Object-Oriented Techniques for Land Use/Cover Classification:Application of Metaponto Area (Basilicata, Southern Italy)

V. Pastore, A. Sole, V. Telesca

Abstract — Sustainable management of natural resources requires constant and detailed monitoring of various aspects of the environment. Land use/cover mapping is considered a key element for planning protection, management and monitoring of semi-natural areas in urban ecosystems. Hence the importance of the information acquired through Remote Sensing, airplane and satellite, has been recognized for decades. The Remote Sensing data offers notable advantages for territorial monitoring, particularly of the vegetated areas, in comparison with data collected on the ground. The study of the spectral response of vegetation gained from airplanes or satellites makes it possible to obtain useful information about plant species and their conditions (density, vegetative state, etc.) in repetitive synoptic images. The research was carried out over an area of study in southern Italy (Basilicata, Metaponto area) near the mouth of the Basento River. For this area, synchronous and geometrically co-recorded aerial photographs and Landsat TM image covering the period May 2004, were developed. Firstly a preliminary analysis was carried out using unsupervised means of classification with the aim of grouping together clusters of multi-band spectral responses that are statistically distinctive. Following this and after having properly defined the levels of segmentation of Landsat images using aerial photographs as a reference, a supervised classification procedure was applied, first pixel-oriented and then object-oriented, obtaining a marked improvement both in accuracy and in the reduction of the "salt&papper" effect of the map obtained by the Maximum Likelihood classifier.

***Keywords*—**Land cover classification, Multiresolution segmentation, Object-oriented methods, Remote sensing.

I. Introduction

ONE of the purposes of remote sensing techniques is to produce thematic maps of the areas investigated (usually areas of the Earth). The drawing up of these thematic maps takes place in three macro phases: the recovery of data, processing, interpretation. The drawing up of a thematic map requires a classification of the territory into areas corresponding to the categories chosen and later reported in the legend of the map itself. During the design phase of this process it is possible to use different process methods: statistical and/or deterministic, analogical and/or digital.

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The products derived from the analysis of remote sensing data have a wide range of applications the territory, the possibility of obtaining constant large scale monitoring of land surface conditions, vegetation present, the detection of phenomena such as landslides, floods, fires, air and water pollution, desertification, climate, change, etc. From an operational point of view images acquired by satellite are distinguished according to their spectra, special and temporal resolution characteristics (Gomarasca, 2005).

The geometric and thematic scale of the products is closely related to the spatial resolution of images. An increase in the latter increases the detail in which it is possible to discriminate objects on the ground and thus increases the scale and detail of maps obtained.

A first approach starts from a visual examination of the images each of which offer a greater or lesser number of clues regarding conditions on the ground, deducible from the examination of the configurations that appear. Normal photo interpretation, however, is conditioned by some objective limits, including the implicit subjectivity of the classification process in the recognition of class issues and as well in the identification of the boundaries between different tiles and the high cost of the process. To overcome this problem, extensive research on segmentation and object-oriented classification techniques which are increasingly recommended as an alternative to traditional methods of classification of remote sensing images has been carried out The first applications date back to the '70s (Haralick and Shapiro, 1985), but more widespread use of these techniques has only occurred in recent decades with the advent of high resolution sensors (Blaschke et al., 2000).

The purpose of this study is to carry out an assessment, based on satellite images with medium spatial resolution of the potential of segmentation and object–oriented classification techniques for the production of maps of land use / cover in order to compare them with conventional visual interpretation both in terms of thematic accuracy and of time required for cartographic product updating.

II. DESCRIPTION OF THE STUDY AREA

The area under study includes the Ionic coast of the Basilicata, near the mouth of the Basento River (Southern Italy).

The river rises in the northern Lucania Apennines, runs from northwest to southeast in the provinces of Potenza and Matera and flows into the Gulf of Taranto. Its basin extends entirely within Lucania territory for about 1535 km2.

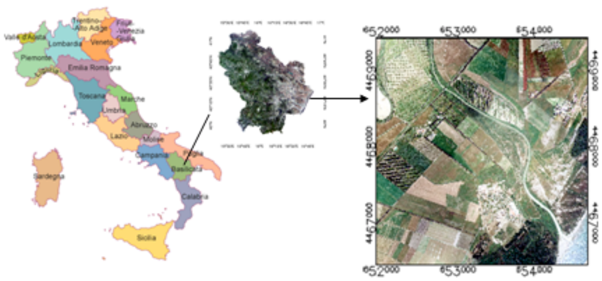

Fig. 1 The study area (Basento River).

