USING REMOTE SENSING IMAGERY AND GIS TO IDENTIFY LAND COVER AND LAND USE WITHIN CEAHLĂU MASSIF (ROMANIA)

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Utilizarea imaginilor satelitare şi a SIG pentru identificarea modului de acoperire şi utilizare a terenului în Masivul Ceahlău (România). În acest studiu am avut în vedere identificarea modului de acoperire şi utilizare a terenului în arealul masivului Ceahlău (România) prin utilizarea imaginilor satelitare şi a tehnicilor GIS. Pentru atingerea acestui obiectiv am utilizat o imagine satelitară Landsat 7 ETM+, care a fost prelucrată cu ajutorul soft-urilor de analiză a imaginilor satelitare şi a soft-urilor GIS în câteva etape principale:
▪ Importarea şi unirea tuturor benzilor spectrale care compun imaginea satelitară, pentru a forma o imagine multibandă;
▪ Stabilirea unor zone de interes pentru fiecare categorie de acoperire/utilizare a terenului în parte, care au fost digitizate on-screen şi cărora li s-au stabilit caracteristicile semnăturilor spectrale;
▪ Clasificarea supervizată a imaginii prin metoda Maximum Likelihood;
▪ Importarea hărţii (rasterului) rezultate în mediu GIS pentru crearea hărţii finale cu modul de acoperire/utilizare a terenului.
În arealul de studiu au fost identificate 9 clase de acoperire/utilizare a terenului: păduri de foioase, păduri de amestec, păduri de conifere, păşuni secundare, vegetaţie subalpină, pajişti alpine, teren agricol, spaţiu construit şi lacuri. În urma analizei distribuţiei acestor clase, s-a constatat că pădurile reprezintă clasa cel mai bine reprezentată, ocupând o suprafaţă de 188,4 km² (56,4% din total), urmată de clasa păşunilor secundare, care ocupă o suprafaţă de 68,2 km² (20,4% din total), de clasa lacurilor (26,6 km² sau 7,98% din total) şi de clasa terenurilor agricole (16,1 km² sau 4,86%).

Cuvinte cheie: Masivul Ceahlău, GIS, imagini satelitare, peisaj, acoperirea terenului

Using remote sensing imagery and GIS to identify land cover and land use within Ceahlău Massif (Romania). In this study we considerer land cover and land use asessment within Ceahlău Massif (Romania) using satellite imagery and GIS.To achieve this goal, we used a Landsat 7 ETM + satellite image, which was processed using specialized software in analyzing satellite images and GIS software in several stages:
▪ Downloading, importing and layer stack of all spectral bands composing satellite image;
▪ Establishment of areas of interest for each category of land cover and land use, which were digitized on-screen and for which spectral signatures characteristics were established;
▪ Supervised image classification using Maximum Likelihood Method;
▪ Importing the resulting map (raster) in GIS environment and creating the final land cover/land use map for Ceahlău Massif.
In the study area we identified nine land cover/land use classes: deciduous forests, mixed forests, coniferous forests, secondary

grasslands, subalpine vegetation, alpine meadows, agricultural land, lakes and built area. By analizing the spatial distribution of these classes, it was found that forests are the best represented class, occupying an area of 188.4 km² (56.4% of total), followed by secondary grassland, which occupies an area of 68.2 km² (20.4% of total), lakes (26.6 km² or 7.98% of total) and agricultural land (16.1 km² or 4.86%).
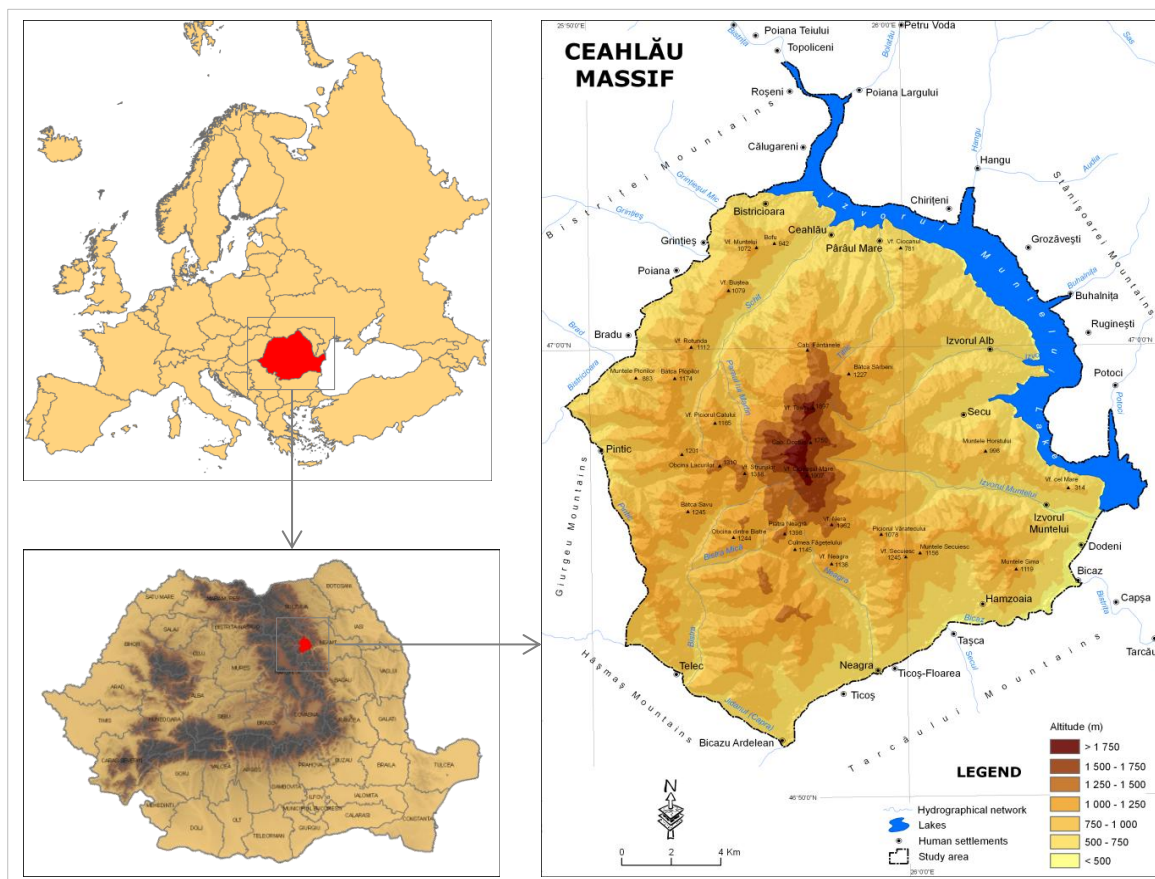
Keywords: Ceahlău Massif, GIS, sattelite images, landscape, land cover

