the analyst. For example, in a remote sensed image of an urban area there is likely to be single-family residential housing. A relatively high spatial resolution (30x30 m) remote sensing device such as the thematic mapper might be able to identify a few pure pixels of vegetation and a few pure pixels of asphalt road or shingles. However, it is much more likely that in this residential area the pixel brightness values will be a function of the reflectance from mixtures of vegetation and concrete. Unfortunately, few planners or administrators want to see a map labeled with such classes as concrete, vegetation, and mixture of vegetation and concrete. Rather, they much prefer the analyst to rename the mixture class as single-family residential. The analyst should only do this if, in fact, there is a good association between the mixture class and single-family residential housing (Jensen, 1986).

Considering this and the fact that the study area is a mountainous area the following classes of elements where chosen to extract thematic information from satellite imagery. The chosen scheme is a level I classification which is close to NLCD 92 system used by USGS (http://landcover.usgs.gov). The land cover classes are:

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

8.4.2. Description of the selected land cover scheme

Like we mentioned before, image classification resulted data need to match the topographic map legend in order to compute the change detection. The topographic map is presenting around the study area water bodies, forests, urban zones and herbaceous vegetation which can be found configured in two separate types: pastures and herbaceous upland. Anderson et al. (1976) and EPA (1992) are defining the land cover types used in remote sensing classification. The definition represents a very precise information source which helped us to configure and to identify the classification scheme and to choose training classes.

8.4.3. Training site selection

The actual classification of multispectral image data is a highly automated process. In many ways, the training effort required in supervised classification is both an art and a science. It requires close interaction between the image analyst and the image data. It also requires substantial reference data and a thorough knowledge of the geographic area to which the data apply. Most importantly, the quality of the training process determines the success of the classification stage, and therefore, the value of the information generated from the entire classification effort (Lillesand et al., 2004).

As part of the training data set refinement process, the overall quality of the data contained in each of the original candidate training areas is assessed and the spectral separability between the data sets is studied.

8.4.4. Extracting and analyzing statistics from the training spectral data

It is necessary to extract statistical values from the training samples spectral response. Statistical values are analyzed to select the features that will be used in the classification process; this has involved both computer graphics and statistical methods to assess the degree of spectral separability between the classes.

8.4.5. Quantitative expressions of category separation

Statistical methods of feature selection are used to quantitatively select the subset of features that provides the greatest degree of statistical separability between any two classes. The basic problem of spectral pattern recognition is: given a spectral distribution of data in *n* bands of remotely sensed data, find a discrimination technique that will allow separation of the major land cover categories with a minimum of error and a minimum number of bands.

A measure of the statistical separation between category response patterns can be computed for all training areas. In Fig. 8.1 the refined training areas are represented. The obtained values from Fig. 8.1 are representing the result of the statistical test which is showing the separability degree of the training areas (Distance F).

Training areas	**Deciduous F.**	**Coniferous F.**	**Mixed F.**	**Herbaceous Upland**	**Barre land**	**Pasture**	**Water**
Deciduous F.	0.000						
Coniferous F.	2.000	0.000					
Mixed F.	2.000	2.000	0.000				
Herbaceous Upland	2.000	2.000	1.968	0.000			
Barren land	2.000	2.000	2.000	2.000	0.000		
Pasture	2.000	2.000	2.000	2.000	2.000	0.000	
Water	2.000	2.000	2.000	2.000	2.000	2.000	0.000

Fig. 8.1 Training area statistics – pair separability (0 = no separability; 2 = perfect separability)

One final note that has to be made here is that training set refinement is usually the key to improve the accuracy of classification. However, if certain cover types occurring in an image have inherently similar spectral response patterns, no amount of retraining and refinement will make them spectrally separable. Alternative methods must be used to discriminate these cover types (Jensen, 1986; Lillesand et al., 2004).

8.4.6. Building spectral libraries

In this study we choose to build the spectral library from the collected spectra during the image analysis process. Thus, by using the unique obtained samples I constructed a spectral library using ENVI software, by using the image from 1988. In order to test for accuracy the classification process results I decided that the spectra library must be created for the image calibrated in radiance as well in reflectance.

8.4.7. Select the appropriate classification algorithm

Various supervised classification methods may be used to assign an unknown pixel to one of a number of classes. The choice of a particular classifier or decision rule depends on the nature of the input data and the desired output (Friedman, 1980).

Among the most frequently used classification algorithms are: parallelepiped classification; the minimum distance technique; maximum likelihood classification; the Mahalanobis distance classification; the binary encoding classification technique, the Spectral Angle Mapper (SAM) (http://www.exelisvis.com).

In order to complete the classification process the Spectral Angle Mapper algorithm has been chosen. This choice was made because we have successfully created a set of unique 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

8.4.8. Spectral Angle Mapper algorithm

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. This technique, when used on calibrated reflectance data, is relatively insensitive to illumination and albedo effects. Endmember spectra used by SAM can come from ASCII files, spectral libraries, or can be extracted directly from the image (as training area average spectra). SAM compares the angle between the endmember spectrum vector and each pixel vector in n-dimensional space. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified (Kruse et al., 1993; Yuhas et al., 1992; Van der Meer et al., 1997; Rowan and Mars., 2003; De Carvalho and Meneses, 2000).

8.4.9. Imagery classification by using SAM

The classification algorithm was applied first for the test image (1988) calibrated in radiance and reflectance. This step was necessary because my intention was to see which of the two calibration methods can provide improvements to the classification result.

The utility of any image classification is ultimately dependent on the production of output products that effectively convey the interpreted information to its end user. SAM classification assumes reflectance data. 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) (http://www.exelisvis.com).

8.5. Classification accuracy assessment

From the obtained results it can be seen that all the statistical factors that where evaluated are very close regarding the values and we can say that by using radiance we can have a better accuracy. But this is not reinforced by the visual evaluation of the resulted map. We saw that there are difference regarding the classification of forest type and herbaceous vegetation. This is because radiance is affected by the quantity of incoming solar radiation and topography (Serradj, 1991). Most of the forests situated on the slopes oriented directly to the Sun, have been classified as deciduous instead of coniferous. In the reflectance case these deficiency has been corrected, and the correct land cover class has been obtained.

8.6. Multi-temporal imagery classification

The multi-temporal imagery classification has involved the usage of the unique spectral library created for the test calibrated in reflectance. Thus, the maps defining land cover layers were obtained for the years 1988, 2000 and 2010 with an overall accuracy which is not falling under 90%. The results of the classification are represented in Fig. 8.2, 8.3, 8.4.

