DEVELOPMENT OF DIGITAL CARTOGRAPHIC DATABASE FOR MANAGING THE ENVIRONMENT AND NATURAL RESOURCES IN THE REPUBLIC OF SERBIA

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ABSTRACT

On it's way to become a member of the European Union, Republic of Serbia need to achieve EU environmental standards. Increased interest in correct management of the environment and natural resources caused strong demand for great amount of information needed in decision-making process. Spatial databases with associated alfanumeric data have especially important role in that process.
This study contains methodology for building and maintaining digital cartographic database as an necessary part of the system for managing the environment and natural resources in the Republic of Serbia. The core of the methodology is developed data extraction from satellite imagery which is, as a fast and low-cost spatial data source, recognised as the basic data source. Its another advantage is multi temporal character which enables mapping environmental changes during time.
The database consists of both raster and vector data with accuracy appropriate to the scale 1:100 000, with associated attribute data.

1. INTRODUCTION

In the contemporary world which has been rapidly changing, correct management of the environment and natural resources is of significant importance for both ecology and sustainable development. Republic of Serbia, on its way to European Union membership, tents to achieve EU environmental standards. One of the steps in that direction was foundation of the Serbian Environmental Protection Agency. Among other tasks, the Agency should store environmental data in an environmental database. Since environmental data have their spatial dimension, the database must meet special requirements: it has to be cartographic as well as statistical.
Environmental management requires data at varying scales. Beside large scale data necessary for local planning and monitoring, there is a need for a database on national level. Accessibility to adequate satellite imagery, which is valuable environmental data resource, enables us to develop such a database in relatively short time and with limited expenses.
This paper contains basic methodology principles in developing the database.

2. FUNCTIONALITY OF THE DATABASE

The spatial data in the database are organized in layers according to different themes and are stored in both vector and raster format. Such strategy comes from the several facts. Vector primitives are better in representing some environmental phenomena. On the other side, strong capabilities of raster-oriented GIS proved to be an irreplaceable tool in spatial analysis. Besides that, raster format is more suitable for representing some other phenomena. Finally, satellite imagery as a significant environmental data resource is also raster oriented. The accuracy of both data types should be appropriate to the scale of 1:100 000 which was chosen as the most suitable for the database on national level. Attribute data associated with the spatial features and possibility of conversion between two data formats enables complete functionality of the database.
Figure 1 shows the place of the database in the environmental information system.

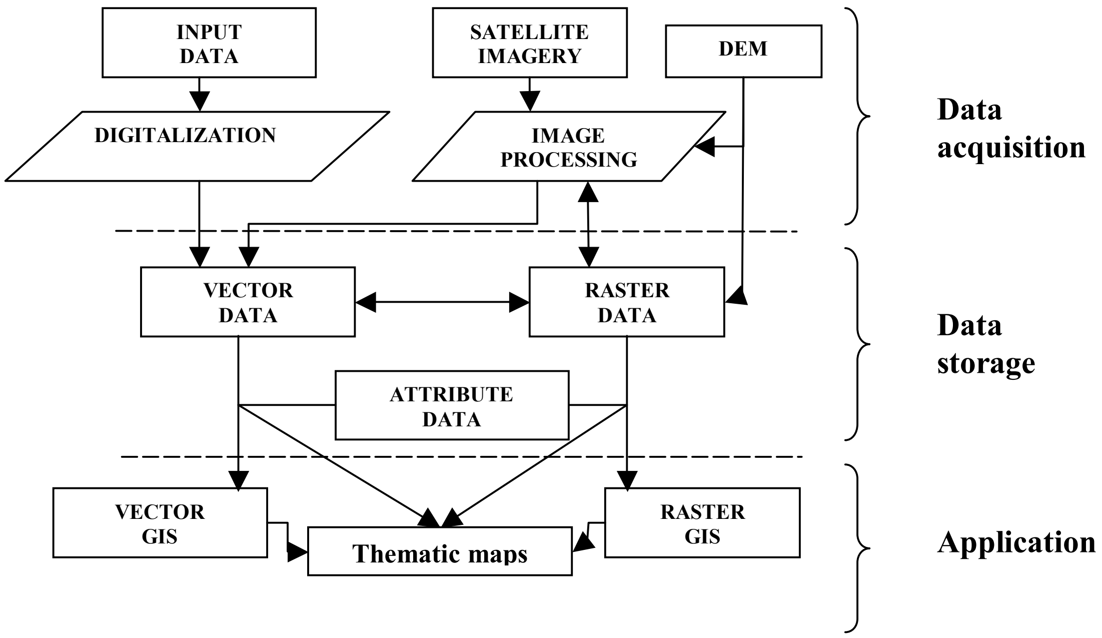

Figure 1: Environmental information system

3. DATA RESOURCES

After studying several possible data resources for the environmental database, Landsat GeoCover data has been chosen to be the basic data resource. There are several reasons for such a choice: a) the scale and the geometric accuracy of the imagery is appropriate for the purpose of a database on national level; b) multispectral and multitemporal character of the imagery enables collecting wide range of data related to the state of the environmental phenomena; c) NASA/USGS and UNEP provide a free copy of the Landsat GeoCover data set to each developing nation of the world through the Global Land Cover Data Facility.