1. INTRODUCTION

Land cover and land use, as part of the geographical landscape structure, has become important issues in recent decades, often addressed both at the scientific, political and popular consciousness. At the same time, new ways of analyzing their structure at a certain moment appeared and improved, most recently using in tandem, both image analysis software for remote sensing and GIS software. For example, GIS and satellite imagery are used in studies regarding forest landscape change [1] [2], spatial and temporal land cover changes [3] [4] or in studies regarding urbanization and peri-urbanization in urban areas [5].

The main objective of this study is to identify land cover and land use within Ceahlău Massif, using satellite imagery and GIS.

Study area. Ceahlău Massif is situated in the Central Group of Romanian Eastern Carpathians, its center being located around the intersection of parallel 46° 58' N with the meridian of 25° 57' E (Fig.1). It is located entirely within the administrative teritory of Neamț county, occupying an area of approximately 292 km². It is bordered to the north by the Bistricioara valley that separates it from Bistriței Mountains, to the east by Izvorul Muntelui-Bicaz lake, on Bistrița valley, which separates it from Stânişoarei Mountains, to the south by Bicaz valley, which separetes it from Tarcăului Mountains and to the west by the opposite valleys of Pintic and Capra [6].

↑ Figure 1. Geographical position of Ceahlău Massif

For a much higher degree of complexity regarding the land cover and for showing the potential of satellite image classification in detecting a large number of land cover classes, the study also refers to the Izvorul Muntelui-Bicaz lake (26 km^2) unit that borders the Ceahlău Massif towards the east, streching the total study area to 318 km^2.

In geological terms, the Ceahlău Massif overlaps almost entirely the flysch zone, being composed of rocks such as sandstones, marls, conglomerates, limestone and dolomite [6-7].

Morphologicaly, it is characterized by the presence of a higher plateau with a length of 6 km and a maximum width of 1 km, plateau which ends outwards through steep cuesta type slopes, of over 500 m, which in their upper part presents specific conglomeratic landforms such as towers, stacks or columns. The maximum altitude within the massif is 1 911 m, located in Ocolașul Mare Peak [8].

Ceahlău Massif is characterized by a temperate-continental climate, with strong mountain influences. Average annual air temperature ranges from 7.2° C in the lower parts of the massif to 0.5° C on the highest peaks [9]. Average annual rainfall ranges between 600-750 mm, with a monthly maximum recorded in the months of June and July. The wind regime in the high peaks is under the influence of western circulation, which records a frequency rate of approximately 45% per year, the annual average wind speed exceeding 10m/s [10]. On the lower slopes and on the valleys, mountain-valley winds prevail, with different directions depending on the orientation of the valley corridor, the average annual wind speed being approximately 2-3 m/s [8].

Local hydrographic network measures 200 km in length and is fully tributary to Bistrița river basin. Watersheds have small areas and therefore maintain liquid flows at low levels. Rivers have steep longitudinal profiles, especially in the upper reaches, wich sometimes exceeds 100 m/km [8].

The soils that characterize this mountain area are podzols and acid-brown soils, as parts of zonal soils group, and acidic peaty soils, peatlands, rendzinas, lithosols and alluvial soils, as parts of intra-zonal soils group, which are imposed by local conditions [8].