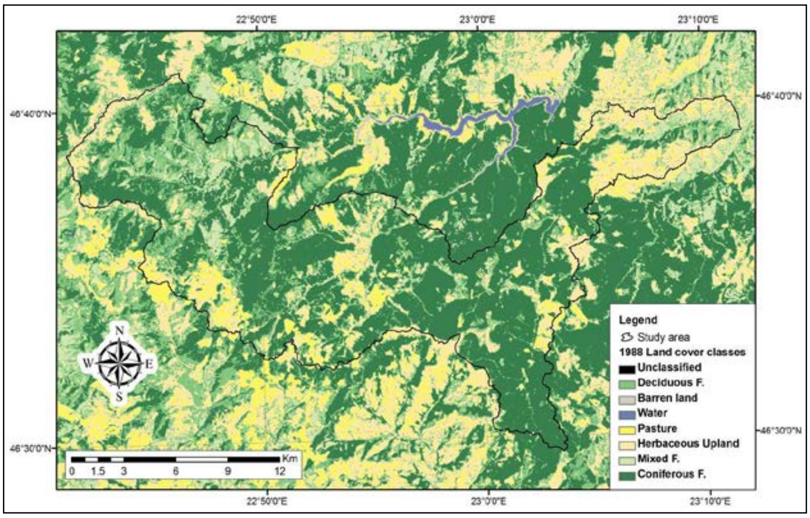

Fig. 8.2 SAM algorithm classification result for 1988.

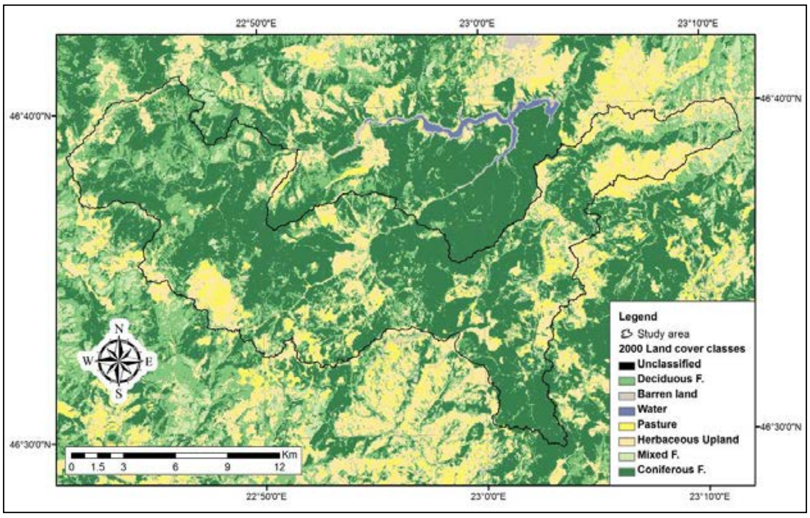

Fig. 8.3 SAM algorithm classification result for 2000.

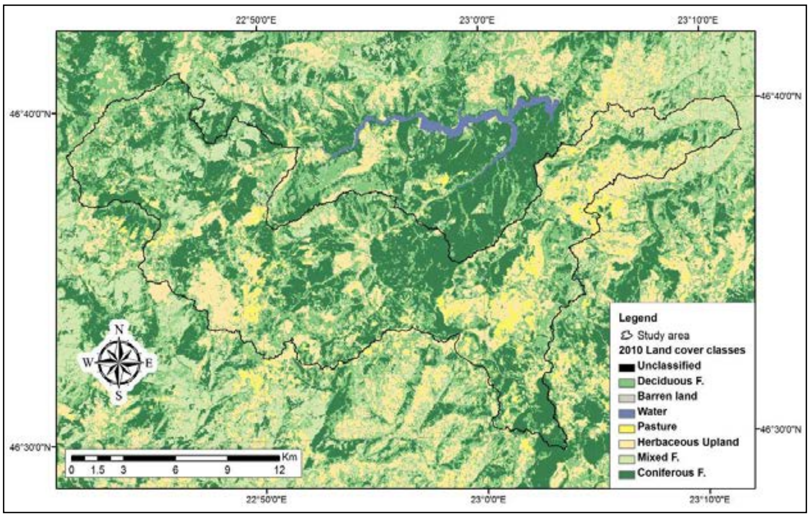

Fig. 8.4 Fig. 8.2 SAM algorithm classification result for 2010.

8.7. Thematic 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 (http://geomatica.como.polimi.it/corsi/rs_ia).

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 (http://weather.msfc.nasa.gov).

Among many ground-oriented data sources are field observations, in situ spectral measurements, aerial reconnaissance and photography, descriptive reports and inventory tallies, and maps (http://www.fas.org).

In this study ground truth has been collected for forest type classes from forestry maps and inventory tables. Three stands that did not change over the time 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).

The test results accuracy showed that the classification method is an accurate one. The method offered very good results even in drought conditions, like in the case of the year 2000.

8.8. Land cover change detection under the studied

In order to detect changes at the land cover level a GIS model has been made. It consider as an input the thematic data obtained after imagery classification (filtered for forest area ≥ 0.27 ha) and the digitized data from the topographic map. This was possible by using the ArcGIS Desktop software.

The results obtained by applying the GIS model were represented in graphical and tabular form. Related to detected changes spatial representation some clarifications must be made. In the map legend process that are marking the change are represented. Area which didn’t suffer any change is classified as “no change”. Changes at the forest cover level are called “deforestation” when the forest surface has changed in another land cover type. Regarding the forest growth process we have called “afforestation/reforestation” the process when the forest appeared at the end of the considered period. Thee terms are described in the FRA report 2010. We called mineralization any change process that has occurred for any kind of surface which is converting to barren land. For the rest, regarding the herbaceous upland and pasture classes we have considered that as an herbaceous vegetation rotation process.

The change detection results are considered only for the studied area and not for all extent of the analyzed image. The occurred change values are presented in the following figures.

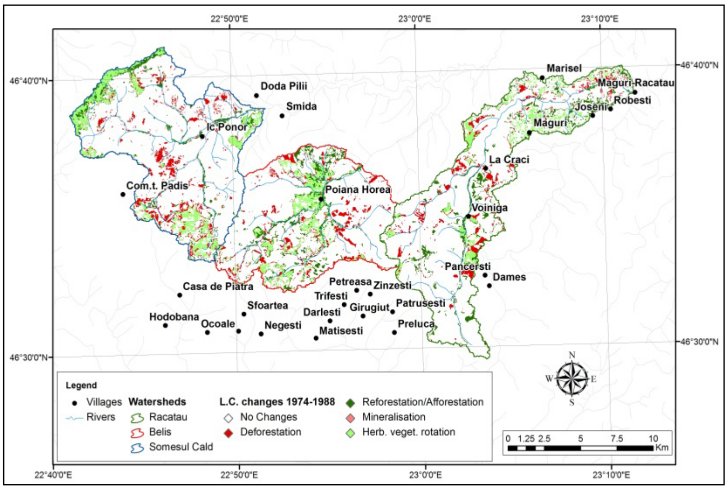

Fig. 8.5 Land cover changes for the period 1974-1988.