The area studied is largely agricultural (70% of examined area/surface) together with areas characterized by coastal forests and a diverse range of habitats and riparian vegetation typical of some Mediterranean areas, which border the river until it reaches the sea. The proposed methodology for this study used the following data set: digital, aerial photographs (1:10000) with a nominal resolution of 1 m on an aerial measurement campaign carried out in May of 2004; 26/05/2004 Landsat image with resolution 30 m, the regional thematic map (1:10000) of the Region Basilicata; land use map of the Corine Land Cover 2000 (30m resolution) and in situ measurement campaigns.

III. MATERIALS AND METHODS FOR LAND COVER CLASSIFICATION

Land-use maps are required for effective management and monitoring of land resources. They are used by scientists for land-use modeling and by government bodies for planning. Object-based classification techniques that make use of image segmentation are gaining interest as methods for producing land-use maps suitable for land change analysis.

The application of these techniques for detailed land-use classification is often limited by the inadequacy of spatial resolution of the images. The main objective of this work was todetermine if fusion of an aerial orthophoto with a Landsat TM image, which is characterized by higher spectral resolution than the photo, could improve semi-automated supervised object based land-use classification.

The specific aims were to determine if fusion at the: pixel; feature; or decision levels, would improve the quality of land-use classification compared to classification of the Landsat image. Preliminary results show that fusion at the feature level had the highest overall accuracy followed by fusion at the decision level, then at the pixel level and finally with no fusion at all. Kappa statistics also indicate the best performing technique to be classification using feature-level fusion. This indicates that fusion at the feature level of LandsatTM data with an orthophoto will improve spatial resolution and accuracy of the resulting land use maps.

A. Image Fusion

While it is generally known that fusion of images acquired on different dates may introduce errors caused by intervening land-cover change (Pohl and Van Genderen,1998), our visual inspection of the two datasets did not show any significant land-

use change. The fusion of the two data sets: the 2004 Landsat TM at 30 m resolution and the orthophoto were carried out based on the two approaches illustrated in Fig. 2.

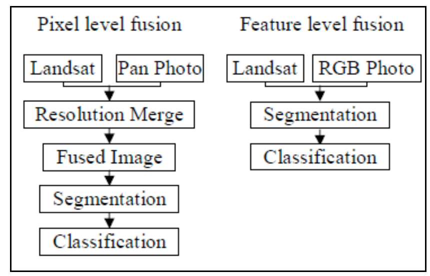

Fig. 2 Flow chart of different approaches.

The PAN-Sharpening algorithm applies an automatic image fusion that increases the resolution of multispectral (color) image data by using a high-resolution panchromatic (B&W) image. Most Earth resource satellites, such as SPOT, IRS, Landsat TM, Ikonos, and Quickbird, provide multispectral images at a lower spatial resolution and panchromatic images at a higher spatial resolution, that permits an easy fusion of images acquired simultaneously by the same sensor. Alternatively it offers the possibility of using different sensors.

The Pan-Sharpening algorithm can also be used to solve the problem of color distortion and dependence on operational data leading to the production of the best color rendering of the image in question. By minimizing color distortion, it maximizes the details of the features and color that is naturally integrated with the spatial characteristics of the object of observation.

B. Segmentation of the Image

Segmentation aims at the partition of an image in disjoint regions, each one homogeneous with respect to some properties like intensity, texture, shape, etc. Such a task is needed in many high-level processing and applications in such diverse fields as remote-sensing, medical imaging, image restoration, or video coding. In remote-sensing applications, the segmentation task is very difficult because of the presence of significant noise components and the intrinsic complexity of the images.

Hence, data modeling becomes quite critical, and the statistical approach may result advantageous with respect to other non-stochastic approaches. The purpose of splitting the image is to divide it into different parts which correspond to different objects in the territory. An object is the entity that the user wishes to classify (piece of soil, geological units, etc..).

The two main approaches to image segmentation are edge based and region based (Haralick and Shapiro 1985, Gorte 1998; Gamanya, De Maeyer and De Dapper, 2007).

The edge-based approach attempts to find the limits of the range by identifying the boundaries between areas of the image with different characteristics. Consequently, regions of the image that are completely surrounded by border pixels become ranges, while the other image pixels may belong to a range or form a new range. The approach based on the definition of regions permits the identification of ranges through the application of the criteria of homogeneity with the other ranges identified.

This algorithm was applied to segment the mosaic of the photographic data obtained from satellite and aerial sources. The purpose of the methodology is to find the ideal threshold for splitting, namely that which best approximates the object on the ground using segmentation. The ranges identified are the result of the aggregation of more than one object on the ground (this is clearly visible in the agricultural areas, where many objects have been united).

The border pixels between two objects are usually mixed in a similar fashion to the two ranges that correspond to the object (Gorte 1996).

