A Land Cover Separability Analysis on Aerial Digital Images

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Abstract: The ground level analysis of land cover, though very accurate, has a punctual character and the observations are difficult to extrapolate to broad scale extent. The Corine Land Cover European program used low and medium spatial resolution satellite images to discern between different land uses and land covers, mapping these areas within a European database. The use of high sensitivity airborne sensors lowered the level of analysis and offered capabilities for small scale mapping of different reflective surfaces. The LPIS National Program (Land Parcel Identification System) offers the possibility of land cover/use analysis on a national level for the year 2005 (year of the flight). The issues that have to be considered in the automatic analysis of these images are related to the different seasons of the image taking and different sensors involved. The paper proposes to perform an analysis of the spectral response in the visible part of the electromagnetic spectrum. The analysis shows low separability of the different vegetation classes, especially in the forested areas (the infrared band is not taken into account). The study shows a good separation of the artificial lands, especially settlements, arable land and orchards. Additional information can be processed using interactive photointerpretation of the images.

Keywords: aerial photos, land cover, land use, separability

1. Introduction

Land cover is a term that includes many aspects as soil, water, ground water, ecosystem biodiversity. The human interference in the natural land cover is one of the agents that affect it and thus leading to the study of the land use. In order to understand the factors that interfere in land cover structure we have to study the land cover separability, using digital aerial or satellite images. The study of land cover/land use separability is important in order to analyze the dynamic of the landscape and the evolution of the processes that can affect it in one way or the other as soil quality, land degradation, climate change. One can also study, at the same time, the separability and correlation between land cover and land uses, the way they interact, and the results of those interactions. By means of the satellite images, and aerial images the different land uses and land covers can be separated.

The ground level analysis of land cover, though very accurate, has a punctual character and the observations are difficult to extrapolate to broad scale extent. The Corine Land Cover European program used low and medium spatial resolution satellite images to discern between different land uses and land covers, mapping these areas within a European database. The launch of very high spatial resolution satellites and the use of high sensitivity airborne sensors lowered the level of analysis and offered capabilities for small scale mapping of different reflective surfaces.

2. Theoretical framework

2.1. Concepts of land cover and land use

From the beginning of the Earth’s surface broad scale analysis, the issue of classifying the nature of the ground cover became important in the natural resource assessment. Even before remote sensing methods have been used in the spatial variability analysis of the ground surface, the maps done by terrestrial means contained a more or less standardized classification of the land cover type. In time, along with human colonization and interfering in natural areas, the concept of land use became of increased importance and described the types of land from an economical perspective.

The land cover, by definition, is the description of the physical nature of the land surface, for example, vegetation, buildings, water and bare soil [3]. Sometimes land cover is
taken to be one and the same with land use because of the lack of standardization in the classification concepts and criteria. The two terms should be clearly differentiated, since land cover deals with features physical description and land use takes into account, with a higher weight, the degree in which those physical properties are useful for the human society development. Land use is, practically about how people use the land cover, the most common classes of use being agricultural and urban land, but there are many other uses. Land use on the other hand is the purpose for which human exploit the land cover [3]. The effects of land use were felt for a long time, but nowadays they expanded. It all began with deforestation and continues nowadays with soil erosion, soil degradation, desertification, all speaking about the manner in which people treat land surface for their own benefit.

Land cover includes everything from crop type, ice and snow, to major biomes including tundra, boreal or rainforest, and barren land.

2.2. Land cover/use mapping methods

Land cover identification, delineation and mapping are important for global monitoring studies, resource management, and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps [2].

Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from year to year. This knowledge will help develop strategies to balance conservation, conflicting uses, and developmental pressures. Issues driving land use studies include the removal or disturbance of productive land, urban encroachment, and depletion of forests.

It is important to distinguish this difference between land cover and land use, and the information that can be ascertained from each. The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred.