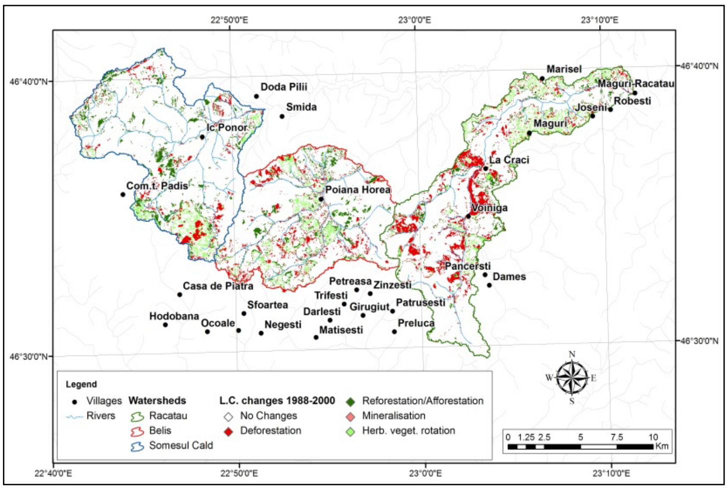

Fig. 8.6 Land cover changes for the period 1988-2000.

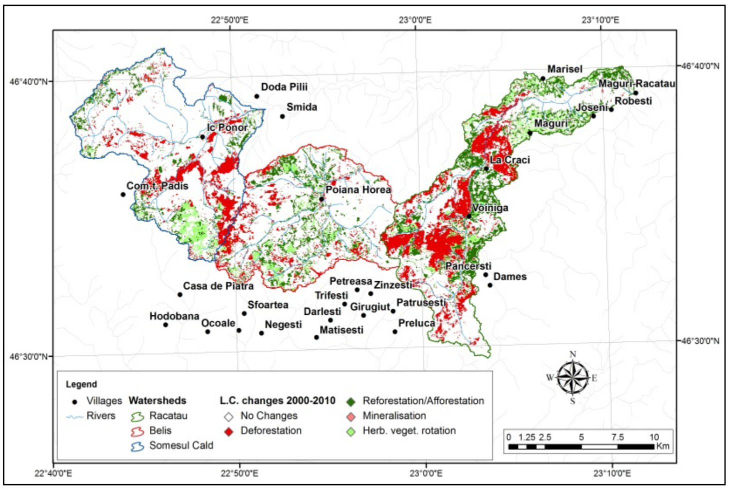

Fig. 8.7 Land cover changes for the period 2000-2010.

In Fig. 8.5, 8.6, 8.7 are represented the land cover spatial changes occurred in the studied period (1974-2010). It can be notice that from the beginning of the studied period there was a small variability regarding the deforestation process. Around Poiana Horea village (Beliş watershed) we can see that during the first analyzed period there was a good forest and vegetation recovery. After 1988 the things changed for all the watersheds and especially for Răcătău. From the spatial distribution of the land cover changes process we can see that the most affected surfaces are situated around Voiniga, in the center of Răcătău watershed (Fig. 8.6). The process is increasing the spatial distribution after 2000. In Răcătău watershed the same area, now, is more affected. The process is also affecting the area around the La Crăci village. It can be notice that the process is also present over a higher surface inside the Someşul Cald watershed. The most affected region is situated in the S-SE of Ic Ponor village (Fig. 8.7).

9. Deforestation assessment for the period 1974-2010

In this chapter the forest degradation, especially deforestation, has been studied for all three catchments.

9.1. What is Deforestation?

Deforestation, as a process, from a generally point of view, are all the processes by which forest or a stand is completely removed from the soil surface and change the land cover. This process can occur due both natural and anthropogenic causes. Deforestation examples include trees drops produced by heavy winds and snow, earthquakes, avalanches, landslides (natural causes), fire (which can be both natural and induced), agricultural expansion, urban sprawl and not least the illegal and irrational cuttings (human causes).

9.2. Deforestation process assessment

The land cover change detection problem is essentially one of detecting when the land cover at a given location has been converted from one type to another. Examples can include the conversion of forested land to barren land (possibly due to deforestation or a fire) (Boriah et al., 2008). The overall evolution of deforestation process in the study area is presented in Fig. 9.1.

To accomplish one of the study objectives, and namely the assessment of spatial and statistics over the deforestation process every catchment was considered in the analysis. In this way it was obtained the situation for each of the catchments.

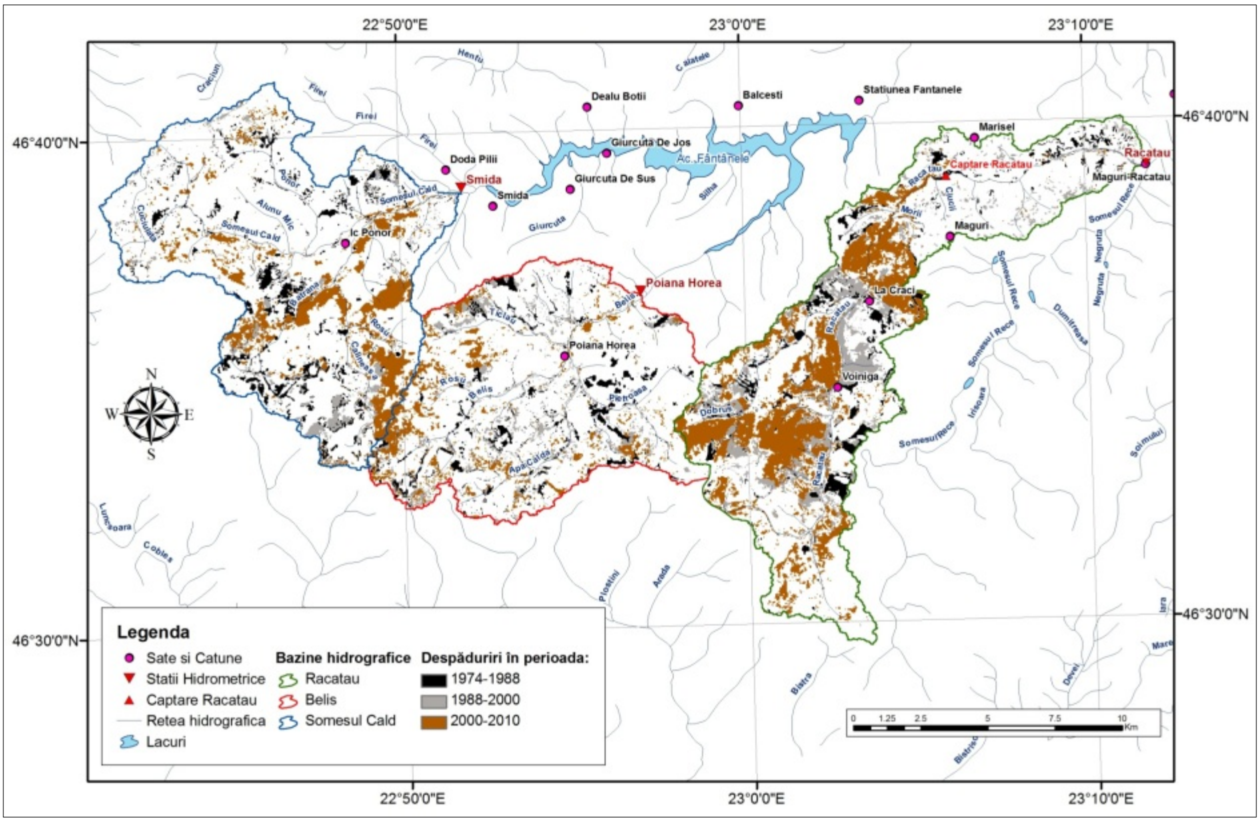

Fig. 9.1 Deforestation process evolution for the period 1974 – 2010.