IV. METHODOLOGY AND APPLICATION

The process of automatic segmentation was calibrated so as to obtain items in accordance with the nomenclature system CLC 2000 (minimum mapping unit: 25 ha). The Landsat scene was drawn up through the use of the pan-sharpening algorithm (software ENVI 4.6) that fuses panchromatic data with multispectral data, preserving the original spectral characteristics (Zhang 2002).

The technique is based on the method of least squares to better approximate the relationship between the gray values of the original image and the fused image. The procedure proved especially useful for the subsequent segmentation in that it increases the accuracy of the identification of objects compared to the same process based on multispectral data only.

The algorithm offers the best performance when spectral wavelengths which fall in the range of acquisition of the panchromatic band are used. For this reason Landsat 5 TM bands selected for production are the visible, the near infrared excluding the band TM6. The merger has prompted further geometric resolution images of the panchromatic band and the spectral content of the bands used. Joint use of the combinations of images obtained by the process of pan-sharpening produced different levels of segmentation. The best results were achieved with a level of segmentation characterized by a scale factor of 40 and weights attributed to geometric heterogeneity and unity factor of respectively 0.2 and 0.8.

RGB Photo LandSat 2004 Fusion image

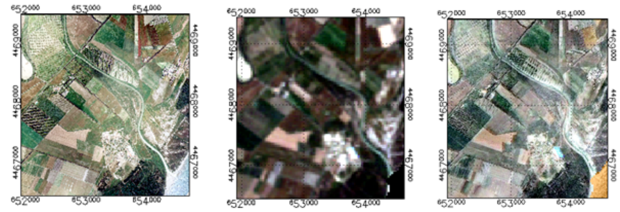

Fig. 3. Comparison of resolution between the images used. Left aerial photographic (ortho RGB) mouth Basento 2004, Landsat TM 2004 and right image obtained after the process of fusion image.

As can be observed the image quality is significantly improved. Regarding spatial resolution the geometric resolution of the aerial photograph is preserved while for the spectral characteristics the contents of the Landsat image are preserved. In this way the capacity to exploit information of a textural, statistical and above all contextual nature leads to the generation of cartographic products which are competitive in terms of thematic accuracy compared to those derived for visual interpretation (Chririci et al. 2006).

The creation of a first level of image segmentation to be classified is considered as the first phase of work. The diverse factors driving the process are set on the basis of the spectral and geometric characteristics of the images obtained from the remote sensing system, the nomenclature chosen and the scale of mapping envisaged, and the rest is totally automatic.

The segmentation is repeated by changing the driving parameters until the size and location of the polygons generated corresponds exactly to the requirements of the chosen system of nomenclature: in practice, trying with a re-iterative method to minimizing the error, generating the largest possible polygons with not more than one class of land cover. This level of segmentation is the subject of the next stage of classification in the sense that each polygon generation must be associated with one and only one class of the nomenclature system chosen. The next phase of the process is the classification itself.

From a viewpoint of possible operational applications we can consider two extreme alternatives used to classify polygons generated by segmentation through:

- manual photo interpretation (this only uses segmentation for the construction of the vector polygons, which thus replaces manual digitizing, the photo interpreter has the task of identifying the derived polygons;
- automatic classification (using supervised or unsupervised classifiers).

V.RESULTS AND DISCUSSION

All images generated by the procedures of classification were subjected to an assessment of accuracy based on the contingency matrices with text areas specially acquired. On the basis of these matrices the calculation of the index of Cohen Khat (Congalton and Green, 1998; Jenness and Wynne, 2004) was made in order to synthetically assess the quality of the classifications derived.

The validation of a thematic map, obtained from classification of remotely sensed image, means to evaluate the accuracy of the information contained in the final map in terms of pixels correctly assigned to the corresponding class on the ground.

The accuracy of the results was assessed through the classification of test set by performing an analysis of the matrix of confusion (Congalton et al., 1983, Story et al. 1986; Chuvieco and Congalton 1988), which compares the classes observed with the assigned category in the classified image. Assessment of the accuracy of classification is a very sensitive stage in the production of thematic maps derived from remotely sensed information as:

- it provides an index of overall quality of the map;
- makes a comparison between different algorithms for classification;
- allows the identification of any errors in image processing (Hay, 1979).

Among the many verification procedures, the use of "matrix of confusion is widespread, as it not only provides more complete estimates than the simple percentage of pixels correctly classified, but also characterizes the errors committed in the procedure thus improving the classification and the considerations arising from them.

