MONITORING OF FOREST COVER CHANGES BY USING MULTI-TEMPORAL AND SPATIAL SATELLITE DATA

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ABSTRACT

Change is intrinsic to ecosystems, but is also the essence of instability and the outgrowth of situations that lack sustainability. It must also be recognized that change can be associated with either restoration or degradation.

Compressed multiband image data provides increased flexibility and practicality for systematic change detection on a regional basis. Combining such capability with conceptual extensions of spatial pattern analysis represents a methodology for systematically monitoring spatial structure of spectral change across landscapes in order to profile characteristic broad scale regimes of change and to indicate trends in those regimes. Sustainability and ecosystem health are watchwords of contemporary ecosystem management. Environmental degradation is a critical and central phenomenon to be addressed by remote sensing. Space-borne instruments enable one to distinguish and monitor forest cover types over large areas and to relate these to changes in local conditions, whether these are caused by climate variation or anthropogenically.

To solve urgent needs in application of remote sensing data, forest changes must be detected based on monitoring spatial and temporal regimes across landscapes. Forest landscape level indices are used to examine forestland cover transitions. Based on classified Landsat TM and SAR ERS1 images for Cernica and Fundulea areas, Romania, conditional probability matrices of land cover transition are compared to measures of landscape structure. Based on proper algorithms for structural composition modeling were defined forest landscape elements being estimated the probabilistic behavior of pixels. This approach suggests a means of linking the probabilistic behavior of the fine scale dynamics to the forest pattern observed at larger spatial scales.

Keywords: changes monitoring, forest cover, remote sensed data, spectral features.

Introduction

Simulating the stochastic nature of change is of fundamental importance in ecology. The non-cartographic meaning of the term "spatial scale" refers to geographic extent (window size) and resolution (the degree to which spatial objects are distinguishable). Scale then becomes a complex variable, which captures the dynamics of change in both space and time. 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. Classification of any given pixel into a discrete land cover class for the purpose of determining change requires that these variables be considered. 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 spatial-temporal modifications in natural and anthropogenic surface features. Depending of the land cover and the objective searched the change detection technique would be selected. These methods include band differencing (McLeod R.D. et al., 1998), transformed band (e.g. band ratios vegetation indices differencing (Collins J.B.et al, 1996) and Principal Components (Richards J.A., 1984) . Techniques based on spectral classification are very useful to detect land cover changes for heterogeneous scenarios, anthropically dynamic regions or those affected by natural changes (mainly produced by geologic hazards). Two of the most common uses of multispectral and multitemporal satellite images are mapping landcover via image classification and landcover change via change detection for forested environments.

Satellite remote sensing in forest research

Satellite remote sensing data has an important role in environmental monitoring at regional, national, and global scales.It provides a powerful tool for spatio-temporal information on forest cover changes. The practical value of remotely-sensed data has increased significantly in this context with the advent of new, very high spatial resolution optical sensors (e.g. the current Indian IRS-1C and forthcoming US Space Imaging IKONOS, QuickBird and OrbView systems) and interferometric Synthetic Aperture Radar (InSAR). However, these new sensors demand new information-extraction methods in order to derive maximum benefit from the data that they produce. Techniques required to infer land use and land-use change from the raw spectral signals that are recorded. This can be achieved most effectively when the image data are analysed, in conjunction with ancillary spatial data, within a geographical information system (GIS) environment. Digital map data products can provide information on various aspects of the of forested areas.

Vegetation cover can be mapped directly at these scales from the apparent brightness measured in several spectral bands. There are some difficulties in assessing trends of vegetation condition, because apparent brightness depends on factors that are independent of the vegetation and varying with time (Duchemin B, 1999). Irradiance of vegetation, on a fine sunny day, depends on sun position in the sky, and this varies with time of day and date. The proportion of that irradiance reflected by the vegetation toward the satellite is controlled by the bidirectional reflectance factor (Robinson, B. F. et al.1979), which is a function of both viewing direction and sun position. Viewing direction can vary from image to image, and even within one image if it has a large swath. The transmission of light through the atmosphere to the satellite is affected by atmospheric conditions, which can vary by the hour. Furthermore, all these problems are compounded in mountainous or hilly terrain, where topography affects both irradiance and reflectance (Hugli H.et al, 1983) by changing the position of sun and viewer relative to the slope normal. (We use the term reflectance to mean a particular value of the bidirectional reflectance factor.) Were developed a lot of models for correcting atmospheric effects, for correction of bidirectional effects of reflectance, 2D and 3D (bi and three-dimensional) numerical models for representing the vegetation canopy and different numerical methods to calculate reflectance.