Regarding the deforestation process evolution in the studied catchments the results are represented in Fig. 9.2, 9.3, 9.4.

If for the Beliș catchment the deforestation process situation is relatively constant during the period 1974-2010, for Someșul Cald and Răcătău catchments the forest surface has suffered for deforestation on about 11%, and respectively 21% from the catchment surface at the end of 2010.

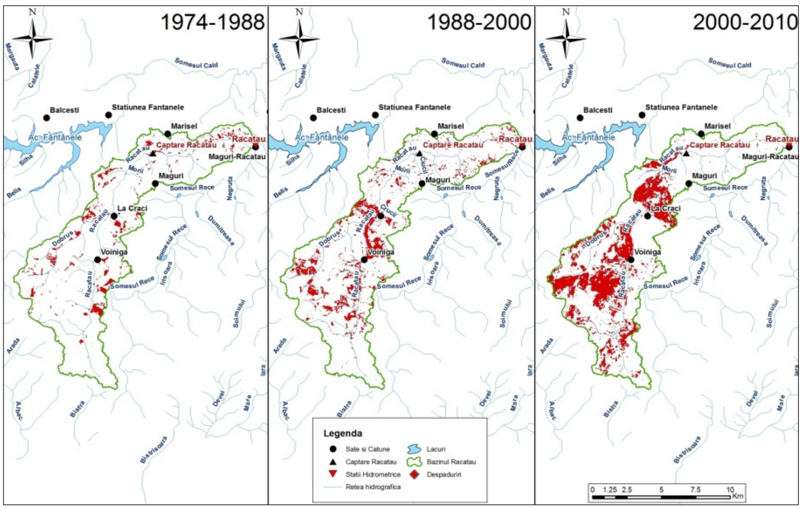

Fig. 9.2 The deforestation process evolution for Răcătău catchment.

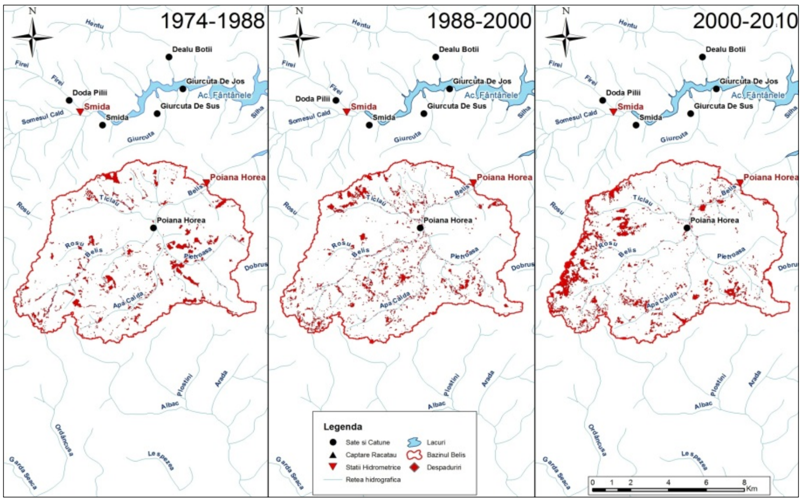

Fig. 9.3 The deforestation process evolution for Beliș.

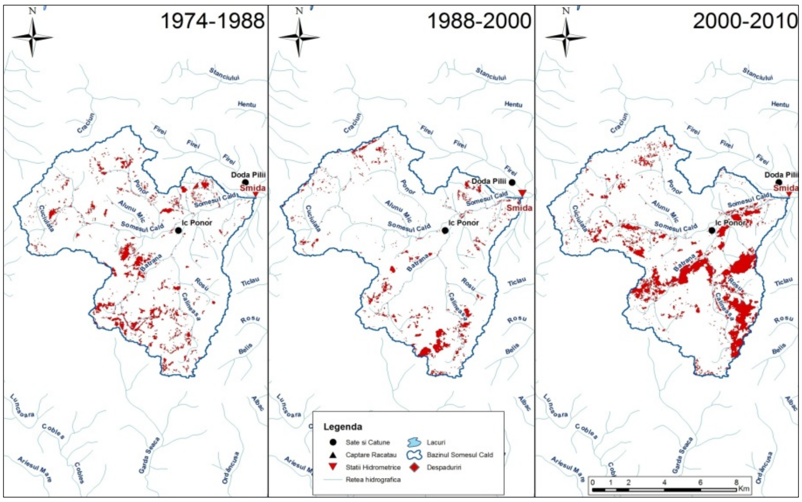

Fig. 9.4 The deforestation process evolution for Someșul Cald catchment.

10. Assessment over the underlying surface change during 1974-2010 and some consequences on several indices that affects surface runoff

This chapter is intending to highlight the deforestation effect in shaping the characteristics of the underlying surface. This was done by using indicators which are calculated by using the forest surface and the rest of cover types.

10.1. Indicators of Underlying surface characteristics changes

It is impossible to study or make inventory for each forest stand in a catchment from the mountainous area. That is why we are using indicators (parameters) to make assessments over the catchments situation regarding the forest cover surface and especially over the role that the forest can have in changing the underlying surface characteristics.

10.1.1. The afforestation degree

The afforestation degree is the simplest indicator that may refer to the catchment underlying surface characteristics. It is given by the formula:

$$C_p\% = \frac{forest\ surface}{catchment\ surface} * 100 \quad (10.1)$$

The afforestation degree variability is shown in Fig. 10.1.

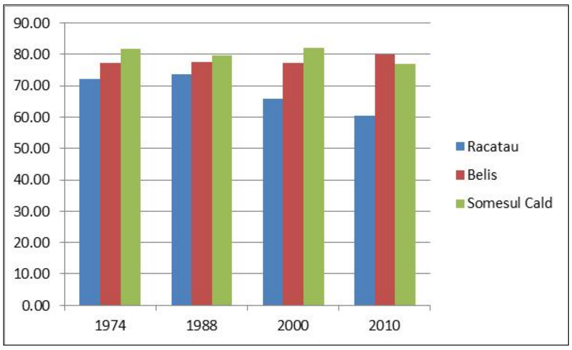

Fig. 10.1 The afforestation degree variability in the period 1974-2010.