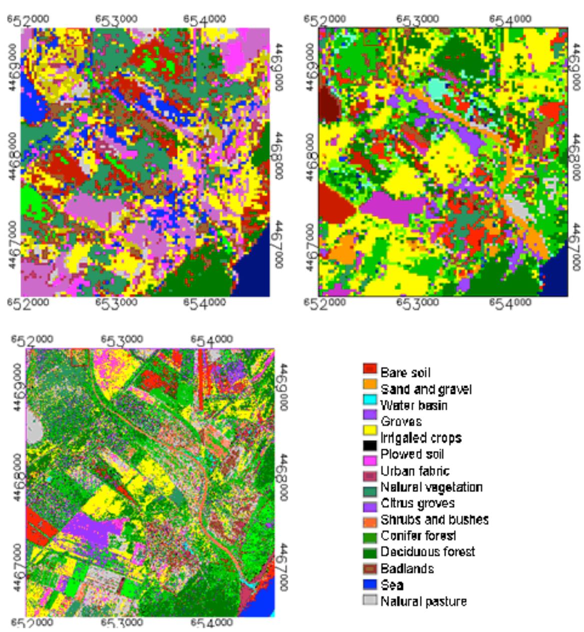

Fig.5. Comparison maps classified pixel-oriented approach (top left), object-oriented (top right) Landsat image and image obtained after the process of pan-sharpening (ortho + Landsat)

Various measures of accuracy are derived from the confusion matrix. One of the best known is the overall accuracy A, which is obtained for each category of land use by dividing the number of pixels correctly classified by the total number of pixels in that class. Several authors have criticized the use of A, stating that some pixels may be assigned randomly to the correct class (Pontius, 2006), and identified Khat Cohen's coefficient of correlation coefficient or K as the standard index of accuracy of classification. The coefficient K is used to express the degree of overall quality of the classification, since it represents the difference between the accuracy achieved and what could be obtained from a completely random image classification: for example, a coefficient K equal to 0.8 means that the classifier has not committed 80% of errors that a random classification would generate.

The present section provides a table with the values obtained for the processed images.

TABLE I

COMPARISON BETWEEN THE MAPS CLASSIFIED IN TERMS OF ACCURACY (OVERALL ACCURACY) AND VALUE-RELATED INDEX K. COHEN

IMAGE	A (*overall accuracy*)	K *coefficient*
ML_Landsat *pixel-pixel*	0.62	0.58
ML_Landsat *object-oriented*	0.78	0.65
ML_Fusion *object-oriented*	0.83	0.77

As expected, the use of the object-oriented approach has resulted in a more accurate classification than the traditional pixel-oriented approach in all the tests carried out. The accuracy of classifications tends to be related to the geometrical resolution of input image: the better the resolution the better the performance of the classification.

Thus while the pixel-oriented approach allows us to obtain acceptable results in terms of thematic accuracy only with Landsat data and other sensors with similar characteristics, the object-oriented approach is sufficiently well suited to the processing of data for digital aerial photographs and any related images sensors such as QuickBird, Ikonos with a high ground resolution.

It was noted that most errors are due to spectral confusion between classes of natural pasture, vegetation evolution and crops, with agricultural and forestry areas with low density.

Recognition of mixed areas, such as complex particle systems, remains problematic because it is very difficult to distinguish urban areas from vegetated areas. The classification errors generated by the object-oriented approach can, however, be easily corrected by a quick manual review of the thematic allocation of the polygons during the segmentation.

VI. CONCLUSION

The tests presented made it possible to give a positive assessment of the introduction of techniques for multi-resolution segmentation and, object-oriented classification aimed at the elaboration of land use/cover mapping, particularly in complex areas such as those that characterize the study area. The results show that the combined use of segmentation techniques applied to images with different geometric resolution, acquired from different sensors and co-recorded on the same area, allows us to overcome the most common problems of multi-scale mapping derivation.

This possibility opens up important applications in analysis and planning, through the process of segmentation and subsequent object oriented classification of images, since it is possible to obtain a final output already in vector format,

suitable for creating a multi-scale database which allows the automatic implementation of the finest rules of mapping derivation. The methodology adopted permitted the verification of the methodology utilized in the implementation of this procedure, which allows us to limit the classification stage (either semi-automatic or based on photo interpretation) to the more detailed single image (in this case, ortho), with the possibility of extending this methodology to the entire scene represented by the Landsat image.

The adoption of this methodology maximizes the objectivity of the derivation process of the mapping of land use, aimed at the creation of standardized products with controlled and replicable geometric quality. These procedures combine the scientific rigor and transparency of traditional procedural methods such as supervised classification, with the flexible option of revising and manually changing the geometry and thematic coverage provided, typical of the classification for photo interpretation.

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