Land cover/use studies are multidisciplinary in nature, and thus the participants involved in such work are numerous and varied, ranging from international wildlife and conservation foundations, to government researchers, and forestry companies. Regional (in Canada, provincial) government agencies have an operational need for land cover inventory and land use monitoring, as it is within their mandate to manage the natural resources of their respective regions. In order to facilitate sustainable management of the land, land cover and use information may be used for planning, monitoring, and evaluation of development, industrial activity, or reclamation. Detection of long term changes in land cover may reveal a response to a shift in local or regional climatic conditions, the basis of terrestrial global monitoring [3].

We can obtain data about the land use and cover from different sources such as land surveys, periodic censuses, and forest inventories, reconstructions by historical geographers, paleo records and remote sensing. All these information helped developing land cover data sets.

These ground – based data are reliable or not depending on the source that monitors them. In poor infrastructure countries or in the ones shaken by wars, the quality of monitoring is not so good, since they can't perform systematic observations and thus the data are not reliable.

The atlas entitled "A Land use/cover change in selected regions of the world" comprises regional maps of land cover through the last century" [3]. Another way of extracting data before the 19th century was population growth, because technology didn't play an important role in data extraction by then, the extent of human activities being very well correlated to the population growth.

The remote sensing method for data monitoring was used in the last 30 years. Thus nowadays the land cover/land use data sets are more reliable by means of the remote sensing satellites which can monitor the data systematically. A problem with land cover is that there are given different definitions to similarly named categories. This might be for example the case of forest which, for example in Finland it is not named forest if the trees are not growing fast enough, since in Great Britain a forest which is to be replanted is called forest.

Land cover mapping serves as a basic inventory of land resources for all levels of government, environmental agencies, and private industry throughout the world. Whether regional or local in scope, remote sensing offers a means of acquiring and presenting land cover data in a timely manner.

Regional land cover mapping is performed by almost anyone who is interested in obtaining an inventory of land resources, to be used as a
baseline map for future monitoring and land management.

The remote sensing techniques are the most practical and cost efficient techniques to be used, in order to obtain a land cover timely regional overview.

For regional mapping, continuous spatial coverage over large areas is required. Remote sensing fulfills this requirement, as well as providing multispectral, multisource, and multitemporal information for an accurate classification of land cover [2].

A land use and land cover classification system which can effectively employ orbital and high altitude remote sensor data should meet the following criteria [5]: the minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85% accuracy of interpretation, for several categories should be about equal, repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another and the classification system should be applicable over extensive areas. Another criteria would be that the categorization should permit vegetation and other types of land cover to be used as surrogates for activity, the classification system should be suitable for use with remote sensor data obtained at different times of the year, effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible. The aggregation of categories must be possible, the comparison with future land use data should be possible and multiple uses of land should be recognized when possible. Some of these criteria should apply to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensor data.

The mapping methods used in this research are the unsupervised supervised classification and visual photo interpretation. The unsupervised and supervised classifications are the two main types of land cover classification. Within the unsupervised classification the pixels are automatically grouped into classes based on natural spectral groupings in the image. This process is not supervised by a person.

On the other hand within the supervised classification, the image analyst supervises the pixel categorization process, by first identifying small sample areas of the land cover classes and then comparing each pixel to the training classes, allocating it to the most similar class.

Those two types of classification have their advantages and disadvantages, namely the unsupervised classification is good because it’s easy to use and quick, but has limited accuracy while the supervised one it’s more accurate and useful, but it’s a time consuming process. In the unsupervised classification the classes selected by the computer may not represent well – defined land cover classes.

These two classifications can be done by means of the spectral responses which can be built up by measuring over a variety of wavelengths, the energy that is reflected or emitted by the targets from the Earth’s surface [2]. In order to interpret correctly the interaction of electromagnetic radiation with the surface we have to understand the factors which influence the spectral response of the features we are interested in analyzing. If we compare the response patterns of different features in only one wavelength we can’t obtain anything, we couldn’t be able to distinguish between them, as it is the case of water and vegetation which are almost always separable in the infrared, but reflect similarly in the visible. The spectral response can also vary with time and location for the same target.