10.1.2. The deforestation effects over the averaged runoff coefficients

Frevert proposed the identification of runoff coefficient depending on land cover, slope and soil texture. The coefficient can range between 0.1, for low slopes, forest vegetation, light soil texture and 1 for slopes wit 100% of runoff possibility.

In order to obtain the spatial distribution and to extract the necessary data for studying the runoff coefficient a GIS model was builded. The results of applying the GIS model are shown in Fig. 10.2.

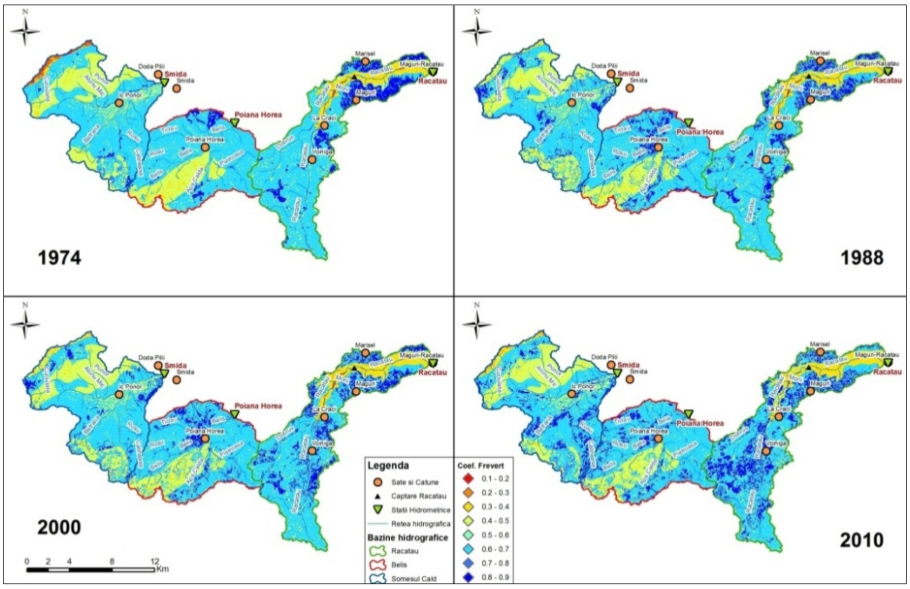

Fig. 10.2 The Frevert coefficient spatial distribution.

From the point of view given by the runoff coefficient, we have calculated the runoff coefficient weighted average for each catchment. For this we used the averaged runoff coefficient equation. The formula is taking into account the surface occupied be each land cover type. The results showed that a clear connection between the Frevert coefficient variability and forest cover surface has been found for Răcătău catchment and for Someșul Cald catchment a smaller connection (10.3, 10.4).

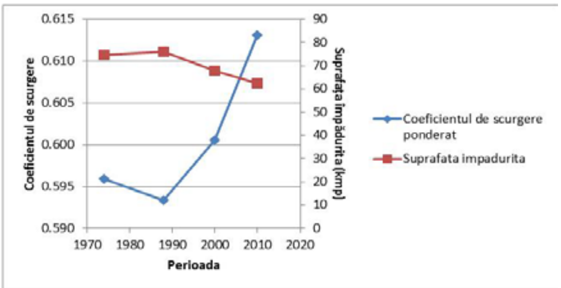

Fig. 10.3 Runoff coefficient variability vs. forest surface in Răcătău catchment.

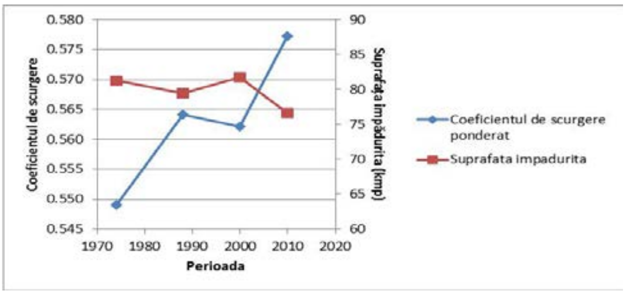

Fig. 10.4 Runoff coefficient variability vs. forest surface in Someșul Cald catchment.

10.1.3. The deforestation effect over the Curve Number index

Curve Number is an empirical parameter used to describe the hydrological potential of an area that can drain water from heavy rains. It is calculated based on the land cover type, hydrological soil group and soil moisture. Changes in the underlying surface can be represented and highlighted by this parameter (USDA-SCS, 1985). CN is a dimensionless coefficient that can vary between 30 and 100. The determination of CN in hydrological studies it is base on the hydrological soil group and the land cover type in normal soil moisture conditions (USDA-SCS, 1985). In our case was constructed a GIS model to obtain the index variability in the studied catchments. The results are represented in Fig. 10.5.

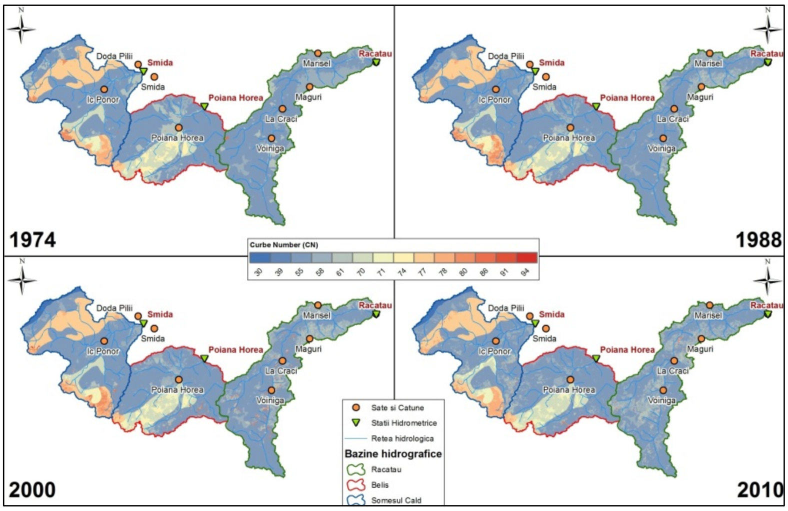

Fig. 10.5 CN index spatial variability in the period 1974-2010.

In the case of CN index the sub-basins area was delineated for the all the catchments. In this way we were able to find the value of the weighted average CN index for each of the sub-basins area.

