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DESIGN OF DIGITAL LANDSCAPE MODEL OF THE TEYNA RIVER WATERSHED FOR THE PURPOSES OF LANDSCAPE-ECOLOGICAL PLANNING

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***Key words**: digital landscape model, landscape ecology, landscape planning, remote sensing, geo-information,*

***Abstract**: Landscape ecology is a relatively new science in the system of sciences. It has emerged from the need of accurate and precise characterisation and mapping of the ecosystem. Since the beginning of the 20th century landscape ecology has been developing its theory, so numerous landscape models were created. These models, however, are actually based on different data sources with different quality, scale, availability etc. The emergence of geo-informatics facilitates greatly data integration and management, as well as complex assessment of landscape. This study represents data integration methodologies using GIS and remote sensing techniques for designing a digital landscape model (DLM) of the territory of the Teyna River watershed. The data used is data for climatic features, such as temperature and precipitation; soil, geology and vegetation. These thematic layers were combined in a DLM with normalized attributive data to perform quick visualization, classification and assessment of the landscape structure of the study area. The resulting 98 secondary landscape units reflect the diversity in natural features and human impact on the study area and provide landscape ecology and land-use planners with a useful tool for decision making aimed at rational land use and nature resource management.*

СЪЗДАВАНЕ НА ЦИФРОВ МОДЕЛ НА ЛАНДШАФТА НА ВОДОСБОРНИЯ БАСЕЙН НА РЕКА ТЕЙНА ЗА НУЖДИТЕ НА ЛАНДШАФТНО-ЕКОЛОГИЧНОТО ПЛАНИРАНЕ

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***Ключови думи**: цифров модел на ландшафта, ландшафтна екология, ландшафтно планиране, дистанционни изследвания,*

***Резюме**: Ландшафтната екология е относително нова наука в системата на науките. Тя се появява в отговор на нуждата от точна и прецизна характеристика и картографиране на екосистемите. От началото на 20-ти век ландшафтната екология развива своята теория. На тази основа са създадени редица ландшафтни модели. Тези модели са основани на различни типове данни с различно качество, мащаб и достъпност. Интегрирането на данните и тяхното управление, както и създаването на модели и оценки на ландшафтите е значително улеснено с появата на гео-информатиката. Настоящото изследване използва възможностите на географските информационни системи и дистанционните изследвания за създаването на цифров модел на ландшафта за територията на водосборния басейн на р. Тейна. Използваните данни в качеството на входни параметри за модела, са данни за валежи и температура, почви, геоложки строеж и растителност. Тези тематични слоеве са комбинирани и нормализирани в цифров модел на ландшафта с цел по-бърза визуализация, класификация и оценка на ландшафтната структура на района на изследване. Получените 98 ландшафтни единици на вторичната структура на ландшафтите отразяват разнообразието на взаимодействието на природните компоненти и човешката дейност и предоставят възможност за взимането на решения за по-рационално планиране на земеползването и природните ресурси.*

Introduction

Landscape ecology is a relatively new science in the system of sciences. It has emerged as a new interdisciplinary science, almost simultaneously in West Europe and Russia in the beginning of 20th century, (Troll, 1939). Its subject is the landscape defined by (Forman and Gordon, 1986) as a mosaic of "interacting ecosystems". These ecosystems are mainly dealt in two-way aspect, in horizontal-structure and vertical-functioning. During recent 15 years this discipline has thrived in terms of public interest, various problems that it solves, i.e. conservation biology, ecosystem ecology etc, and the widening approach for problem solving. All this aspects have many direct implications as for example the number of articles published worldwide concerning landscape ecology (Turner, 2005). The subject of landscape ecology is spatial and temporal in its nature. This comes to address new approaches to solving the connection between landscape pattern and the process. The connection of structure-pattern-function and the historical and ecosystem approach has brought the need for more complex and diverse way of problem solving.