Vegetation is composed of a complex of phytogeographical elements with different origins, such as Eurasian, Central-European, alpine and circumpolar elements. Botanical surveys have inventoried a total of 1 099 genders, with 2 994 species, 66 subspecies and 117 varieties [8][11].

2. DATA AND METHODOLOGY

2.1 Data

We used satellite images, orthophotos at 1: 5000 scale, 1:25 000 scale topographic maps and existing spatial databases.

Satellite images

For this study we used a satellite image, captured by the Landsat 7 ETM+ satellite on August 17, 2010, with minimal cloud cover over the entire surface being analyzed. The spatial resolution of such images is 30 m, resolution considered sufficiently detailed for analysis on land cover and land use over large areas.

Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) was launched on the 15th April 1999. It has an repetitive and circular orbit, with an inclination angle of 98.2° with respect to the equator and an orbital altitude of 705 km. Each orbit takes approximately 99 minutes, with over 14.5 orbit being completed in a day and results in a 16-day repeat coverage [12].

The sensor instaled on board operates in the visible and infrared ranges. The spectral and spatial ground resolution of the sensor can be found in Table 1:

Table 1. Landsat ETM+ Specifications on the basis of Lillesand et al. [12] and Kramer [13]

Band No.	Wavelength (μm)	Spectral light	Pixel/Ground resolution(m)	Principal Applications
1	0.45 – 0.52	Blue	30	Distinction of soils, water and vegetation
2	0.53 – 0.61	Green	30	Distinction of vegetation
3	0.63 – 0.69	Red	30	Distinction of vegetation and soils
4	0.78 – 0.90	Near infrared	30	Biomass and urban area
5	1.55 – 1.78	Shortwave infrared	30	Distinction of vegetation and rocks
6	10.42 – 11.66	Thermal infrared	60	Measuring of temperature
7	2.10 – 2.35	Shortwave infrared	30	Amount of water in vegetation and soils
8	0.50 – 0.90	Panchromatic	15	Distinction of areas

As satellite data provider was used the Earth Explorer Database [14], which distributes remotely sensed data free of charges. The image was downloaded at L1T

level (orthorectified). A detailed tutorial on how to download the images can be found on the website [15].

Ortophotos, topographic maps and existing spatial databases

To facilitate image classification we used a number of additional data sources, such as ortophotos at 1:5 000 scale (available for consultation on Inspire Geoportal) [16], topographic maps at 1:25 000 scale and CORINE Land Cover 2006 database [17]. These data were used only to compare the results obtained from supervised classification of satellite image with the situation shown on the maps or existing databases.

2.2 Data pre-processing

The first step was to unzip the downloaded Landsat image and to union spectral bands to form multi-band images, using ERDAS IMAGINE 2009 program. In most cases the analyzed satellite image covers a much larger area than the studied area. Also, the satellite images can present image noise or spots that are irrelevant in the analysis of the geographical environment, such as clouds, which can easily lead to misinterpretation of data. For this reason, the pre-processing stage of satellite images is absolutely necessary. The main actions undertaken were: geometric processing and overall image enhancement.
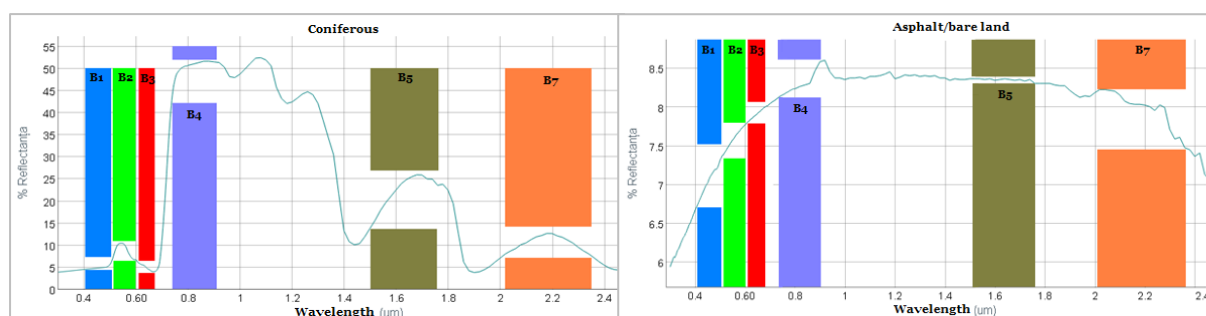
Geometric processing

In this stage the satellite image was clipped to a subset of the case study area in order to focus on the relevant data. Other operations were not made, since the image used was cloud free and with no other undesirable elements. Landsat imagery provided by the Earth Explorer include a UTM projection and a WGS84 datum and ellipsoid respectively. Thus a geometric correction was unnecessary.

Image enhancement

Image enhancement is valuable to detect and define information classes since they have different spectral characteristics [18].

Different spectrum of electromagnetic radiation for different types of surfaces allows us to appreciate its type. In Figure 2 are showed the spectral signature characteristics for two of the land cover and land use classes found in Ceahlău Massif area [19].