The artificial surfaces and the natural ones have different spectral responses. A. Gruen et al., 1997, stated that the artificial surfaces as, buildings, roads, canals, have a continuous surface segmentation of homogenous material, interrupted by discontinuous edges, most buildings could be described as simple, geometric shapes, while the natural surfaces are random shapes and structures. Thus the trees may appear circular from above, but they have more irregular outlines then buildings. All these differences can be noticed by means of the spectral signatures variations. In NIR most materials have low reflectance while vegetation not, depending on the season.

All these characteristics can be interpreted by visual interpretation by direct and indirect criteria, namely tone, shape, size, shadow and association. Recognizing these targets is the key to interpretation and information extraction. The interpretation using the elements above is actually part of our daily life.

The steps one needs to do in order in order to get to the visual photo interpretation are the following: first we have to do a pre-processing of the image, namely geometric and radiometric correction, than we have to improve the appearance of the imagery – image enhancement (spatial filtering and contrast stretching) and then image transformations. The image transformation step is almost like the
image enhancement, the only difference being that here the transformation is done by the combined processing of data for multiple spectral bands unlike the image enhancement where the processing is done for only one channel of data at a time.

The last step is image processing and analysis, when the pixels are digitally identified and classified in the data.

3. Material and Methods

The research was conducted in the Varatec-Agapia region of the Neamt County, North-Eastern part of Romania. The materials used for the study were orthorectified aerial images, acquired in 2004, with 0.5 m spatial resolution, from the visible spectral channel (Figure 1).

The study involved the analysis of the spectral signatures from two groups of classes within the spectral bands combined in the colour RGB aerial photo, in order to study the separability. The first group of classes consists of arable terrains, settlements, pastures and degraded lands, and the second group of beech, coniferous, sycamore and orchards. The image sampling was performed in the Signature editor module of the Imagine Software, module used for creating the spectral signature files (.sig), added in the image supervised classification process. The unsupervised and supervised classification methods were also used, in order to see whether the methods are able to analyze the separability of the classes taken into account. We used ERDAS Imagine in order to extract spectral responses and to do the supervised and unsupervised classifications.

When using the supervised classification method the usage strategy is simple. The classes were recognized on the aerial photos after we previously were on field and made some sample plots in the area to be studied or from what we knew before about the location of the site. There can also be used maps. Knowing what’s on the field, one can separate the classes and give them category names [4]. Training sites are located afterwards. These areas represent each, known land cover category, and on the computer display are delimited by polygons. The classes chosen for the study were houses categorized by the colour of the roof (because in the supervised classification we have to choose broader classes for a better separability degree), pastures, coniferous, deciduous, shadows were a separated class and regeneration areas. Then there are calculated mean values of the pixels enclosed in each class. The spectral signatures from each class were collected using the AOI (Area of Interest) tool, trying to have the same number of items (30 training areas for each land cover class) and then were imported in the Signature Editor command from the Classifier Software of ERDAS Imagine program.

The separability of the classes constituted on the field analysis was graphically analysed on bi-dimensional charts of the pixel values in the training areas from pairs of image layers of the aerial photo. The average value and standard deviation were calculated in the Microsoft Excel Software.

![Fig. 1. Aerial orthorectified image of the Varatec-Agapia region (Neamt County), used in the research.](image-url)
4. Results

The bi-dimensional representation of the pixel values within the layers of the aerial image (Figure 2 and 3) show a strong spatial autocorrelation between the channels of the visible spectrum.

When combining the red and blue layers the settlements and the degraded lands separated very well from the pastures and the arable, while from the second group of classes the orchards and the coniferous are separated but not as clear as the ones from the first group did, when combining the red and blue.

