LANDSCAPE-ECOLOGICAL DATABASE FOR THE PRUT HEADWATER

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Geographical and Organisational Provisions

The Prut River sources are located in the Chornohora Natural Region, the Ukrainian Carpathians. The area is notorious for the highest point in Ukraine –Hoverla (2056 m). This peculiarity, however, is not the only attraction of the locality. Alternation of harder sandstone and softer mudstone flysch stripes determined a system of scenic parallel ridges with relative heights of 300-800 m, stretching in NW-SE direction.. The geomorphology of the main watershed ridge, where Hoverla is situated, is complicated by relict cirques – consequences of Pleistocene glaciations. The glaciations also formed a trough valley normal to the stretch of the secondary ridges, occupied now by the Prut upper flow (Fig, 1).

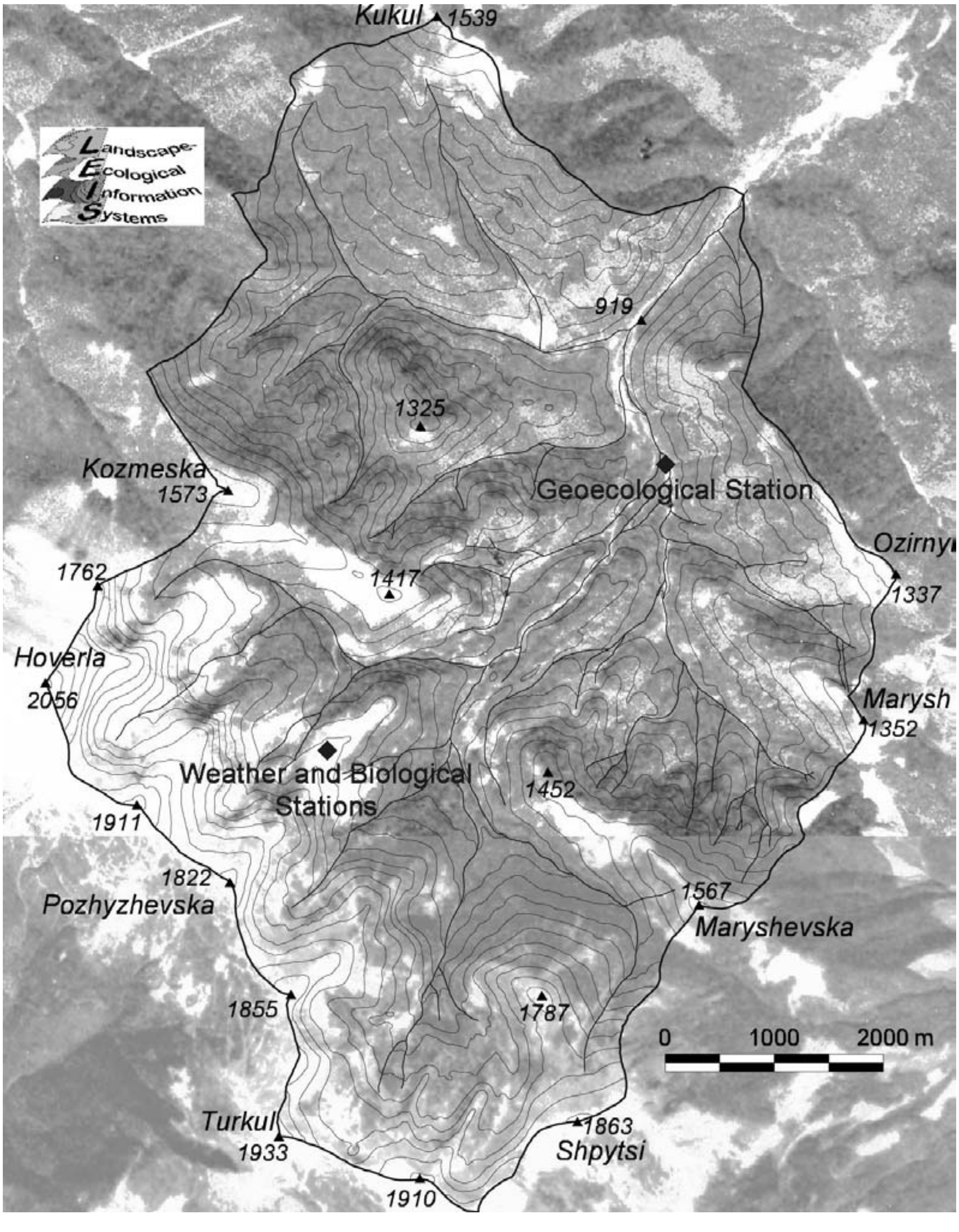

Figure. The Prut headwater basin. Satellite image overlaid with topography

Diverse geomorphology caused pronounced differentiation of the topoclimate and thus of the natural vegetation. The latter is represented by alder formations in valley bottoms; beech and fir forests at lower elevation levels (up to 1200 m); spruce forests occupying lower and intermediate height positions (up to 1600 m), formations of mountain pine (*Pinus mugo*) and juniper as well as high-mountain meadows representing the highest vegetation belts. This landscape mosaic forms habitats for numerous animals, among which one can mention brown bear, roe, wild pig, deer, or hare. Although structure of the biocenological cover has been violated in some places during decades by timber harvesting and sheep grazing, the area is known for many rare and extinctive plant species, such as *Primula halleri, Helictotrichon planiculme, Carex curvula, Lilium martagon, Salix hastata, Huperzia selago, Gentiana acaulis, Arnica montana*, as well as animals – for example, lynx, otter, owl, golden eagle, wood-grouse [1].