↑Figure 2. Spectral signatures of selected classes [19]

As can be seen, vegetation (coniferous forests) has its characteristic spectral signature with the green peak in the spectrum of visible green light, a slight decrease in the visible red spectrum and a boost in the near infrared. In contrast, bare land and man made surfaces have an almost constant spectral signature that is maintained at a lower level of electromagnetic radiation spectrum.

For the accuracy of land cover and land use classification, false colour composite of the available satellite bands are used.

A full colour image is based on the Red Green Blue system (RGB), which is an additive colour mixing [18]. The RGB system allows using three coresponding colour guns that display available satellite spectral bands. This offers a posibility to combine bands and colour guns in different way in order to enhance the image. For a true colour composite one uses the red colour gun for spectral bands in the visible red light, green colour gun for spectral bands within the visible green light and the blue colour gun for spectral bands in the visible blue light. For false colour composites (FCC) one can use each available satellite spectral band. Thus, this is a useful tool of image enhancement for the reason that it allows a simultaneous visualisation of information from three separate spectral bands as well as information that are not visible to the human eye in the infrared wavelengths [18].

One false colour composite was used to detect surfaces in this study area. It has band 4 in the red colour gun, band 5 in the green colour gun and band 3 in the blue colour gun (R:4, G:5, B:3). This composite is useful because it allows us to differentiate between forests (which appear in reddish colour) and secondary grasslands, which appear in yellow-green shade. Also, we can differentiate urban/rural built areas, water courses or lakes units, as well the agricultural lands.

2.3 Supervised classification

Establishing the main classes of land cover and land use

Based on the information gained from the literature, the study of additional cartographic documents and satellite image that has undergone operations described above, we established the main land cover and land use classes that are representative for the study area. These classes are: deciduous forests, mixed forests, coniferous forests, secondary grasslands, subalpine vegetation, alpine meadows, agricultural land, lakes and built area.

Creating spectral signature classes

An accurate classification of the satellite image requires gathering a large number of spectral signatures. For this study, this operation was done by on-screen digitizing.

The identification of spectral signatures classes for each category of land cover and land use can be difficult, especially in terms of 30 m spatial resolution of Landsat satellite images, that can lead to a mixture of several spectral signatures in a single pixel. Common image processing systems offer possibilities such as scatterplots to enhance those signatures [18]. For this study, we digitized 100 areas of interest for each category of land cover and land use. These areas of interest were made in explicit areas in order to be representative and complete. The spectral signature class statistics were estimated out of the 4-5-3 composite.

Maximum Likelihood Classification

Maximum Likelihood method is one of the most used algorithms for supervised classification of satellite images. It quantitatively evaluates the variance and covariance of the spectral response patterns of an unknown pixel [12]. The algorithm is able to recognise the spectral characteristics of each class in an unknown data set via the statistical data obtained by digitised areas of interest beforehand [12][20]. The algorithm calculates, based on the density probability functions and on the pixel value, the probability that an unidentified pixel belonging to each spectral class. In the end, the pixel would be assigned to the most likely spectral class or be assigned as unclassified if the probability values are below a user defined threshold [12].

The outcome of the Maximum Liklehood Classification was a thematic map of Ceahlău Massif for the year 2010, according to the spectral classes described above.

Map accuracy assessment

Accuracy assessment of the Maximum Likelihood classification was determined by means of a confusion matrix (sometimes called error matrix), which compares, on a class-by-class basis, the relationship between reference data (ground truth) and the corresponding results of a classification [21]. Such matrices are square, with the number of rows and columns equal to the number of classes, i.e. 9. For all classes, the numbers of reference pixels are presented in Table 2.

Table 2. Confusion matrix for Maximum Likelihood classification

Classified data	Reference data									
	A	B	C	D	E	F	G	H	E	Row total
Lakes (A)	**6589**	0	0	0	0	0	0	0	0	6589
Coniferous (B)	0	**4241**	180	0	0	0	0	1	2	4424
Mixed (C)	0	85	**13044**	146	0	25	0	1	2	13303
Deciduous	0	0	425	**3100**	0	123	19	0	4	3671

(D)									
Built area (E)	0	1	9	0	**380**	11	41	0	0	442
Agricultural (F)	0	0	47	181	1	**2424**	96	7	6	2762
Secondary grassland (G)	0	0	1	46	2	33	**5573**	22	14	5691
Subalpine vegetation (H)	0	0	1	1	1	2	7	**350**	11	373
Alpine meadows (I)	0	0	3	1	0	3	11	12	**330**	360
Column total	6589	4327	13710	3372	384	2621	5747	387	360	**37585**

The diagonal elements in Table 2 represent the pixels of correctly assigned pixels and are also known as the producer accuracy. Producer accuracy is a measure of the accuracy of a particular classification scheme and shows the percentage of a particular ground class that is correctly classified [22]. It is calculated by dividing each of the diagonal elements in Table 2 by the total of each column respectively:

Producer accuracy = $c_{aa}/c_{\cdot a}$ x 100 %
where,
c_{aa} = element at position a^{th} row and a^{th} column
$c_{\cdot a}$ = column sums

The minimum acceptable accuracy for a class is 90% [23].