The GeoCover data set is designed to provide global Landsat imagery at three temporal intervals. Acquisition dates are circa 1970-80, 1990 and 2000 utilizing, respectively, the Landsat MSS, TM and ETM+ sensors. All data is orthorectified or, in other words, corrected for terrain displacement and errors in image geometry (RMSE is 50m for TM and ETM+ and 100m for MSS) and projected in UTM projection (Zone 34).

Data that cannot be extracted from satellite imagery have to be obtained in another way, mostly by digitizing another data source (topographic and thematic maps, aerial imagery, very high resolution satellite imagery, etc.). However, it has to be considered that such a way of obtaining data increases both time and expenses. Thus, one of the most important steps in developing the database is defining the method for data extraction from Landsat imagery.

4. THE METHOD

There are two types of data related to environment which can be extracted from Landsat imagery. First type gives the information about the spatial location of certain environmental objects of interest. The other provides facts about the state of the identified objects. For example, in a process of image interpretation we can locate an area covered by pine forest and at the same time its condition (e.g., presence of a disease, degree of moisture, etc.).

Thus, the first part of the method is mapping the environmental phenomena. It means locating environmental objects that belong to the certain phenomenon by classification of satellite imagery. Considering recent studies related to different classification concepts, a hierarchical-object oriented classification is chosen to be incorporated in the method.

As the task of the second part of the method, conditions of environmental phenomena can be determined using parameters defined by theoretical knowledge (e.g., vegetation indices as indicators of biomass degree) and by establishing empirical relations between environmental features quality parameters and spectral parameters of satellite images.

In further text the accent will be put on classification of environmental objects.

4.1. Object oriented classification

Although well-known and widely used, pixel-based classification techniques are limited at present. Based on procedures that utilize set of radiance measurements obtained in the various wavelength bands for each pixel, they show insufficient classification accuracy. The concept of object oriented classification means that important semantic information, necessary to interpret an image, is not represented in single pixels, but in meaningful image objects and their mutual relationships. Compared to pixel-based aproach, the basic difirence is that object oriented procedures does not classify single pixels but image objects, previously extracted in an image segmentation step.
For this research, eCognition software is used in peforming object-oriented classification.

4.1.1. Image segmentation

Segmentation is a method of generating image objects by subdividing an image into separated regions-segments. Similar pixels are aggregated into segments with respect to predefined homogeneity criteria. The definition of homogeneity is flexible and consists of a trade-off between spectral and spatial homogeneity.
Thus, segmentation process requires three parameters to be defined.
Scale parameter: this parameter determines the maximal allowed heterogeneity of the objects and thus indirectly influences the average objects size. Larger scale parameter will produce larger objects.
Color/Shape: parameter defines to which percentage the spectral values of the image layers contribute to the entire homogeneity criterion as opposed to the percentage of the shape homogeneity
Smoothness/Compactness: in the case when the shape criterion is larger then 0, it is composed of two parameters: smoothness and compactness. Using them, user can determine whether the objects will become more compact or smoother.
By adjusting these parameters, the process leads to image objects that satisfy our need for homogeneity and scale for certain environmental phenomena.