While optical bands of satellite sensors are very useful for assessment of forest cover health and seasonal changes, thermal infrared bands are providing information regarding forest system dynamics. Some limits to more extensive utilization of thermal IR data are due to the high complexity of structural and spectral parameters of forest canopy. Satellite remote sensing data are applied for vegetation species differentiating, to detect changes in the structure and condition of vegetation resulting from water stress, insect infestation, or disease damage. One of the most important utility of remote sensing data is forest classes and stand conditions distinguishing. Spectroradiometric ground truth measurements are providing useful data for a better interpretation of satellite imagery.

Study Areas And Data Used

The test areas selected for this analysis, Cernica and Fundulea zones, placed to the Eastern part of Bucharest town as in presented in figure 1.

Investigated areas are bounded by latitudes 44.3 (N and 44.5 (N and longitudes 26.2 (E and 26.4 (E , being land sandy zones, with a diversity of forest tipes as well as agricultural areas with different natural resources categories .Forest area contains hardwoods like maple tree (Acer tataricumi) and oak tree (Quercus pedunculiflora) as well as different crops and secundary lawn with Festuca valesiaca, Andropogon ischaemum, characteristic for sylvosteppe region.Soils are of chernozem types. This area is belonging to Romanian Plain and has a continental climate, not very humid. Were used Landsat-5 TM data over the study area (183/29 path/row), acquisition date 27/03/ 1989 and SAR ERS-1 (orbit 9356,frame 2709 acquired at 30/04/1993 ; orbit

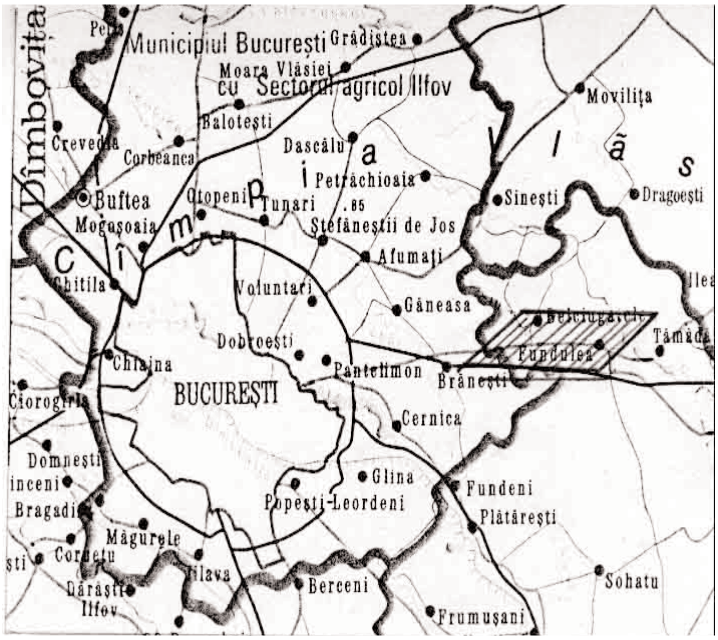

Figure 1. Test area sites.

10358, frame 2709 acquired at 9 /07/1993 and orbit 10859, frame 2709 acquired at 13/08/1993).

Methods

Forest land cover and land cover change monitoring at regional and global scales requires satellite data to identify and map landscape features and patterns with sufficient detail.

Analytical methods based on image-by-image interpretation are too time-consuming for large areas studies .A potential solution is to develop algorithms or classifiers that can be generalized for new images from different spatial, temporal or sensor domains. We also assess the effects of atmospheric corrections on generalized classification accuracies.

Methods involved the integration of data recorded by different satellite sensors, optical and microwave, through newly developed algorithms. The main aim of this paper is to investigate the spatio-temporal changes over Cernica and Fundulea vegetated area. The main objectives have been: to identify, assess and measure the key processes operating in this land- cover ecosystem. This paper evaluates the use of visible/infrared (VIR) satellite imagery and Synthetic Aperture Radar (SAR) for mapping the extent of environmental changes and impact on this vegetated (Serban F, et al., 1993; Zoran M. et al, 1996). VIR images contain information about the reflectivity of objects while

SAR images contain data about the geometric and electrical characteristics of the objects as radar pulses can also penetrate vegetation to some degree depending on the wavelength and vegetation thickness.

