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Urban and peri-urban environment dynamics assessment by satellite and in situ monitoring data

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ABSTRACT: Urban and peri-urban environment dynamics is of great interest for future planning and decision making as well as in frame of local and regional changes. The study focuses on the assessment of environmental changes for Bucharest metropolitan area, Romania by satellite remote sensing and in-situ monitoring data. Spectral signatures of different terrain features are used to extract structural patterns aiming to separate surface units and to classify them into general categories. The synergetic analysis and interpretation of the different satellite images (LANDSAT: TM, ETM; SAR ERS 1; IKONOS) acquired over a period of more than 20 years reveals significant variations in the organization of the urban space among central, median and peripheral zones. SAR imagery is very useful for morphological urban structures extraction leading to an aerodynamic roughness mapping, while optical imagery is better suited for dynamics mapping.

It was delimited residential zones of industrial zones which are very often a source of pollution. Are also emphasized the particularities of the functional zones from different points of view: architectural, streets and urban surface traffic, some components of urban infrastructure as well as habitat quality. The growth of Bucharest urban area in Romania has been a result of a rapid process of industrialization, and also of the increase of urban population. Information on the spatial pattern and temporal dynamics of land cover and land use of urban areas is critical to address a wide range of practical problems relating to urban regeneration, urban sustainability and rational planning policy.

1 INTRODUCTION

Urban decision makers face complex and very dynamic environments, which require up-to-date information supplied by efficient data extraction systems. Urban systems play a vital role in social and economic development in all countries. Their environmental changes can be investigated on different spatial and temporal scales. The quality of urban environment directly influences the social and economic development of the city. Urban environment consists of two components:

1) the natural environment, which includes the total of varieties of different natural phenomena and elements, such as terrain, geology, air, water, soil, and climate (original environment);

2) the artificial environment, including urban social environment and urban environment pollution resulted from human's activities. The social environment represents urban socio-economic and cultural conditions. Urban land cover types and their areal distributions are fundamental data required for a wide range of studies in the physical and social sciences, as well as by municipalities for land planning purposes (Weng 2001).

Urban zone represents a highly complex area containing a continuum variety of many different spatial, temporal and spectral scales: spatial variability due to the varied landscape; temporal variations are attributed to periodic seasonal changes over the year; spectral variability is due to the great variety of materials and structured associated with the urban area (Biging *et al.* 1998).

Changes in urban land cover include changes in biotic diversity, actual and potential primary productivity, soil quality, runoff, and sedimentation rates, and cannot be well understood without the knowledge of land use change that drives them. Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is a main type of land use and land cover change in human history. It has a great impact on climate. So called "peri-urban belt" is a zone located outside the city and characterized by a mix of farmers and households working downtown. Urban and peri-urban dynamics evaluation is aimed to get the information on environmental condition and in support of the policy making and selection during environment planning and management. In Romania, land use/land cover patterns of Bucharest metropolitan area have undergone a fundamental change due to accelerated economic development under its economic reform policies since 1989.

2 SATELLITE REMOTE SENSING APPLICATION FOR URBAN DYNAMICS

Satellite images offer great potential of urban areas mapping, being used as an important tool for spatial dynamics and urban morphology assessment. A difficulty in using remote sensing technology for urban and peri-urban studies is the diversity of features found in the environment, including different targets like concrete, asphalt streets and avenues, roofs of different materials, exposed soil, grass, trees, and water .Some of these targets are smaller than the pixel resolution. A landscape is composed of ever-changing elements. Their spatial and temporal patterns distinguish a landscape to an observer; at the same time they inform us of the complexity of dynamic processes at various scales. The changing pattern of the landscape, including the changing biophysical properties of that landscape, is a central theme in the fields of landscape ecology and environmental quality management and planning. Satellite remote sensing instruments provide measurements at a variety of pixel resolutions, spatial extents and temporal scales. However, due to variability in illumination, atmospheric effects, and instrument calibration, conventional supervised or unsupervised classification techniques have difficulty providing pixel to pixel comparisons between images from different times. Different mathematical approaches were applied to modeling land use dynamics. Change detection is the process of identifying differences in the state by observing it at different times.Various change detection techniques have been developed for analyzing of spatio-temporal modifications in natural and anthropogenic surface features (Batty *et al.* 2001). Digital change detection comprises the quantification of temporal phenomena from multi-date imagery. Remote sensing platforms are becoming more numerous, and have improved spatial and spectral resolutions, bringing closer the goal of surface operational monitoring. The problem involves detecting changes between two data sets: one before and the other after the change. In the case of progressive or gradual changes, such as erosion, reforestation, urban infrastructure changes, more than one image may be necessary (Bergen *et al.* 2005).