The emergence of landscape planning and landscape ecology planning dates back to the end of 60s of 20th century (Ndubisi, 2002). Some of the pioneers in landscape-ecological planning in Europe are Slovak's scientists Ruzicka and Miklos, who developed in 1982 their LANDEP model based on the evaluation of landscape suitability, conflict of interests and assessment of assumed impacts of proposed intentions for development of new activities. Some of the most well-known approaches are the American methodology METLAND, (elaborated for metropolitan agglomerations), the Dutch methodology A.P.A., the Australian methodology SIROPLAN or LUPLAN, the Canadian methodology ABC, Kozová (2008). Landscape-ecological planning has become the most common practice for land-use and conservation planning (Antipov and Drosdov 2002, Dobrolubov et al. 2006). Moreover, due to the incorporation of all natural and societal features of the environment and its systematic approach, it has become very common solution to solve complex global, regional and local issues for Sustainable Development. Simultaneously to the developing of the paradigm of landscape-ecological planning the connection between GIS and remote sensing to landscape ecology was outlined in numerous publications and two monographs, (Haines-Young, 1993). Recently the need for an object-oriented landscape GIS for nature and cultural landscape is a topic of many publications, (Dobrolubov et al 2006; Navulur, 2007).

The legislative basis of landscape-ecological planning and assessment was laid out in 1985, when the European Union enacted the mandatory procedures for ecological revision and environmental impact assessment (EIA). With some delay, they were incorporated in national legislation and updated, in 1997, (Antipov and Drosdov, 2002). In the year of 2000 the Council of Europe enacted European Landscape Convention (PEBLDS), [1]. It was ratified from 10 member countries including Bulgaria. The harmonization of the convention and foreseen specific actions that shall be taken on a national and local scale for the signing parties are laid out in Articles 5 and 6 of the Convention. Adoption and harmonization of the Convention is to be undertaken by the responsible organizations, while the responsibility of public and scientific community is to communicate and provide the best available practices for the implementation of the Convention.

The main objective of present study is to design a digital landscape model (DLM). The term DLM is relatively new and was coined in the publications of (Kolejka, 2002 and 2006). Despite that, there are terms with almost equal meaning in the scientific literature such as *regional natural (land) units* or (Finke, 1986) and *Landscape Description Units* (LDU), (Vogiatzakis et al., 2004) as well as the term *landscape character units* accepted in European Landscape Characterization – LANMAP 2, (Muncher et al, 2009).

The objective is achieved through accomplishment of several steps:

1). Data collection – collecting archive and institutional data for the study area;

2). Data manipulation – preparation, i.e. georeferencing, digitization, rectification, attributive data entry, geodatabase management;

3). Design and analysis of DLM – linear combination of the input data layers, topological editing and statistical analysis of the DLM.

Study area

The study area of present work is the Teyna Watershed. The basin of the Teyna River is located in the North part of Sofia kettle at the footsteps of *Sofiyska Mala Planina* Mountain. The total area of the test site is – 4.775 km^2. The altitude ranges from 500 m.a.s.l, at the Iskur River Gorge, to 964 m.a.s.l. on the topmost part of the watershed. Climatic conditions are Temperate-Continental to Transitional. Due to the fact that almost 28.74% of the slope exposition is oriented to the South and 35.44% to the East, the local climatic conditions are assumed to be drier than those of the Sofia kettle.

Materials and methods

The main dataset for the study was organized into a geodatabase in ArcInfo 9.2/ArcCatalog 9.2. The digital layers were stored in feature classes and feature datasets in UTM projection WGS 84 geoid -Zone 34. The raster dataset consists of 5 m cell size DEM, created from topographic maps contour lines and elevation points in 1:5 000 scale, water bodies and stream network. The derived aspect and slope from the DEM and the calculated temperature and precipitation maps were stored in separate raster catalogue.