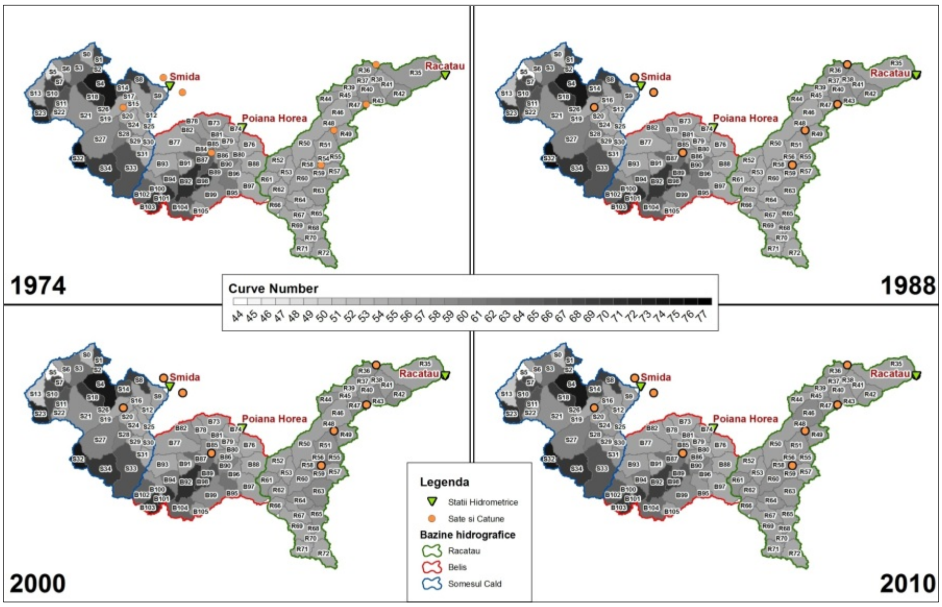

Fig. 10.6 CN index variability at the sub-basins level for the period 1974-2010.

It should be noted that although the CN index is calculated according to the type of land cover and stationary conditions, it suffers when is used in strong forested areas. Even splitting the catchments in sub-basins didn't reveal a significant CN variability, although the underlying surface degradation processes were quite consistent in two of the catchments. For arguing this statement we binged in discussion the studies and the reports made by Canfield et al. (2005), Tedela et al. (2012) and Steven (2003).

In order to conclude and to indicate the possible influence of the deforestation process in the underlying surface characteristics changes we made a comparison between the annual averaged runoff departures values from the normal runoff values for the period 1981-2010 and runoff coefficient variability (Fig. 10.7, 10.8)

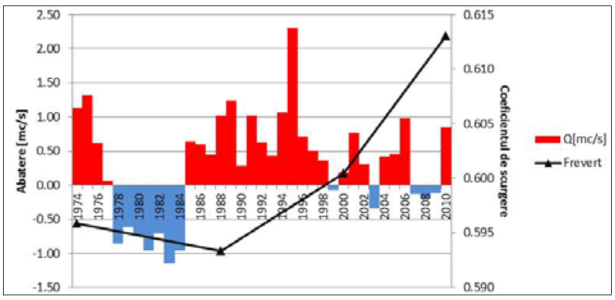

Fig. 10.7 Frevert runoff coefficient vs. annual averaged runoff departures values from the normal 1981-2010 (Răcătău).

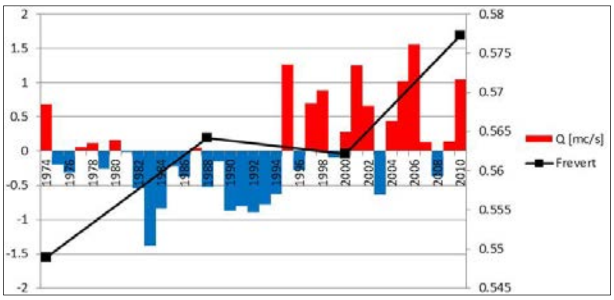

Fig. 10.8 Frevert runoff coefficient vs. annual averaged runoff departures values from the normal 1981-2010 (Someșul Cald).

It can be seen that where deforestation occurred on significant surfaces, the runoff coefficient follow the runoff variability, and where deforestation occurred on smaller surfaces, like in the case of Someșul Cald catchment, the runoff coefficient is following somehow the runoff variability, but it can be seen that the missing of land cover data from the beginning of the period is affecting the variability assessment.

However, if we consider the runoff coefficient definition, given by the runoff rational method (Chow, 1962), which says that the runoff coefficient value is the ratio between measured runoff and the total runoff that falls in a certain area and time we can say that the mentioned examples are highlighting the fact that massive deforestation have a significant role in the process of underlying surface characteristics changes, which is the surface that precipitations encounter on their way to the point of runoff.

11. Conclusions

The research theme presents the application of a methodology for mapping and analyzing the layer evolution that is found at the soil surface, called “land cover”. A special view has been accorded to the deforestation process and not least to the possible effect that this process can play in shaping the conditions necessary for runoff appearance through their influence over the underlying surface change characteristics.

In this study we used multiples methodologies for highlighting the vegetation variability, and forests in particular. It can be seen from the expression that the method that highlighted the vegetation variability is a general one. The method is using the NDVI index. This method is an approximate method, a general one, because it considers all surfaces covered with vegetation by not making distinction between the vegetation types, and the values represented on the maps are mainly dependent by a threshold.

Satellite imagery classification method is the second used method. It allows defining different types of land cover classes. The methodology used in determining land cover types was not simple. This method involved various calibration and iterative sampling operations. This was a very delicate and sensitive operation. As a result the operations offered the possibility to build a unique spectral library which was used in the classification process for the entire satellite imagery database.

The deforestation process assessment for the considered catchment areas was performed by using ArcGIS software and some other calculus software like Excel and SPSS. By using ArcGIS software we constructed a full automatic algorithm that detects the land cover changes. Thus, information’s regarding the surface changes could be obtained. The changes are considered for a surface for at least $900m^2$ (1 pixel in Landsat imagery). The processes that caused the variability were considered for all types of vegetation, and of course for the other types as well. In this way were identified processes like deforestation, reforestation/afforestation or mineralization.

Using the indicators that can highlight the deforestation effect over the underlying surface characteristics changes is one of the most important facts. In this way a study regarding deforestation will have an important significance. Thus, from a simple ratio as the afforestation degree which describes the proportion occupied by forest against a catchment area, in the final more complex indices were considered. They are taking into account the terrain configuration and the land cover type. This is a wish, especially because we are talking about mountainous catchments where large slopes and soil types may provide the possibility for floods and erosion occurrence.

12. References (selection)

Anderson J.R., Hardy E.E., Roach J.T., Witmer R.E., (1976). A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper, No. 964. USGS, Washington, D.C.

Bariou R., Lecamus D., Henaff L. F., (1985). Dossiers de télédétection. Indices de végétation. Centre Régional de Télédétection, Université de Renne 2 - Haute Bretagne.

Bishop Y., Fienberg S., and Holland P., (1975). Discrete Multivariate Analysis--Theory and Practice, MIT Press, Cambridge, MA, 575 pp.

Boriah S., Kumar V., Steinbach M., Potter C., Klooster S., (2008). Land cover change detection: a case study. In KDD ’08: Proceeding of the 14th ACM SIGKDD international conference on Knowledge discovery and data mining, pages 857–865, New York, NY, USA, ACM.

Brown Felicity, (2009). Total forest coverage by country. Environment Data. The Guardian.

Campbell J. B., (1983). Mapping the Land: Aerial Imagery for Land Use Information. Washington, D.C.: Association of American Geographers.