4.1.2. Classification-a hierarchical approach

Object oriented classification is a process of assigning of each image object to a certain or no class. Image objects, previously generated in a segmentation process are not only described by the value and statistic information of the pixels they consist of, but they also carry texture, form and topology information. Thus, the feature space related to image objects is much bigger than the one related to single pixels.
Although there are many ways to perform the classification, the hierarchical approach is chosen since its superiority over supervised classification has been proved (Avci and Akyurek, 2004).
In this case, classifying image objects means assigning each of them to a certain environmental phenomena (e.g., pine forest, continuous urban fabric, etc.). Environmental phenomena represented on Landsat images, with regard to different spectral and spatial characteristics, form a natural hierarchical structure (Figure 2). Following that structure, hierarchical classification implies subsetting image area into several parts with respect to predefined spectral and spatial rules. Hence, three type of knowledge can be used in establishing the rules in hierarchical classification:
Generated spectral knowledge: makes the rules that can be used to discriminate one class from the other (e.g. using vegetation indices to discriminate vegetation and non vegetation regions), obtained from remote sensing literature and empirical research.
Spectral classification rules obtained from training data: training data determines place of class vectors in n-dimensional feature space, where “n” is number of data layers involved in classification.
Spatial knowledge: knowledge about spatial relationships between environmental objects increases classification accuracy.
The rules are practically incorporated in two classifiers to be used: a nearest neighbor classifier and fuzzy membership functions. While the nearest neighbor classifier describes the classes to detect by sample objects for each class which the user has to determine, fuzzy membership functions describe feature intervals wherein the objects do belong to a certain class or not by a certain degree. As the result of applied classifier/classifiers on each level of the hierarchy structure, new image which consists of target classes for further decomposition is created. The process goes from the top to the bottom of the hierarchical tree (Figure 2).

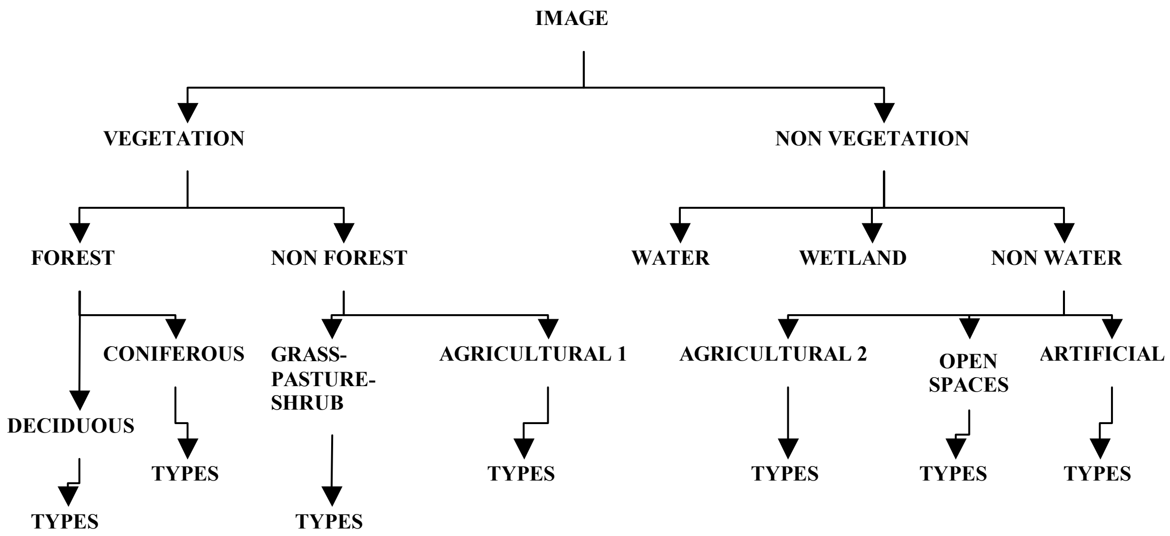

Figure 2: Global hierarchical structure

An example of hierarchical object-oriented classification algorithm will be shown on the Tamis River test area in the northern part of Serbia, where several forest types were mapped.
To perform segmentation, scale parameter value of 10 was chosen as the most suitable one. Shape factor wasn't involved in the process by assigning it to 0. In the next step generated image objects were then analyzed with regard to different features based on the properties of the input spectral bands (Figure 3).