Results and discussions

Data collection and data manipulation are usually regarded as most important stages in terms of time and resources in each Earth sciences research. These stages include data preparation, i.e. georeferencing, rectification, digitization, attributive data entry, geodatabase management of data layers. The main layers produced as input parameters for DLM are: Geology, Relief's main derivatives: slope and aspect reclassified to maps of geochemical landscapes and map of cardinal and ordinal directions of slope; Climate types, Vegetation types and Soil types. All this data was organized, maintained and manipulated in the personal geodatabase.

Geology (rock types) of Teina River watershed is very important natural feature which act as the main fundament for natural landscape units. The bedrocks are a diverse mixture of Neogene-Quaternary argillite, Ordovician-Silurian argillite, alevrolite, schist, sandstone, breccias etc. All these rocks are more or less loose in structure, so that they facilitate the manifestation of erosion. Their outcrops are observed on the slopes of Iskar River gorge. The lithology of the rest part of the region is composed mainly of flish: argillite, silicite, sandstone with Palaeozoic and Cainozoic age, where the Palaeozoic rocks prevail. The human impact on geology of the study area has many aspects; from which the excavations and embankments are the most apparent. The downside effect from human activities also reflects local geochemical background in terms of destruction of natural geochemical path flows and creation of new anthropogenic geological conditions. In the Basin of the Teyna River such examples are the former decommissioned *Kutina* coal mine and *Brezi Vruh* uranium-ore extraction site.

Slope and *aspect* are the two important DEM derivatives which are used in standard terrain analysis. Aspect was reclassified and generalized to eight main cardinal and ordinal directions. After reclassification of the DEM slope derivative to 2 classes from 0 to 8 degrees and from 8 to 56 degrees, the class values were again reclassified to produce a map of the geochemical landscapes. The map of geochemical landscapes is based on the conception of geochemical landscapes as a paragenetic chain of elementary landscapes interconnected by migration of chemical elements Perelman and (Kasimov, 1999). The geochemical landscapes are grouped accordingly to: 1). *Eluvia* or autonomous; 2). *Trans-eluvia* – geochemical landscape with mainly transport function of the chemical elements and compounds, regardless of geochemical barriers, existing in nature etc.; 3). *Accumulative-alluvial*- are those geochemical landscapes which are transitional in their nature and are usually in the mid or lower parts of slopes; 4). *Super-aquatic* are those landscapes which are mainly influenced by high level of the water-table. The elementary geochemical landscapes are connected by common inflow and outflow of chemical compounds, water, energy and information into cascade landscape geochemical systems, (Perelman and Kasimov, 1999).

Climate of the region is classified as temperate/mesothermal climate – Group C in Köppen climate classification. For 20 years period, i.e. 1994-2005, the climate of the territory is Cw - Warm temperate climate with dry winter. That is due to the fact that Pwmin < Psmin and Psmax > 10 Pwmin, (Kottek et al, 2006). The climate index for all landscapes is set to be of the same origin because the territory falls completely within the aforementioned climate class. The local climatic conditions of the *Teina* River basin are influenced mainly from the South-East openness.

Region's *vegetation* is represented mainly of deciduous oaks (most prominently *Quercus frainetto* Ten., as well as *Q. cerris* L., *Q. pubescens* Willd.) which are the primary vegetation of the watershed. European Beech is interspersed with conifers such as Scots Pine, Macedonian Pine, Silver Fir and Norway spruce mostly on the mountain slopes from 800 to 1200 m.a.s.l. This situate the Teina River watershed in the ecoregion of Balkan mixed forests according to both the WWF and Digital Map of European Ecological Regions by the European Environment Agency, (Olson, 2001). It belongs to the biome of temperate broadleaf and mixed forests and the Palearctic ecozone. Because of the openness of the watershed in East-South direction the belt of the coniferous forest is missing. The majority of vegetation is artificially afforested with durable to pollution forest types. Some of these species found on the study area are: Scots pine (*Pinus sylvestris* L.) and European Black Pine (*Pinus nigra* L.).