On the other hand when combining the red and green spectral bands the orchards are the ones with a great degree of separability from the other species, as the settlements did when combining the red and blue spectral bands. This time from the first group of classes the degraded lands are the ones which separate better from the other species. The settlements are separated too but not as well as the degraded lands.

The arable terrains and the beech have a relatively low degree of separability on both cases, being difficult to distinguish from the other classes. Pastures and coniferous are the ones which tend to be a little better to distinguish.

The green and blue spectral bands combination has, as a result, the better distinguishing of all the classes from the first and second group. The settlements are clearly separated from the arable, degraded lands and pastures.

The tree species are well separated too, but the better separation is the one of the beech and the orchards.

In the charts in which the two groups of classes were combined we can notice that the separability can be better distinguished. Thus at the chart where the red and green spectral bands are combined we can notice that the sycamore, coniferous and beech have a low degree of separability, we can hardly distinguish which is which, since the orchard and the degraded lands have the best degree of separability and the settlements, the arable and the pastures separability can be distinguished at some rate.

The separability of the species, sycamore, coniferous and beech has the same low degree of separability as they do at the combination on the red and green bands. This time the orchards are not as well separated as in the first case, but the settlements and the degraded lands have a good degree of separability in this situation too. The arable and the pastures have some degree of separability but it is not very clear.

On the chart containing the two groups of classes analyzed together (fig. 2.a and b), for the green and blue spectral bands combination too, it can noticed that in this combination the separability can be easily distinguished for all the classes. The coniferous and the sycamore overlap a little but their separability can be noticed unlike in the other two situations.

![Fig. 2](image)

Fig. 2. Land cover separability charts based on spectral response of all the land cover classes taken into account within the RGB components of the aerial images: a. band 1 and 3; b. band 2 and 3.
Fig. 3. Land cover separability charts based on spectral response of the two groups of classes taken into account within the RGB components of the aerial images: a. human affected lands separability on band 1 and 3 combination; b. tree species separability on band 1 and 3 combination; c. human affected lands separability on band 1 and 2 combination; d. tree species separability on band 1 and 2 combination; e. human affected lands separability on band 2 and 3 combination; f. tree species separability on band 2 and 3 combination.
The analysis of the average pixel values and standard deviations of each class (Table 1) showed different spectral responses for the classes taken into account. The highest pixel values can be observed, within each spectral channel, for the class "degraded lands", as the lowest values characterize the training areas corresponding to the coniferous species. Within the forest types of land cover, the sycamore and beech have higher values of the reflectance and lower variability of the data (lower standard deviations). Overlapping on the forest cover is the class "orchards", with values not significantly different in terms of average pixel value; the standard deviation is larger in the case of orchards than the forest, with a maximum in the red layer of the image and a minimum in the blue layer.

The maximum standard deviation is noticeable in the case of settlements and can be correlated with the highly different used in constructions and land management. Also a high variability is shown in the case of the arable lands, given by the differences in land cultivation, the season of the image taking and in the humidity of the soil.

Table 1. Average pixel values and standard deviations for each land cover class within the three image layers of the aerial photo.

<table>
<thead>
<tr>
<th>Land cover class</th>
<th>Image layer 1</th>
<th>Image layer 2</th>
<th>Image layer 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
</tr>
<tr>
<td>Arable</td>
<td>192.67</td>
<td>15.57</td>
<td>185.78</td>
</tr>
<tr>
<td>Settlements</td>
<td>178.46</td>
<td>21.14</td>
<td>174.57</td>
</tr>
<tr>
<td>Degraded Lands</td>
<td>227.78</td>
<td>8.63</td>
<td>227.68</td>
</tr>
<tr>
<td>Beech</td>
<td>140.48</td>
<td>6.71</td>
<td>148.45</td>
</tr>
<tr>
<td>Orchards</td>
<td>135.97</td>
<td>15.11</td>
<td>157.67</td>
</tr>
<tr>
<td>Sycamore</td>
<td>144.82</td>
<td>8.94</td>
<td>151.59</td>
</tr>
<tr>
<td>Pastures</td>
<td>189.84</td>
<td>7.81</td>
<td>194.50</td>
</tr>
<tr>
<td>Coniferous</td>
<td>129.18</td>
<td>11.36</td>
<td>136.70</td>
</tr>
</tbody>
</table>