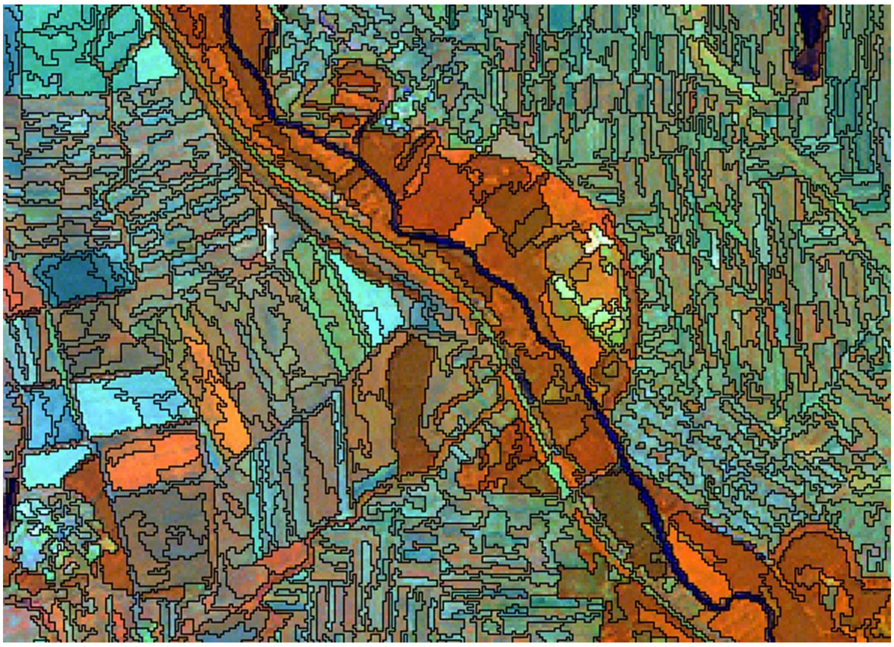

Figure 3: Generated image objects with 451 band combination in the background

For the first level of hierarchical classification which implies decomposition of the environment on two basic parts: vegetated and non-vegetated, Normalize Difference Vegetation Index (NDVI) was used and the threshold value for discrimination was set to 0.12 (Figure 4).

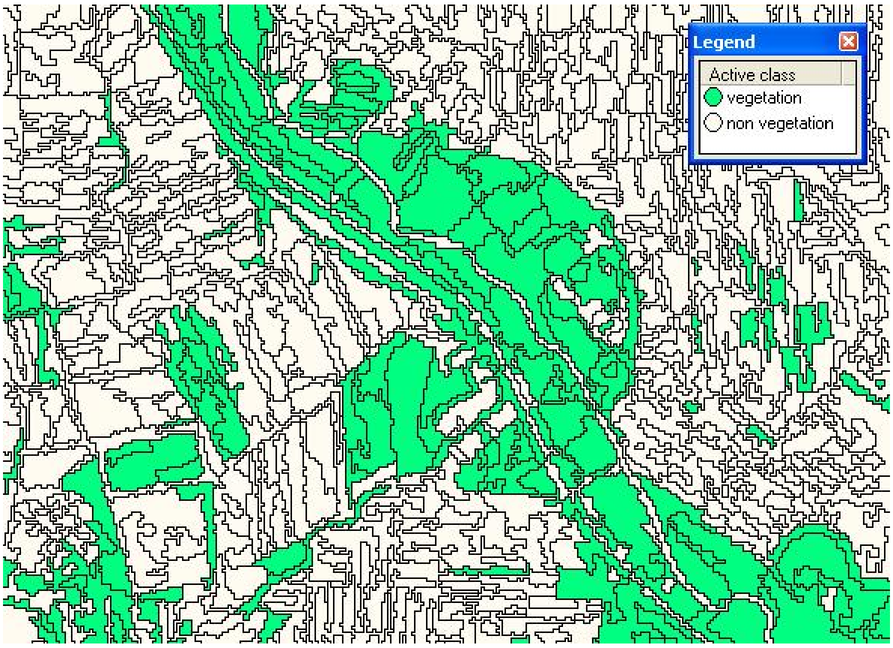

Figure 4: Classified vegetated and non vegetated areas

Further analysis implies subsetting vegetation regions on two sub-classes: forest and non forest. Investigation of spectral bends brought as to the conclusion that several of them have influence in those two classes discrimination. Thus, a transformation of the channels called "brightness" has been used in the discrimination. "Brightness" is defined as a sum of the mean values of the layers containing spectral information divided by their quantity computed for an image object. Threshold value was set to 66. The result is present in the Figure 5.