User Accuracy is a measure of how well the classification is performed. It indicates the percentage of probability that the class which a pixel is classified to on an image actually represents that class on the ground [23]. It is calculated by dividing each of the diagonal elements in a confusion matrix by the total of the row in which it occurs:

User accuracy = $c_{ii}/c_{i\cdot}$ x 100%
where,
$c_{i\cdot}$ = row sum

Table 3. Producer and user accuracy for all the classes

Class	Producer accuracy		User accuracy	
	(Pixels)	Percent (%)	(Pixels)	Percent (%)
Lakes	6589/6589	100	6589/6589	100
Coniferous	4241/4327	98.01	4241/4424	95.86
Mixed	13044/13710	95.17	13044/13303	98.05

Deciduous	3100/3372	91.93	3100/3671	84.44
Built area	380/384	99.22	380/442	85.97
Agricultural	2424/2621	92.66	2424/2762	87.76
Secondary grassland	5573/5747	97.28	5573/5691	97.92
Subalpine vegetation	350/387	90.43	350/373	93.83
Alpine meadows	330/360	91.66	330/360	91.66

A measure of overall behaviour of the Maximum Likelihood classification can be determined by the overall accuracy, which is the total percentage of pixels correctly classified [22]:

$$\textbf{Overall accuracy} = \sum_{a=1}^{u} \text{ca}/Q \ x \ 100\%$$

where, Q and U is the total number of pixels and classes respectively. The minimum acceptable overall accuracy is 85% [24].

The Kappa coefficient, K is a second measure of classification accuracy which incorporates the off-diagonal elements as well as the diagonal terms to give a more robust assessment of accuracy than overall accuracy. It is computed as [25]:

$$K = \frac{\sum_{a=1}^{u} \frac{caa}{Q} - \sum_{a=1}^{u} \frac{ca \cdot c \cdot a}{Q^2}}{1 - \sum_{a=1}^{u} \frac{ca \cdot c \cdot a}{Q^2}}$$

where $c_a\bullet$ =row sums. The Maximum Likelihood classification yielded an overall accuracy of 95,3% and kappa coefficient 0.94, indicating very high agreement with the ground truth.

2.4 GIS operations

The resulting raster was imported in GIS environment where certain operation have been made: raster reclassifying, areas calculation and final map preparation (adding title, legend, scale bar etc.).

3. RESULTS AND DISCUSSIONS

3.1 Ceahlău Massif land cover/land use map for the year 2010

The land cover and land use map (Figure 3) show the spatial distribution of each class in the study area.

Forests are the dominant land cover class in 2010, accounting for 56.4% (188,4 km² or 18 840 ha) of the study area. Forests occupy areas between altitudes of 420-1750 m, being better represented in the central part of the massif.

Deciduous forests occupy the low side of the Ceahlău Massif, being representative at altitudes ranging from 450-700 m. They are better represented in the area of Savu Hill, on the lower slopes of Lacurilor Hill, on the slopes of the Izvorul Muntelui valley and also on the Făgeţelului Hill in the Bistra river basin. Zonal woody vegetation is represented by pure beech forest, framed here in *Symphito cordati – Fagetum* association. Along beech forests, also meet insulated hornbeam-beech forests, belonging to *Carpino – Fagetum* association [8].

The main representative species for this area are: *Fagus silvatica* (beech), *Carpinus betulus* (hornbeam), *Fraxinus ornus* (ash), *Betula verrucosa* (birch), *Acer campestre* (maple), *Corylus avelana* (hazelnut tree). Along watercourses, azonal woody vegetation is represented by alder warblers (*Telekio speciosae – Alnetum incanae*) and shrubbery belonging to *Myricarietum germanicae* association [8].

The physionomy of this forest area has been greatly affected by human influence, who built settlements in the valleys at the foot of Ceahlău Massif. Instead of a continuous belt of beech forests that once surrounded the massif, today can be found only fragments, including secondary grasslands or pine, fir and spruce plantation [8].

Mixed forests occupy, in terms of altitude, the interval between 650-700 m to 1100-1200 m, being represented in a mixture of deciduous and coniferous species. The most common are fir tree - beech forests, belonging to *Pulmonario rubrae – Fagetum* association, which are frequent between 700-1000 m altitude and fir tree-spruce forests, belonging to *Hieracio rotundati – Abietetum* association, forming a belt between 1000-1200 m altitude. Insulated, pure beech forests can be found up to an altitude of 1050 m.

Generaly, mixed forests occupy important surfaces in the upper basin of Schit stream (in the area of *Piciorul Calului Hill* and *Plopilor Hill*), in the middle and upper basin of Izvorul Alb stream, on the slopes of *Mount Sima* and also on the slopes bordering Izvorul Muntelui-Bicaz Lake.

Coniferous forests streches from 1100-1200 m to 1700 m in altitude. The dominant species are pure spruce forests, belonging to *Hieracio rotundati – Piceetum* association. Within this vegetation sector, can be found, mostly on the rocky terrain, pure larch stands, at *Poiana Luminişului* and under *Bâtca Neagră* rocks. Also in this sector can be found *Abies alba* and *Pinus silvestrius* – glacial relict [8]. Generaly, coniferous forests occupy important areas within *Boiştei Hill*, *dintre Bistre Hill* and also on the slopes bordering Izvorul Muntelui-Bicaz Lake.