Carletta J., (1996). Assessing agreement on classification tasks: The kappa statistic. Computational Linguistics, 22(2). pp. 249–254.

Carr J. R., Glass C. E., Schowengerdt R.A., (1983). Signature Extension Versus Retraining for Multispectral Classification of Surface Mines in Arid Regions, Journal of Photogrammetric Engineering and Remote Sensing, Vol. 49, No. 8, pp. 1193 - 1199.

Chander G., Markham B., (2003). Revised Landsat-5 TM Radiometric Calibration Procedures and Postcalibration Dynamic Ranges, IEEE TGARS, VOL. 41, NO. 11.

Chehata N., Orny C., Boukir S., Guyon D., (2011). Object-based forest change detection using high resolution satellite images. ISPRS PIA 2011 (Photogrammetric Image Analysis). 5-7 Octobre, Vol. 38 Part 3/W22, pp. 49-54, Munich, Allemagne.

Conea I., Badea L., Stoicescu N., (1984). Plaiuri carpatice, 223p. Ed. Sport-Turism, București.

Congalton R. G., (1991). A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data, REMOTE SENS. ENVIRON. 37:35-46.

Coppin P.R., Bauer, M.E., (1996). Digital change detection in forest ecosystems with remote sensing imagery. Remote Sensing Reviews 13:207-234.

Costea G., Haidu I., (2010). Detection of recent spatial changes regarding landuse in small basins from the Apuseni Natural Park, Geographia Technica, No. 2/2010, Cluj Univeristy Press.

Costea G., Serradj A., Haidu I., (2012). Forest Cartography using Landsat Imagery, for Studying Deforestation over Three Catchments from Apuseni Mountains, Romania. Advances in Remote Sensing, Finite Differences & Information Security, WSEAS PRESS.

Diaconu C., Şerban P., (1994). Sinteze şi regionalizări hidrografice, Editura Tehnică, Bucureşti.

Domniţa M., Craciun A. I., Haidu I., (2009). GIS in determination of the discharge hydrograph generated by surface runoff for small basins. Geographia Technica, No. 2, pp. 11-22.

Dutcă, I., Abrudan, I.V., (2010). Estimation of Forest Land Cover Change in Romania between 1990 and 2006. The Bulletin of the Transilvania University of Brasov. Vol. 3 (52). Series II, ISSN 2065-2135, pp. 33-36.

F.A.O., (1996). Satellite imagery for forest decline assessment and monitoring. Pilot study in Poland (en., fr.). Remote Sensing for Decision-Makers Series (F.A.O.). no. 13 / F.A.O., Rome (Italy). Sustainable Development Dept., 6 p.

Green A.A. , Berman M., Switzer P., Craig M.D., (1988). A Transformation for Ordering Multispectral Data in Terms of Image Quality with Implications for Noise Removal, IEEE Transactions on Geoscience and Remote Sensing, vol. 26, pp. 65-74.

Guyot G., (1989). Signatures spectrales des surfaces naturelles. Collection «Télédétection satellitaire no 5 », Paradigme, Caen, 178 p., 82 fig., 2 tabl., 14 x 21 cm, 97 FF.

Haidu I., Bilașco Șt., (2005). Implementarea S.I.G în calculul viiturilor de versant (Simpozionul„Sisteme informaționale geografice, Chișinău). Ed. Univ. Al. Ioan Cuza, Iași.

Haidu I., **Costea G.**, (2009). Applied GIS for designing the database and mapping specific to forestry, Lucrările Simpozionului "Sisteme Informaționale Geografice", Nr. 14, Editura Universității "Alexandru Ioan Cuza", Iași.

Haidu I., **Costea G.**, (2012). Remote Sensing and GIS for the forest structure asssessment at the small basins level in the Apuseni Natural Park, Studia Universitatis Babes-Bolyiai Geographia, No. 1/2012.

Holonec L., (2007). Incendiile de pădure și efectele lor asupra ecosistemelor forestiere, Revista Protecția Plantelor, nr. 65, ISSN 1453-2271, pag. 17-21.

Homrani Bakkali A., (2000). Teledétédetection de la dynamique de la dégradation de la végétation steppique aride et semi-aride au Maroc : cas de la vallée de N'Zala-Zaouit Sidi Hamza (Errachidia). Mémoire de 3ème cycle Agronomie, option : Ecologie et Aménagement.IAV.HassanII, Rabat, pp : 60-69.

Iacob Ersilia, (1971). Munţii Apuseni, Studiu hidrologic, Teză de doctorat, Cluj-Napoca.

Iacobescu O., (2000). Fotointerpretarea unor aspecte hidrologice în bazinele hidrografice mici din zona montană. Bucovina Forestieră – serie nouă, anul VIII, nr. 2/2000, pp. 30- 38.

Institutul de Geologie și Geografie (Academia Republicii Populare Romîne). (1960). Monografia geografica a R.P.R., vol. I, Geografie fizică, Editura Academiei R.P.R., București.

Jensen J. R., (1996). Introductory Digital Image Processing. Prentice Hall, Upper Saddle River, New Jersey, 318 p.

Keil M., Scales D., Winter R., (1995). Investigation of forest areas in Germany and Brazil using SAR data of the SIR-C/X-SAR and other SAR missions, Geoscience and Remote Sensing Symposium, 1995. IGARSS '95. 'Quantitative Remote Sensing for Science and Applications', Internaţional, vol. 2, pp. 997 - 999.

Knorn, J., Kuemmerle, T., Radeloff, V.C., Szabo, A., Mîndrescu, M., Keeton, W.S., Abrudan, I., Griffiths, P., Gancz, V., Hostert, P., (2012). Forest restitution and protected area effectiveness in post-socialist Romania. Biological Conservation.

Kozak, J., Estreguil, C., Vogt, P., (2007). Forest cover and pattern changes in the Carpathians over the last decades. European Journal of Forest Research, Springer Berlin / Heidelberg, ISSN: 1612-4669, vol. 126.

Kruse F. A., Lefkoff A. B., Boardman J. B., Heidebreicht K. B., Shapiro A. T., Barloon P. J., Goetz A. F. H., (1993). The Spectral Image Processing System (SIPS)- interactive visualization and analysis of imaging spectrometer data. Rem. Sen. of Env., 44, 145-163.

Kuemmerle, T., Muller, M., Rusu, M., Griffiths, P., (2009). Land use change in southern Romania after the collapse of socialism. Reg. Environ. Change 9 1–12.

Landis J.R., Koch G.G., (1977). The measurement of observer agreement for categorical data, Biometrics 33 (1): 159–174. DOI:10.2307/2529310. JSTOR 2529310. PMID 843571.

Lau Alvin Meng Shin, Hashim Mazlan, (2007). The design and building of spectral library of tropical rain forest in Malaysia. In: The 28th Asian Conference on Remote Sensing 2007, PWTC, Kuala Lumpur, Malaysia.