Two of the most common uses of multispectral and multitemporal satellite images are mapping land cover via image classification and land cover change via change detection and derived surface bio-geophysical parameters. The recently available Very High Resolution (VHR) satellite images holds a potentially rich source of useful information for the observation of urban features (air, soil, vegetation, water), changes and functioning (Morisette *et al.* 2000). The large amount and good quality of available data also gives spurs to improve on existing algorithms or develop new algorithms. Remote sensing can be used to map major urban features, land cover types, detailed land use or urban infrastructure, from which can be derived secondary socioeconomic parameters and the invisible elements of urban infrastructure. Remote sensing also contributes to a better representation of the spatial heterogeneity of cities, a counter tendency to the limitations of models that tend to reduce geographic space to the single dimension of distance, thereby hiding important spatial patterns in land use and landscape features.

3 STUDY AREA AND DATA USED

Study area (Figure 1), urban zone Bucharest, placed in the Southern part of Romania is bounded by latitudes 44.33 °N and 44.66 °N and longitudes 25.90 °E and 26.20 °E. It was selected along a climatic and environmental gradient and was characterized in terms of hydrology, geomorphology, soil and vegetation properties that control or contribute to functioning. Bucharest has a star-shaped urban structure, as a result of the particular way of the city's development over more than 5 centuries (documented since 1459). The city has expanded in a concentric manner around a medieval centre (princier house – named Curtea Veche) as well as a radial one along the roads to the capital of Valachia, later all over Romania, in modern city of Bucharest (approximately 2 millions habitants and 230 km^2). The Dambovita River, a tributary of the Danube, crosses the Northern part of the city, and has meanders, partly filled by an artificial lake. Other lakes are visible in the center and in the lower part of the image. The circular zone in the South is a forested area, with a large building in the center. The city has a total surface of 226 km^2. The altitude varies between 55.8 m at the Dambovita Bridge in Catelu, south-eastern Bucharest, to 91.5 m at the Militari church. Several lakes stretch across it, the most important being Lake Floreasca, Lake Tei and Lake Colentina. In the center of the capital there is also a small artificial lake Ciurel.

The following satellite data have been used: Landsat TM (3/07/1984, 27/03/1989, 21/08/1990), Landsat ETM (23/07/2002, 12/09/2004), SAR ERS-1 sets of data (30/07/1992,

Figure 1. Test site urban and peri-urban Bucharest.

25/11/1992, 30/12/1992 and 30/04/1993, 09/06/1993, 13/08/1993) and IKONOS 25/07/2005. All SAR images have been taken in descending mode. ENVI 4.3, IDL 6.3 and ILWIS 3.1 software were used.

4 METHODS

The main objectives of this paper consisted in developing and validating new techniques based on satellite imagery for mapping and monitoring urban dynamics in urban and peri-urban Bucharest. Linear and non-linear combinations of channels, Principal Component Analysis (PCA) and Relative Channel Analysis (Carr *et al.* 1999), HIS (Intensity-Hue-Saturation) transforms, spectral mixture analysis and unsupervised classification using Maximum Likelihood algorithm assisted by an unsupervised clustering procedure were applied on the available Landsat TM, ETM, SAR ERS-1 and IKONOS idat. Ground reference data were acquired to characterize the spectral properties of pure urban surfaces for validation of the image classification. Spatial and temporal dynamics of landscape are of great importance for optical and stochastic models applied to various landscapes and biophysical processes (Ludwig *et al.* 1988). Images provided by optical sensors contain information about the surface layer of the imaged objects (i.e. color), while microwave images provide information about the geometric and dielectric properties of the surface or volume studied (i.e. roughness).

In order to implement the land-cover allocation process, are required spectral–temporal signatures for urban target classes. These are derived on the basis of a version of the unsupervised classification based on Landsat TM and ETM data. Because urban development is not generally replaced by agricultural or forest land over time, we reclassified as urban all pixels that were labeled urban in the rasterized 1989 land-cover dataset, but not classified as urban in the 2004 unsupervised classification.

After the last two centuries of intense and unprecedented urbanization, we need a clear understanding of the ongoing trends of urban growth for a better insight of their possible future. Two main processes are analyzed: first, the inter-urban concentration of population, with its consequence of a relative decline of the smallest towns; second, urban sprawl, including a shift of population density in the central part of cities towards their peripheries. Bucharest metropolitan area has experienced a large built-up growth .This process may correspond to secondary residence extensions, recent building of touristic infrastructures and secondary cities growth. Various techniques of image analysis are explored here in order to describe and characterize the built-up dynamics in this area. On panchromatic images local texture of built up zones is more heterogeneous than that of other land cover zones, such as bare soils, cultures and natural vegetation. A Principal Component analysis technique from local texture parameters, such as local entropy on grey tones, standard deviation, white top hat, multidirectional gradient is computed to enhance built-up spaces at each date. The extraction of built-up zone is obtained by a high threshold on the first component. Reconstruction is use to eliminate non-urban elements and to reconnect built-up surfaces. Once the growth is mapped, various techniques are used in order to explore some hypothesis concerning the localization of such a rapid built-up process. Spatial distribution of urban growth is studied with covariance analysis.