The main *soil types*, which play major role in the landscape structure, on the territory are Chromic Luvisols with 45.8 % of the watershed's area. These soils are mainly located on the lower parts of the slopes, whereas the next prevailing soil type, i.e. Cambisols, with its 36.37 % are located on a higher altitude. The rest 17.4 % are covered with bare soil or Antroposols, which is connected to the human impact on soils in the region.

Data manipulation of the input layers is represented mainly by storing and managing raster and feature classes into predefined coordinate system and extent. The normalization of the attributive data in the geodatabase was achieved through separate storage using relationship classes in table format. Attributive data for the layers: Slope, Aspect, Climate, Vegetation and Soil was manually input into the model, reclassified and sub-sampled from input layers in order to achieve homogeneity of the DLM's inputs.

The DLM was designed and created by combining the graphical and attributive representation of the input layers. After post processing the output layer with resulting landscapes of the Teyna River watershed the resulting layer has 452 individual landscape character units or ecotopes. Their description in the landscape model consists of 1). Relief parameters: geochemical landscape types and aspect; 2). Geology – rock types and their alternations; 3). Climate parameter – climate type according to Köppen climate classification, (Kottek et al, 2006); 4). Vegetation – vegetation associations according to the vegetation map of the watershed; 5). Soil – main soil types according to the FAO soil nomenclature (Ninov, 2005).

The third stage of the DLM creation was the linear combination of all data layers into a sole DLM model of the secondary landscape structure, **Fig. 1**. Due to the fact that most data layers are derived from databases with different level of scales and detail, it was necessary to “clean-up” the gaps, i.e. small landscape units under 0.1 ha, and topology omissions or commissions. After topology editing of the input layers they were linearly combined using union function assigning to each natural feature and parameter equal importance in the model. This equal importance or weight is essential to perform the subsequent steps of generalization of the input parameters using multivariate statistics. There are many introductory and specific courses which deal with application of multivariate statistics in conservation and landscape ecology, (Thaddeus, 1994; Turner, 2001). Their actual application in landscape ecology is about to become inevitable because a large amount of data has become available. Nowadays, the most commonly used multivariate statistical methods are: clustering, ordination and almost all known kinds of statistical distributions. This abundance of methods employed is due to the complexity of natural features and the Nature as the system of all systems. The applied statistical methods in present study include hierarchical clustering to “aggregate” the landscape character units. It is important to emphasize that not any statistical approach is able to solve the most specific part of the research, i.e. the expert knowledge of spatial-temporal relationships in the study area. Therefore, a subsequent check out of the clustering result is very important to remove “errors” from the statistical output.

As a result from the multivariate transformations of landscape characters they were grouped to 98 landscape character units or ecotopes represented by generalized attributes of the natural features, **Fig. 1**. This “aggregation” is achieved through not only semantic generalization of the input parameters, but also throughout topology rules, detection of graphic conflicts etc. The codes of the landscape character units are composed by concatenation of the attributive data of each nature feature in the following order soils, vegetation type and geology. When read a climate, which is homogenous in the study area, has to be taken into account.

Conclusions

The current study represents a design and creation of a digital landscape model for the territory of the Teyna River watershed using the means of geo-information technologies and multivariate statistics. The main results of the analysis of landscape structure at two levels of classification and generalization shows that the results achieved are reliable and can be used in preparation of DLMs for wider territories by using the means of GIS and statistical approaches. The study also implies that landscape modelling is a tool for preparation of a reliable, fast and, ultimately, a necessary aid to support decision makers and spatial planners, landscape architects etc. The landscape character map derived from DLM is a comprehensive in nature, due to its complexity and descriptiveness. It can be utilized to numerous and various applications at any scale including spatial domain. This makes landscape modelling and DLM in particular, indispensable for any planning and decision making in the era of Sustainable Development. It is essential for land-use and landscape-ecology planning to use the available geo-information techniques in order to develop better strategies and approaches toward nature-resource management. It is important to be summarized also that stakeholders, decision makers and territorial planners are connected through GIS, RS and expert systems with actual state-of-the-art problem solving of natural and cultural landscape issues for sustainable development.