Based on the information obtained from the spectral separability of the features described above, the classification of the image was performed. The first step is represented by the unsupervised classification (Figure 4a) of the image in eight classes, based on the histogram of the image, within the specialised module of the ERDAS Imagine software. This automated classification reduces the variability of the pixel values and brings forward the forest – non-forest distinction. It is interesting because it is a single layer image with pixel values corresponding to classes constituted from all the values in the three layers of the input image.

A second step is the supervised classification of the same image (Figure 4b). The class with the highest variability (settlements) has been divided into three different classes, more correlated with the land use of the terrain: houses with gray, red and black roofs. For comparability of the data, the class “shadows” was added in order to prevent the pixels in these areas to interfere with the other similar classes.

The results of the classification show a medium accuracy of the data. The differentiating between coniferous and broadleaved species is low, with a high influence from the slope exposure (the slopes that receive full light have an overestimated broadleaved species proportion). Also the separability between the pastures and orchards is low, with a high fragmentation due to the isolated bushes.

5. Discussions

The use of high spatial resolution aerial photographs in the semi-automatic extraction of land cover and land use features is sometimes limited by the high variability of the spectral response and the deficiencies in radiometric rectification accuracy [6].

The visible part of the electromagnetic spectrum shows technically low separability of the data regarding especially vegetation cover, as it is the case taken into account. The high autocorrelation between the layers of the image reduces the inputs given by the use of multiple channels, but could improve the separation of
some classes (the case of the combination between channel 2 and three). The overlapping of the spectral response corresponding to the classes of forest (coniferous and broadleaved) and the influence of the site exposure on the reflectance is related also to the season of image taking. As mentioned in the literature [7], the best moment for species separation for in case of mixed forest is the beginning or the end of the vegetation season (not the case of the aerial images, taken in May-June 2005).

The high variability of the spectral signatures also prevents the choosing of “pure” elements as training sites for the supervised classification.

The case of the settlements is the most illustrative: a high variety of land covers can be found in a very small area, with the single common characteristic that they represents habitat modifications done by the man.

The solution for increasing the accuracy of the mapping is represented by the visual photo interpretation, which can add contextual information on the spectral response of the different reflective surfaces. Even though it is more inefficient than the image classification, it could represent the only option in the separation of overlapping classes of land cover and land use.

![Fig. 4. Examples of image classification of aerial images: a. Unsupervised; b. Supervised.](image-url)
6. Conclusion

The land cover classes' separability analysis on aerial photos shows that in the case taken into study, the individualisation of the classes is different, depending on the nature of the reflective surface. The classes characteristic for the forest are not distinctive enough, their separability being seriously influenced by the exposition of the slope. The pixel values characteristic for these classes are also overlapping on the spectral response of the orchard areas, but with a higher variability on the last case, due to the different angles of light incidence on the isolated crowns of the fruit trees.

The highest variability is shown by the settlement areas and the arable lands, both given by the human activity of habitat modification. These areas are mandatory to be mapped using interactive photo interpretation, due to the additional context information needed for the separation. A good separability is shown in the case of degraded lands, especially against the pastures signature (as surrounding environment).

The supervised classification showed a medium accuracy in the separation of data. The lack of contextual information input lowers the separability of the land cover features and makes the method unlikely to be used in the case of high variability aerial image data. Also a big liability is represented by the differences in sensor and image taking season.

All these reasons would recommend that the main option for land cover/use mapping is the visual interpretation, completing in this way the information revealed by the spectral response of the different active surfaces.

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