All SAR images have been taken in descending mode. Radial direction is almost East-West. In PRI format the speckle is slightly decreased by a multilook processing. The pixel size is 12.5 meter in both directions. The images were geometrically corrected to fit a topographic map with a scale of 1:100 000, on which vectors were digitized for the subsequent geocoding of the satellite images. As software package was chosen PCI's EASI/PACE on a super graphic computing station. Data processing techniques consisted in the following steps: (1) reading the satellite data from the CCT magnetic tapes and including these in PCIDSK databases; (2) atmospheric corrections; (3) despeckling of the SAR ERS-1 images with 7x7 Frost filter, and Lee filter for a better discrimination of different cover units as well as for more efficient textural features extraction; (4) data conversion from 16 bits radar data to 8 bits images using AVS (Application Visualization System); (5) geometrical correction and geocoding the images by using topographic map and 20 ground control points selected and second order polynomials to perform the image -map registration (the total RMS error was of 0.535 pixels); (6) the registration-synergism between the Landsat MSS, TM geocoded image and SAR ERS-1 images.

Results

By digital processing was generated composite color image for Landsat TM bands (4/5/3) corresponding to spectral ranges (4 from 0.76-0.90 µm; 5 from 1.55-1.75 µm; 3 from 0.63-0.69 µm), as is shown in figure 2 for Cernica area without atmospheric corrections (left side image) and with atmospheric corrections (right side image). It has been found that the best accuracy has been provided by the following bands combinations: TM 3/4/5, 2/3/4 and 2/4/5. Single band 5 yielded the best overall results, but band 4 seems to be the most useful, as it appeared in all of the three bands combinations. The two-band analysis indicated that bands 4 and 5 yielded in many cases the best results. For TM1 band was removed striping noise and provided un-corrected and corrected images. Based on CORINE methodology (CO-oriented Information on the European Environment) was provided environmental features classification for Landsat TM 4/5/3 and SAR ERS-1 images.For SAR ERS-1 data was produced a multitemporal image as is presented in figure 3. Unsupervised and supervised classifications were done for several spectral bands combinations.

Analogously to the possibility to emphasize spatial and linear structures by filtering in the spatial domain, spectral characteristics of multispectral data can be enhanced by the adaptation of the adequate filters as linear transformation. By comparing the two processing procedures it can be stated that Principal Component Analysis, as well as "Spectral Mean Value", shows the same thematic information content concerning environmental features. Spectral mixture analysis and unsupervised classification using

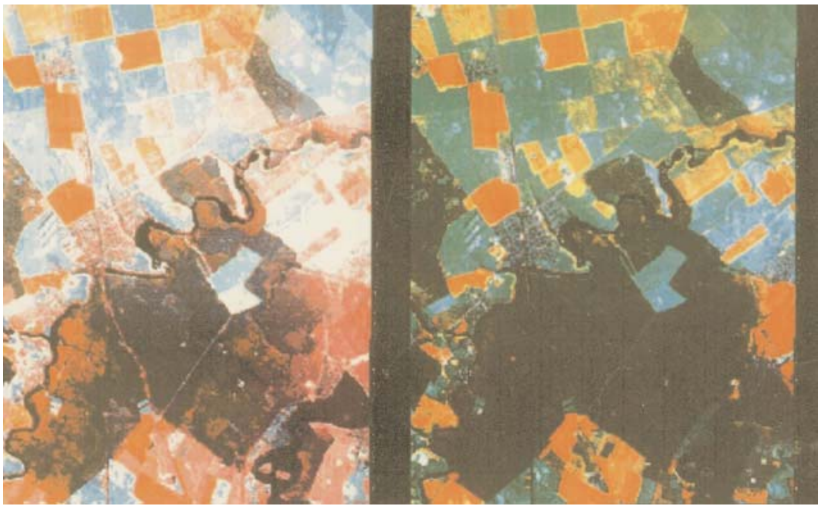

Figure 2. Landsat TM 4/5/3 for Cernica area without atmospheric correction (left side image) ; with atmospheric correction (right side image).