Lillesand T.M., Kiefer R.W., Chipman J.W., (2004). Remote Sensing and image Interpretation. Fifth Edition, John Wiley and Sons Inc., New York, 764p.

Lin C., (2001). The Dependence of reflected radiance and reflectance of the forest vegetation - a case study of cyclobalanopsis glauca, the 22nd Asian conference on Remote Sensing, Vol. 1, pp. 610-615.

Matthews E., (1983). Global vegetation and land-use: new high-resolution databases for climate studies, Journal of Applied Meteorology, 22:474-487.

Mihai B., Săvulescu I., Sandric I., (2007). Change detection analysis (1986–2002) of vegetation cover in Romania: A study of alpine, subalpine, and forest landscapes in the Iezer Mountains, Southern Carpathians. Mountain Research and Development 27:250–258.

Moțoc M., Trăsculescu Fl., (1959). Eroziunea solului pe terenurile agricole și combaterea ei. Editura Agrosilvică de Stat, București.

Muehrcke P., Muehrcke Juliana O., Kimerling A. J., (2001). Map Use: Reading, Analysis, and Interpretation. JP Publications. ISBN 978-0-9602978-5-6.

Murayama Y., Thapa R.B., (2011). Spatial Analysis and Modeling in Geographical Transformation Process: GIS-based Applications. Springer Science +Business Media B.V. GeoJournal Library Series, Vol. 100, 1st Edition, ISBN:978-94-007-0670-5.

National Engineering Handbook, Section 4, Hydrology, Part I-Watershed Planning, USDA, Soil Conservation Service, Chapter 7, August, 1964, 7.3 - 7.5.

Oliver C.D., (1980). Forest Development in North America following major disturbances. For. Ecol. Management 3: 153 –168.

Olofsson P., Torchinava P., Woodcock C.E., Baccini A., Houghton R.A., Ozdogan M., Zhao F., Yang X., (2010). Implications of land use change on the national terrestrial carbon budget of Georgia, Carbon Balance and Management, 5:4 doi:10.1186/1750-0680-5-4.

Olsen J. S., Watts J., Allison L., (1983). Carbon in live vegetation of major world ecosystems. U. S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN, 164 p.

Pascual, C.A., García-Abril, A., García-Montero, L.G., Martín-Fernández Susana, Cohen, W.B., (2008). Object-based semi-automatic approach for forest structure characterization using lidar data in heterogeneous Pinus sylvestris stands. For Ecol Manage 255(11):3677–85.

Popescu Şt.G., (2009). Fotogrammetria pe înţelesul tuturor, Curs în format electronic, FIFIM.

Purkis S.J., Klemas V., (2011). Remote Sensing and Global Environmental Change. Wiley-Blackwell, Oxford, 368pp, ISBN 978-1-4051-8225-6.

Richard McCuen H., (1982). A Guide to Hydrologic Analysis Using SCS Methods Prentice Hall, Inc. Englewood Cliffs, New Jersey.

Richards J.A., (1999). Remote Sensing Digital Image Analysis, Springer-Verlag, Berlin, p. 240.

Rowan L.C., Mars J.C., (2003). Lithologic mapping in the Mountain Pass, California area using Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) data. Remote Sensing of Environment, Vol. 84, p. 250-266.

Schwarz M., Steinmeier Ch., Waser L., (2001). Detection of Storm Losses in Alpine Forest Areas by Different Methodic Approaches Using High-resolution Satellite Data; - In: Bégni, G. (ed) Observing our environment from space: New solutions for a new millenium. Lisse, Balkema. 251-257.

Schwengerdt R., (2007). Remote Sensing 3rd, Elsevier (Academic Press). 515p.

Serradj A., (1991). Classification sur une forêt orientale des Vosges après élimination des effets de pente, Photo interprétation, Vol. 30 n° 3-4 (1991/1992).

Sommer Shelly, Wade Tasha, (2006). A to Z GIS: An Illustrated Dictionary of Geographic Information Systems, ESRI Press.

Steven C. McC., (2003). Hydrologic Evaluation of the Curve Number Method for Forest Management in West Virginia, Report Prepared for the Division of Forestry Charleston, West Virginia.

Strîmbu B.M., Hickey G.M., Strîmbu V.G., (2005). Forest conditions and management under rapid legislation change in Romania. Forestry Chronicle 81, 350–358.

Şerban G., Touchart L., (2007). Un nouveau parc naturel autour d'un vieux lac artificiel : les enjeux d'une Roumanie en transition dans les monts Apuseni, Géocarrefour, 2007, vol. 82 n. 4 : pp. 243-253.

Tedela N., McCutcheon S., Campbell J., Swank W., Adams M., Rasmussen T., (2012). Curve Numbers for Nine Mountainous Eastern United States Watersheds: Seasonal Variation and Forest Cutting. J. Hydrol. Eng., 17(11). 1199–1203.

Townshend J. R. G., (1981). Image Analysis and Interpretation for Land Resources Survey, Chapter 4 in Terrain Analysis and Remote Sensing, J. R. G' Townshend, Ed. London: George Allen & Unwin Ltd', pp. 59-108.

Tucker C.J., (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment, 8, 127–150.

Tucker C.J., Miller L.D., (1977). Soil Spectra Contributions to Grass Canopy Spectral Reflectance, Photogrammetric Engineering and Remote Sensing, 43:721-726.

USDA, Soil Conservation Service, (1972). National engineering handbook, Section 4, hydrology. Chapters 7, 8, 9, and 10. U.S. Govt. Print. Off. Washington, DC.

Ustin Susan L., (2004). Remote sensing for natural resource management and environmental monitoring, John Wiley & Sons, 736 pages, ISBN-13: 978-0471317937.

Van der Meer F., Vasquez-Torres M., Van Dijk P.M., (1997). Spectral Characterization of Ophiolite Lithologies in the Troodos Ophiolite Complex of Cyprus and its Potential in Prospecting for Massive Sulphide Deposits. IJRS, Vol. 18, No.6, p. 1245-1257.

Yuhas R.H., Goetz A.F.H., Boardman J.W., (1992). Discrimination Among Semi-Arid Landscape Endmembers Using the Spectral Angle Mapper (SAM) Algorithm. Summaries of the 4th JPL Airborne Earth Science Workshop, JPL Publication 92-41, pp.147-149.

Yuji Murayama, Rajesh B. Thapa, (2011). Spatial Analysis and Modeling in Geographical Transformation Process GIS-based Applications, Dordrecht, New York : Springer, USA.

Zha Y., Gao Y., Ni S., (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. IJRS, 24(3). pp. 583-594.

***Codul Silvic al României, Legea nr. 46/2008, Pub. în Monit. Of., P. I nr. 238/27 martie 2008.

***Legea nr. 2 din 15 aprilie 1976, Emitent: Marea Adunare Națională, Publicată în: Buletinul Oficial nr. 35 din 23 aprilie 1976.

***Programul naţional pentru conservarea şi dezvoltarea fondului forestier în perioada 1976-2010. Revista Pădurilor nr. 2/1976.