Analyzing the altitudinal distribution of forest, it is noted that predominantly forest stands ranges between 600-1400 m altitudes (approx. 90% of the total).

Considering the slopes inclination, most of the forest stands occupy slopes between 16°-30° (approx. 60%), 31°-40° (approx. 20%), under 16° (approx. 14%) and above 40° (approx. 6%). The largest areas of forest occupies sunny and partly sunny slopes (70%), while approx. 30% occupy shady slopes.

Secondary grasslands represents the second category in terms of occupied area. They represent 20.4% of the analyzed area (68.2 km² or 6820 ha). Typically, secondary grasslands occurred where forest areas have disappeared, especially in the basins of Schit, Bistra, Neagra or Pârâul Alb streams. This is particularly visible in the area of some villages like Ceahlău, Telec, Bicazu Ardelean, Izvorul Muntelui or Izvorul Alb.

Secondary grasslands with the highest prevalence in the deciduous and mixed forests are those composed of red fescue and grass field, belonging to *Festuco rubrae – Agrostetum capillaris* association. More rarely, meadows composed of tall oatgrass (*Arrhenatheretum elatioris*) or golden tall oatgrass (*Trisetetum flavescentis*) can be meet. Also, there can be found species like: *Poa pratensis* (bluegrass), *Trollius europaeus, Campanula glomerata* (bluebell), *Carlina acaulis, Trifolium repens* (clover) etc. [8].

In the coniferous forest sector, instead of the cleared spruce-tree forests, are installing secondary red fescue grasslands (*Scorzonero roseae – Festucetum nigricantis*). Herbaceous vegetation is supplemented by *Hieracium transilvanicum, Melampyrum silvaticum, Luzula maxima, Luzula silvatica, Calamagrostis arudinacea, Campanula abietina (bluebell), Listera cordata, Oxalis acetosela,* various ferns and lichens etc.

Lakes occupy a surface of 26,6 km² (or 2 660 ha), which represents approx. 7.98% of the analyzed area. Izvorul Muntelui-Bicaz lake, which is located at the eastern border of Ceahlău Masif, is the main lake unit that can be found in the study area.

Agricultural land represents approximately 4.86% (16.1 km² or 1610 ha) of the analyzed area. Agricultural land around households are reduced in size and unsuitable for mechanization work, agricultural products obtained being used only for their own consumption.

Built area has a share of 4.06% within the study area. It is found mainly in the middle and lower sectors of the valleys that drain Ceahlău Massif, especially along Schit, Izvorul Muntelui, Bistra and Bicaz valleys. Built area is represented by a city – Bicaz, located in the southeastern part of the mountain, at the confluence between Bicaz and Bistriţa rivers, and by a series of villages, most important of which are Ceahlău village (located on the valley of Schit river) which manages also Durău resort, important built area with numerous tourist accommodation, Bicazu Ardelean and Taşca villages, located in the southern part of the massif, on the valley of Bicaz river, and Izvorul Muntelui village, located on the Izvorul Muntelui valley, in the east-south-eastern part of the massif.

In this class of land cover can be integrated a range of industrial and hydrotechnical construction, such as cement plants in Bicaz and Taşca, and the dam on the Bistriţa river that generated Izvorul Muntelui-Bicaz lake. Also, in the middle, high part of Ceahlău Massif, there are 2 tourist cottages (Dochia and Fântânele), Ceahlău hermitage and its associated buildings and also Toaca Peak weather station and chalet.

Subalpine vegetation (3,20% - 10,6 km²or 1 060 ha) and **alpine meadows** (3,10% - 10,6 km² or 1 060 ha) represent classes with the lowest surfaces.