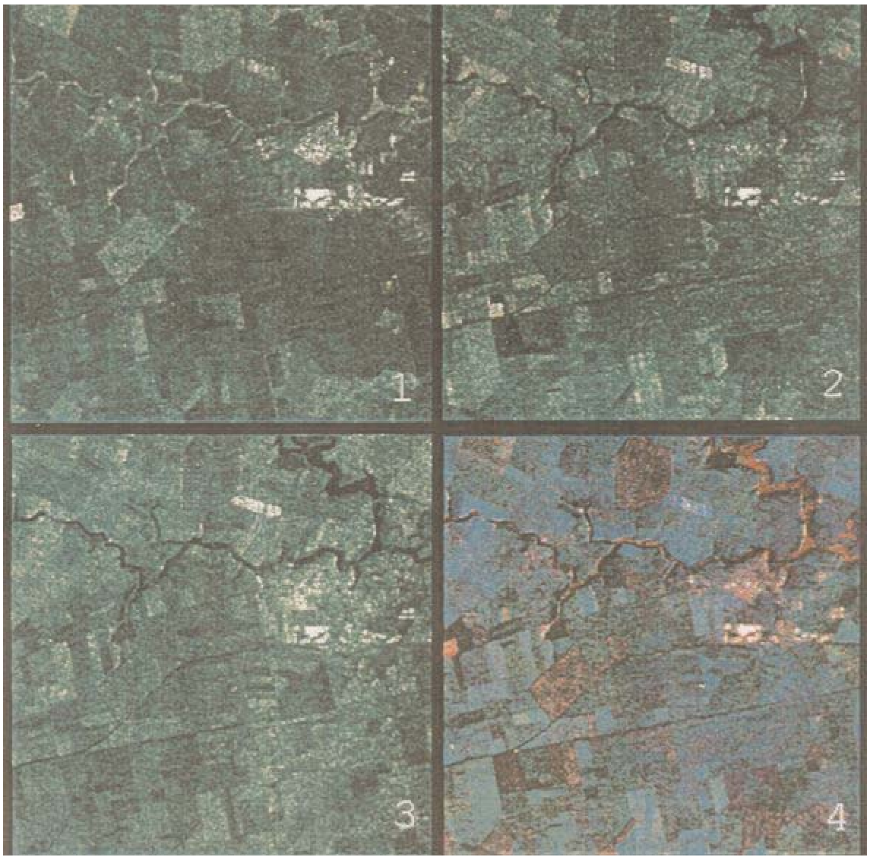

Figure 3. Synthetic Aperture Radar SAR ERS-1 image for Fundulea area: image 4 is multitemporal (by fusion of 1,2,3 images)

Maximum Likelihood algorithm assisted by an unsupervised clustering procedure were applied on the available Landsat TM and SAR ERS-1 images. Thematic maps have been produced to control the parameters under consideration during the study periods.

Developments in change detection using compressed multiband image data provide increased flexibility and practicality for systematic change detection of vegetated areas and forest cover on a regional basis. Change detection analysis requires: at least two independent data sets acquired under different conditions; satellite data with different ground resolution; the position of the pixel array has an important role and changes from image to image; even with high dynamics, land cover changes only occur in the space and time range (per km , per year), for greater periods of observation appear technical changes of sensors which may lead to differences in image quality; the selection of data require frequently nearly the same seasonal date, which is not always possible from different technical and economic reasons.

Changes of spectral properties of vegetation and forest cover types could be explored by suitable wavelengths of electromagnetic spectrum dependent on spectral sensors characteristics of spaceborn systems like Landsat MSS, TM, ETM, Spot, SAR -ERS, IKONOS.

Conditional probability matrices of land cover transition are compared to measures of landscape structure. Based on proper algorithms for structural composition modeling is possible to define forest landscape elements, being estimated the probabilistic behavior of pixels. This approach suggests a means of linking the probabilistic behavior of the fine scale dynamics to the forest pattern observed at larger spatial scales.

This investigation explores a probabilistic spatial model of landscape transition from measures of landscape between landscape patch structure and spectral reflectance by fusion of remote sensing data. This study explores the link between landscape patch structure and the individual pixel transition of interpach heterogeneity. Was demonstrated that both Landsat TM data and Synthetic aperture radar (SAR) are useful for detecting and predicting biophysical properties of forest ecosystems. Although single frequency-polarization data are of limited utility for detecting forest characteristics, multi-channel and multi-temporal data exhibit substantial sensitivities to many components of forest systems, including biomass, density, basal area, and canopy height.

Conclusions

The forest service is currently at the threshold of a new world in resource management based on satellite imagery information, Geographic Information Systems and on advanced spatial decision support systems. Scientific management of vegetated areas and forests must consider maintaining of diversity of animal and plant communities without degrading long-term productivity of the land. This requires the evaluation of the consequences of resource management activities through time on all elements of the ecosystem and at landscape as well as stand-level scales. Management of forest ecosystems at landscape scales means projecting and evaluating interactions and cumulative impacts on many resources at a time. It requires an integration of observational data, science, practice, and management experience.

Forest ecosystem is increasingly endangered by global or regional environmental changes, due to excessive deforestation, environmental pollutants, to the reclamation of wetlands for agriculture, urbanisation/industrialisation, engineering of water flows, etc. A scientific study on mapping vegetated covers , forest types, extent, spatial distribution and forest biomass as well as forest cover changes under different land use conditions must be based on the analysis of multi-temporal , multi-scale satellite images of different level of ground and spectral resolution .Future study is the exploitation of hyperspectral sensors potential as MERIS to provide repetitive information on spatio-temporal changes in forested zones for better monitoring and management for real-time decision makers.

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