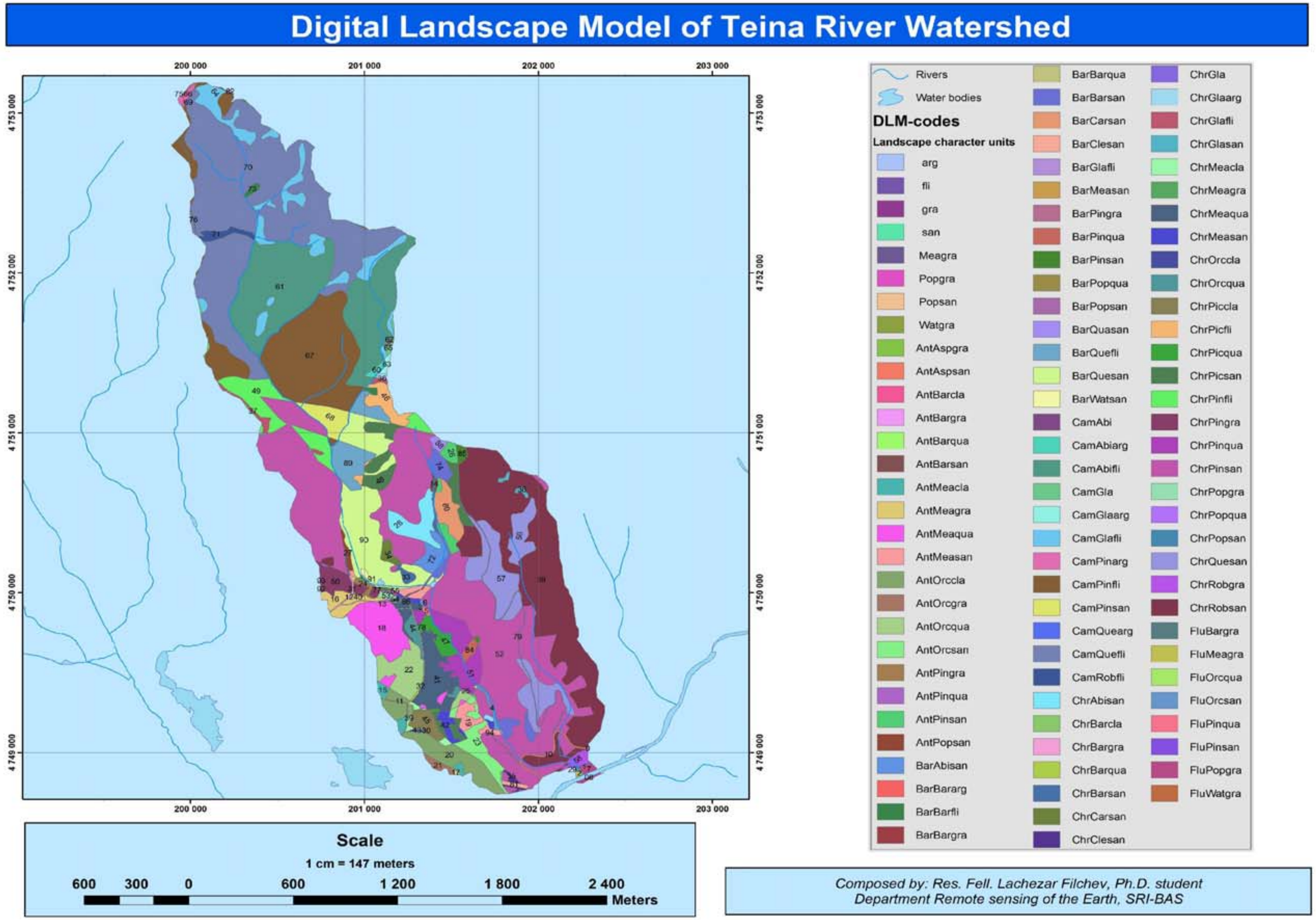

Fig. 1 Digital landscape model of the Teyna River watershed

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