5 RESULTS

The study area is comprised of urbanized, undisturbed, coastal river Dambovita and agricultural regions. These different types of land uses have distinct spatial edge frequencies or texture that can be used as input into classification algorithms. Urban areas typically have significant texture resulting from buildings and street grids, whereas homogeneous areas such as agricultural fields have little to no texture. Land use information for the study site was obtained as vector polygon coverage. Twenty-four classes are defined in this coverage and include residential, industrial, commercial, agricultural, and natural (undisturbed) land uses. In situ land use data and different radiometric were analyzed too. Land cover types, present in several different land use categories, can cause interpretive difficulties for users of classified data. The results of this study showed that several key land cover classes were confused due to the spectral similarity of these classes. The number of land cover classes used in the initial study, 24, was reduced to 8 major classes to reduce misclassification. A hard classification of the Landsat TM, ETM data was then performed using a maximum likelihood decision rule. Bayesian coefficients (weighting factors that reflect the probability of occurrence for a given class in the scene) used in the Maximum Likelihood Classification were somewhat arbitrarily determined based on qualitative estimation of the area each class occupied within the study region. Methods involved the integration of data recorded by different satellite sensors, optical and microwave, through newly developed algorithms. Images provided by optical sensors contain information about the surface layer of the imaged objects (i.e. color), while microwave images provide information about the geometric and dielectric properties of the surface or volume studied (i.e. roughness). Figure 2 presents Landsat ETM 23/07/2002, PCA 3/2/1 analysis. The analysis and interpretation of the different satellite images shows significant variations in the organization of the urban space among central, median and peripheral zones. There are two types of structures in the central and median zones that are in a continue change. The central zone, with its far more complex functions (politico-administrative, cultural, entertainment, residence, etc) displays monumental buildings (continually built from the end of 19 century till these days). The median zone is mostly a residential zone with private houses of a traditional fashion, modestly equipped. The peripheral zone consists of residential neighborhood, with characteristic tall buildings of 4–10 floors, poorly equipped as well as industrial buildings and amusement parks and lakes. It was delimited residential zones of industrial zones which are very often a source of pollution.

Are also emphasized the particularities of the functional zones from different points of view: architectural, streets and urban surface traffic, some components of urban infrastructure as well as habitat quality. The growth of Bucharest urban area in Romania has been a result of a rapid process of industrialization, and also of the increase of urban population.

At regional scale, both Landsat TM images TM (3/07/1984) and ETM (12/09/2004) have been processed in order to quantify urban growth from 1984 till 2004, showing how the city grew around its centre. The bands 1, 2, 3, 5, and 7 in both Landsat TM and ETM images were highly correlated to each other. Band 4 had the lowest correlation to any other band. Band 5 had high co-variance values with other bands in both 1984 and 2004 images. Image differencing was applied to PCA transformed images. Brightness values of no-change areas were distributed around the mean value of each difference image. Very

Figure 2. Landsat ETM 23/07/2002, PCA 3/2/1.

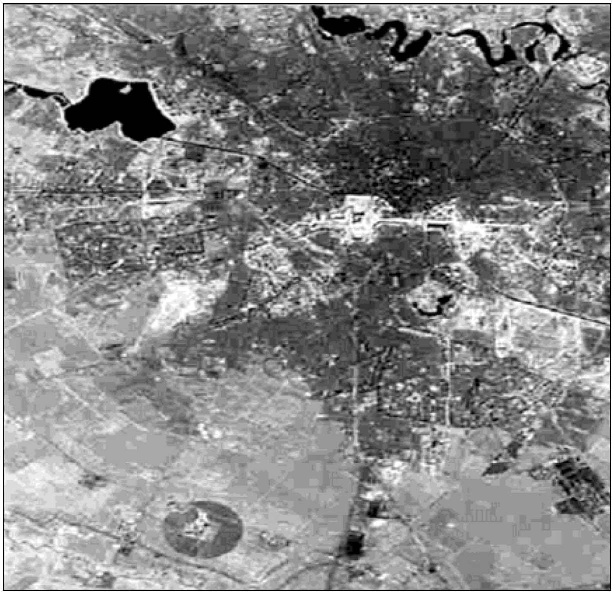

Figure 3. Urban changes in Bucharest area between 1989 and 2004.