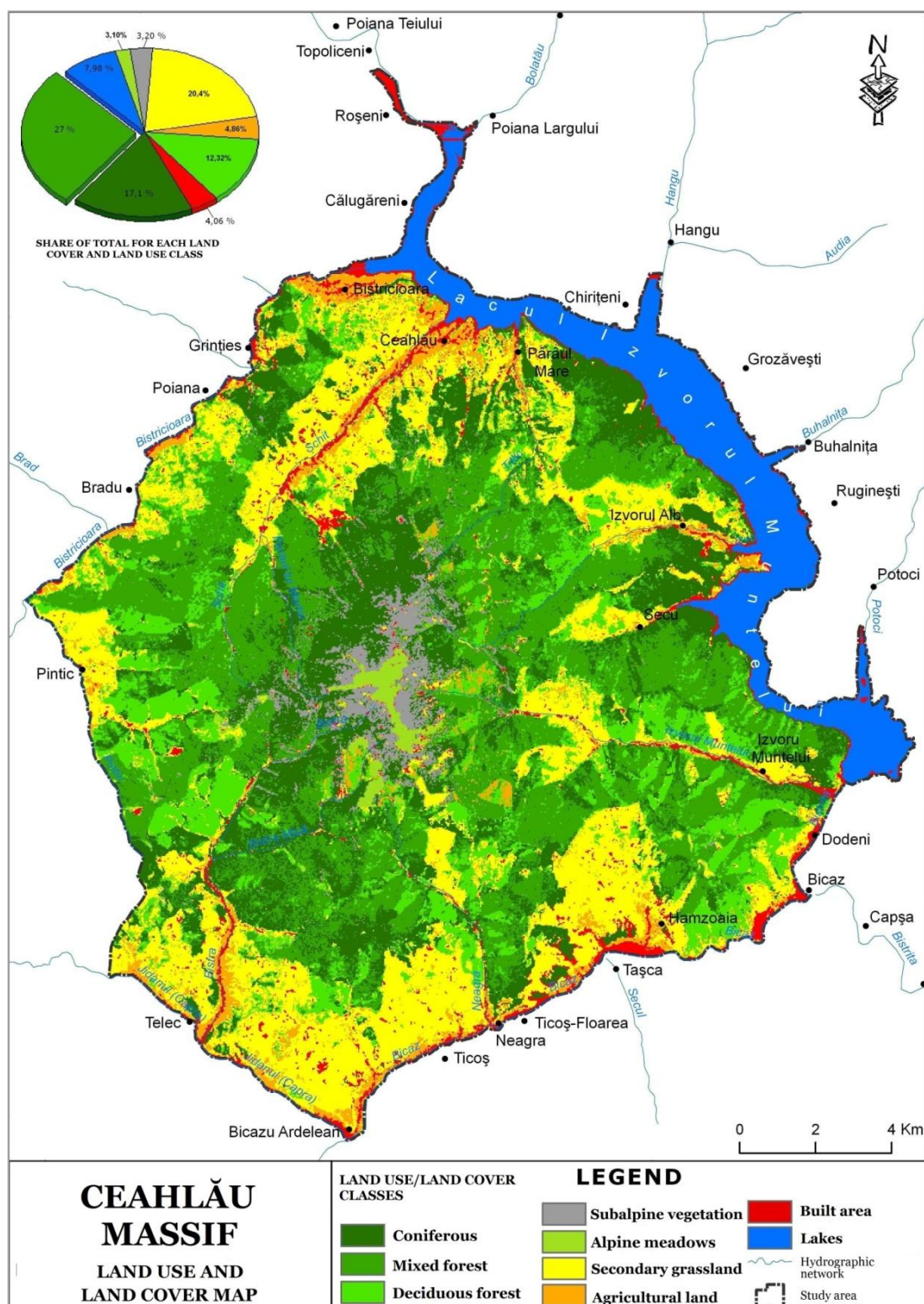Figure 3. Ceahlău Massif land use and lan cover map for the year 2010

These classes occupy the whole area between the upper limit of spruce forests (1460 - 1700 m) and the highest points of Ceahlau Massif: Ocolașul Mare Peak – 1911 m and Toaca Peak – 1897 m. This area is dominated by junipers (*Rhododendron myrtifolii –*

Pinetum mugi), vestiges of old juniper trees that were destroyed by cutting and arson. Alongside junipers, there can be found blueberry bushes (*Campanulo abietinae – Vaccinietum myrtilli*) or dwarf junipers bushes (*Campanulo abietinae – Juniperetum sibiricae*) [8].

Alpine meadows on the Ceahlău Massif plateau are represented by communities belonging to the association *Potentillo chrysocraspedae – Festucetum airoidis*, which here have secondary character (were installed on site of cleared junipers). On calcareous cliffs can be found grassy phytocenosis belonging to associations such as *Artemisio erianthae – Gypsophiletum petraeae, Saxifrago moschatae – Drabetum kotschyi, Diantho tenuifolii – Festucetum amethystinae, Seslerio bielzii – Caricetum sempervirentis* etc. Calcareous cliffs associations have great importance as they are home to many endemic and sub-endemic species [8].

The current structure of land cover has territorial implications both in terms of economic activities and in terms of environmental quality.

For example, related to the predominance of forests in the study area, a related woodworking industry has developed, over 80% of all industrial enterprises in the region having the activity field in woodworking and manufacture of wood and cork products [26].

The built area in Schit river basin is closely linked to the development, especially after 1990, of tourism activity in the Ceahlău Massif, being constructed at this time a large number of tourist accommodation units. Currently, only on the territory of the commune Ceahlău (to which belong Durău resort) there are over 42 such acommodation units. This is also reflected in the tourist flow recorded in 2010, with Ceahlău commune holding joint rule with 22 289 acommodated tourists [26].

Related to the cement plants in the southern part of the Ceahlău Massif, on Bicaz river valley, there is a potential danger related to pollution with particulate matter and sediment particules, but in recent years there were not recorded values exceeding the legal admitted limits.

4. CONCLUSIONS

The Maximum Likelihood classification of the satellite image generated a producer accuracy ranged between 90.43% (for subalpine vegetation) and 100% (for lakes) and a user accuracy ranged between 84.44% (for deciduous forests) and 100% (for lakes). Also, the overall accuracy of the classification was 95.3%, with a Kappa value of 0.94, which indicates very high accuracy.