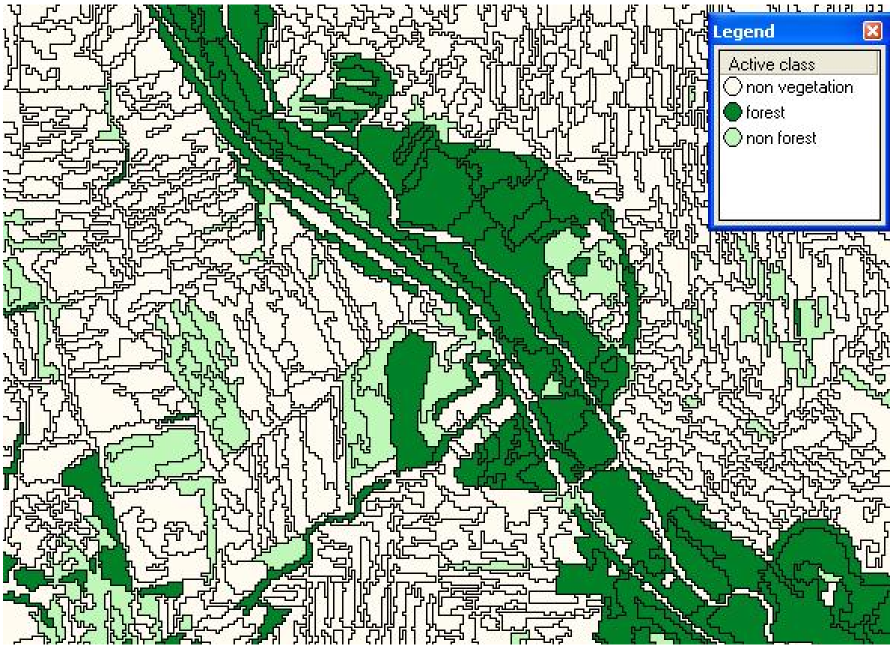

Figure 5: Forest and non forest areas

Finally, the last part of the process is classification of the forest types. Using local, recently updated forestry maps as an ancillary data, 3 forest types were recognized. Training fields were chosen for each of the forest type and nearest neighbor classifier was applied. The result, shown in the Figure 6 was compared to the local forestry maps and overall accuracy of 90% was satisfactory.

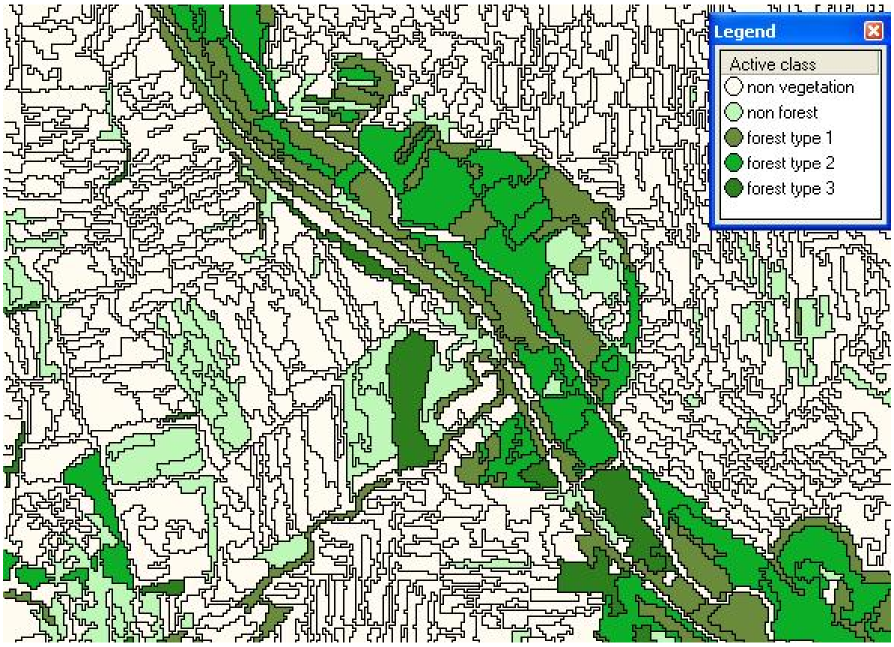

Figure 6: Map of extracted forest types

5. CONCLUSION

Development of the environmental database on national level in the Republic of Serbia has to be fast and non expensive. To satisfy these demands, Landsat imagery was chosen as the basic data resource and hierarchical object-oriented classification was incorporated in the method of mapping environmental phenomena. Basic characteristics of both the data and the method were presented. Further research should define exact parameters and rules for discriminating the classes in the hierarchical structure which will maximize accuracy of mapping the environmental phenomena.

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BIOGRAPHY OF THE AUTHOR

Dragutin Protic was born in Belgrade, 18 June 1974. After finishing high school, he entered Department of Geodesy-Faculty of Civil Engineering at the University of Belgrade, where he graduated in 2001. He is currently on graduate studies on the same Department, specializing in cartography, remote sensing and GIS.

After completion his undergraduate studies, he was working as a demonstrator on cartography courses on the Department of Geodesy for 2 years. In May 2003 he was appointed a teaching fellow. During 2002 he was engaged in REC- Regional Environmental Center for Central and Eastern Europe as a trainer for implementation of Local Environmental Action Plan project.

Dragutin Protic has published two works: "Using the ILWIS software for creating raster thematic maps" (2001), and "Global expansion of raster GIS and Image processing tools" (2002).