dark or bright pixels represented the areas that had been changed between 1989 and 2004 (as can be seen in Figure 3). Change area due to the decrease of vegetation was of 12%, while the change area due to increase of buildings was of 14, 3%. The overall accuracy

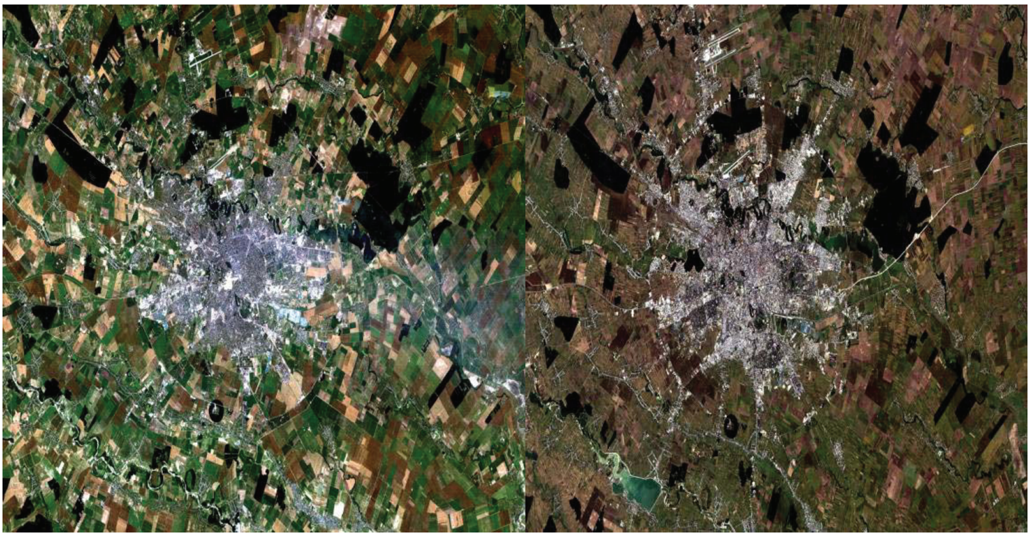

Figure 4. Bucharest urban growth during 1984–2004, Landsat TM (3/07/1984) and ETM (12/09/2004).

was 81%. Baneasa, the Northern district of the Bucharest city have grown almost reaching the lake which bears the same name. Peri-urban belt have been extended also.

6 CONCLUSIONS

Information regarding the characteristics and spatial distribution of land use/cover as well as its changes with time is essential for environmental research, management and policy making. Bucharest town has experienced rapid land transformation in the recent decades and will continue to develop rapidly in the near future. Its suburban area suffers the pressure of accelerated land use transformation, which causes great vulnerability in natural systems. The challenge of conserving landscapes in growing metropolitan area requires the continuity of sustainable systems of agriculture and forestry. Thus, it is interesting to study the specific dynamics of peri-urban agriculture, which is different from those of rural territories. The Bucharest urban sprawl contributes to the loss of identity in the territories that are progressively integrated in the urban space. Its environmental equilibrium is very weak. The system of green areas conceived as a network of greenways is essential to restore the environmental quality. Agriculture can play an important role concerning this issue. In the next future years for Bucharest town was proposed to be built a green forest belt.

REFERENCES

Batty, M., Howes, D. 2001. Predicting temporal patterns in urban development from remote imagery, J. P. Donnay, M. J. Barnsley, & Longley P. A (Eds.), *Remote sensing and urban analysis*, 185–204, London: Taylor and Francis.

Bergen, K., Brown, D., Rutherforda, J. & Gustafson E. 2005. Change detection with heterogeneous data using ecoregional stratification,statistical summaries and a land allocation algorithm*, Remote Sensing of Environment* 97, 434–446.

Biging, G., Colby, D. & Congalton, R.G. 1998. Sampling systems for change detection accuracy assessment in *Remote Sensing*, S. Lunetta, & C.D. Eldvidge (Eds.), MI: Ann Arbor Press.

Carr, J.R., Matanawi, K. 1999. Correspondence analysis for principal components transformation of multispectral and hyperspectral digital image, *Photogrammetric Engineering and Remote Sensing*, 65, 909-914.

Ludwig, J.A., Reynolds, J.F. 1988. *Statistical ecology: A primer on methods and computing,* 337–345. New York: John Wiley and Sons, Inc.

Morisette, J.F., Khorram S. 2000. Accuracy assessment curves for satellite based change detection. *Photogrammetric Engineering and Remote Sensing,* 66, 875–880.

Weng, Q. 2001. A remote sensing–GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, *China, International Journal of Remote Sensing* 22 (10) 1999–2014.