The classification monitored a prevalence of forests within Ceahlău Massif, with a share of 56.4%, followed by secondary grasslands (20.4%) and lakes (7.98%). Other classes share a percentage ranged between 3.10% (alpine meadows) and 4.86% (agricultural land). The use of GIS in this study facilitate further operations such as raster reclassification, areas calculation and final map preparation.

Forest areas play an important role in the region's economy, with more than 80% of all industrial enterprises in the region having the activity field in woodworking and manufacture of wood and cork products. Tourism is another important economic

activity in the region, with an important number of tourist acommodation units, especially in Durău resort area, which is reflected in a high prevalence of built area on the land use map.

5. REFERENCES

[1] SĂVULESCU I., MIHAI B. Mapping forest landscape change in Iezer Mountains, Romanian Carpathians. A GIS approach based on cartographic heritage, forestry data and remote sensing imagery, Journal of Maps, 429-446, 2011.

[2] KUKKONEN M., KÄYKHKÖ N. Spatio-temporal analysis of forest changes in contrasting land use regimes of Zanzibar, Tanzania, Applied Geography, Volume 55: 193-202, December 2014.

[3] OTTINGER M, KUENZER C., LIU G., WANG S., DECH S. Monitoring land cover dynamics in the Yellow River Delta from 1995 to 2010 based on Landsat 5 TM, Applied Geography, 44: 53-68, 2013.

[4] STEFANSKI J., CHASKOVSKYY O., WASKE B. Mapping and monitoring of land use changes in post-Soviet western Ukraine using remote sensing data, Applied Geography, Volume 55: 155-164, December 2014.

[5] KONTGIS C., SCHNEIDER A., FOX J., SAKSENA S., SPENCER J.H., CASTRENCE M. Minitoring peri-urbanization in the greater Ho Chi Minh City metropolitan area, Applied Geography, 23: 377-388, 2014.

[6] STĂNESCU I. Masivul Ceahlău, Ţara Giurgeului, Depresiunea Dărmăneşti, Podişul Covurlui, vol. „ Cercetări în geografia României", Edit. Stiinţifică şi Enciclopedică, Bucureşti, 1980.

[7] ROMANIA GEOLOGICAL MAP, Sc. 1:200 000, Topliţa Sheet (L-35-VIII) and Piatra Neamţ Sheet (L-35-IX), Romanian Institute of Geology, Bucharest, 1968.

[8] PLANUL DE MANAGEMENT AL PARCULUI NAŢIONAL CEAHLĂU, 2009.

[9] MIHĂILESCU FL. Diferenţieri termice în zona masivului Ceahlău şi a lacului de acumulare Izvoru Muntelui, vol. „ Simp. de geograf. Fizica a Carpatilor, Bucuresti,1970.

[10] MIHĂILESCU FL. Studiu climatic şi microclimatic asupra Văii Bistriţei cu lacurile de acumulare

[11] ZANOSCHI V. Flora şi vegetaţia Masivului Ceahlău, rez. Teza Doctorat, Univ. „Babeş-Bolyai" Cluj, 1970.

[12] LILLESAND, T.M. AND KIEFER, R.W., CHIPMAN J.W. Remote Sensing and Image Interpretation. John Wiley & Sons, New York, 2000.

[13] KRAMER, H.J. Observation of the Earth and its Environment. Survey of Missions and Sensors. Springer, Berlin/Heidelberg/ New York, 2001.

[14] http://earthexplorer.usgs.gov/

[15] http://geospatial.org

[16] http://inspire.ancpi.ro

[17] http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-3

[18] SALLABA Fl. Potential of a Post-Classification Change Detection Analysis to Identify Land Use and Land Cover Changes. A Case Study in Northern Greece, Bachelor's Degree in Physical Geography and Ecosystem Analysis, Lund, Sweden, 2009.

[19] BALDRIDGE A.M., HOOK S.J., GROVE C.I., RIVERA G. The ASTER spectral library version 2.0., Elsevier, Remote Sensing of Environment 113: 711–715, 2009.

[20] RICHARDS, J.A. AND JIA, X. Remote Sensing Digital Image Analysis: An Introduction. 3rd Edition, Springer, Berlin/Heidelberg/New York, 1999.

[21] LILLESAND T.M., KIEFER R.W., CHIPMAN J.W. Remote Sensing and Image Interpretation, John Wiley & Sons, Hoboken, NJ, USA, 2004.

[22] AHMAD A. Analysis of Maximum Likelihood Classification on Multispectral Data, Applied Mathematical Sciences, Vol. 6, no. 129: 6425 – 6436, 2012.

[23] STORY M., CONGALTON R. Accuracy assessment: a user's perspective, Photogrammetric Engineering and Remote Sensing, 52: 397 – 399, 1986.

[24] SCEPAN J. Thematic validation of high-resolution global land-cover data sets, Photogrammetric Engineering and Remote Sensing, 65: 1051 – 1060, 1999.

[25] JENSEN J.R. Introductory Digital Image Processing: A Remote Sensing Perspective, Pearson Prentice Hall, New Jersey, USA, 1996.

[26] INS (National Statistics Institute).