The idea to preserve this region as a model natural area arose at the beginning of the 20th century, and in 1921 the first portion of protected land within the headwater basin was established together with a research station on Polonyna Pozhyzhevska. In 1955 the whole basin was declared a protected area, and in 1980 it became a core zone of the newly-created Carpathian National Park [1]. In 1978 the Ivan Franko University of Lviv purchased an old tourist accommodation in the Prut valley bottom to transform it into a geographical (geoecological) research and training station. After a period of dilapidation, it has been gradually revivified since 1999.

The area is well-studied from the geological, geomorphological, climatic, pedological, geobotanical, zoological standpoints [e.g., 8, 7, 1]. It has been also used as a model for integrated terrain studies by geographers from the Ivan Franko University [e.g., 6]. For two decades it is used as a training site for the geography students, who learn here basics of integrated terrain mapping, topoclimatic and hydrological surveys, geobotanical and environmental studies.

All these developments made it appropriate to initiate formation of a respective GIS, which might be used as a model for the research and training on management of nature protected areas.

Landscape-Ecological Principles of GIS Organisation

It is decided that the GIS will be built using principles of ***landscape ecology*** – an integrated geographical and biological discipline, which studies the totality of land features (soil, air, vegetation, etc.) in its spatial and temporal differentiation. Such a totality of interacting land components is called a geosystem, or (geo)ecosystem, or, simply, landscape [9, 2].

Landscape ecology possesses rather refined methods to study spatial differentiation of the physical environment – The landscape is interpreted as a polystructural formation, whose spatial structure can be conveyed by several complementary map overlays coherent with each other. Emphasis on the study of functional relations between different land properties provides good grounds for environmental imitation modelling aimed to determine, for example, the rate of environmental change, resistance of the environment against different types of anthropogenic load, or land-use suitability [e.g., 2, 5].

These basic notions of landscape ecology are used to design the database of the GIS. Such a GIS is proposed to name a ***landscape-ecological information system (LEIS)***. The core of the LEIS database is formed by two vector map themes (layers) with polygon topology and extended attribute data. The themes represent petrogenic and landcover units [3, 4].

The ***theme of petrogenic units*** conveys spatial differentiation of landforms together with superficial continental deposits and primary soils. Such an integrated representation is based on the landscape-ecological knowledge about close inter-dependence of the mentioned land features. Furthermore, the same map layer is used to represent mosaic of edaphic habitat conditions and thus distribution of potential natural vegetation. The ***theme of landcover units*** reflects spatial structure of actual vegetation and so-called technogenic cover (e.g., architectural structures, impermeable surfaces).

The overlay of the two geographical data sets allows to establish a rather complex picture of the landscape's spatial structure determined by abiotic, biotic and anthropogenic factors. Significant reduction of map themes in the primary database as well as their improved consistency allow to minimise spatial error propagation and to avoid logical incompatibility of attribute data in multiple overlays. It is also evident that reduction of map layers improves GIS performance in complex spatial queries and modelling, and saves resources on data automation, updating and storage.

It should be mentioned, however, that the initial landscape-ecological database contains other map themes, which are used as additional sources of information, some of which are discussed below.

Initial Database Structure

The initial landscape-ecological database – i.e. the primary data sets that are used for subsequent landscape-ecological modelling – can be rather conditionally divided into a topographic and thematic ones [4]. Initial ***topographic database*** was derived from a 1:25,000 topographic map – the largest-scale material available for the area. The map revealed completely obsolete landcover information, representing situation of 1972. Therefore, it was decided to scan and rectify somewhat fresher (1985) high-resolution composite colour space photograph taken from the "Salut" Orbital Station, instead. Preliminary tests showed that the image can be processed to derive the main vegetation classes. Topographic contours, elevation points and drainage network (all digitised from the topographic map) were used to produce a hydrologically correct DEM of the area and to obtain derivative raster data sets, such as slope, aspect and slope curvature (profile and plan). Systematic information on the topographic database is given in Table 1.

Table 1

Structure of topographic database

#	Name	Format	Attribute data	Source
1	Basin's limit	Vector, lines & polygons	Boundary type	Topographic map 1:25,000
2	Elevation points	Vector, points	Elevation value, name	Topographic map 1:25,000
3	Topographic contours	Vector, lines	Elevation value	Topographic map 1:25,000
4	Drainage network	Vector, lines	Stream type, Strahler rank, Shreve rank, name	Topographic map 1:25,000, field survey
5	Trails	Vector, lines	Width, surface type	Topographic map 1:25,000, field survey
6	Composite RGB satellite image	Raster, 5x5m	None	"Salut" MKF-6 composite photograph
7	Digital elevation model	Raster, 10x10m	Elevation value	Contours, elevation points, drainage network
8-11	Slope, aspect, plan & profile curvature	Raster, 10x10m	Slope, aspect, curvature values	Digital elevation model

Thematic database embraces information that cannot be directly derived from topographic maps. Its core is to be formed by the two themes mentioned above – those of petrogenic and landcover units. However, prior to production of these overlays, some other thematic geographical data sets have to be created.

The theme on ***bedrock geology*** is digitised from the respective unpublished map compiled in the 1:50,000 scale by V. Vashchenko and colleagues (1985), Lviv Geological Prospecting Expedition. The vector layer has a line-and-polygon topology with the attribute data on geological boundaries (faults, overthrust, etc.) as well as on stratigraphy and petrology of the bedrock.

The theme of ***landscape-ecological field observation sites***, in spite of simple geometry, has an extensive attribute database. It is gradually supplemented with new data on geomorphology, soils and vegetation, collected during field surveys on relatively small sites that are cartographically interpreted as points. Their location is determined in the field with the help of portable GPS receivers. The scope of the attribute database is defined by the technique of the field landscape studies, which has been elaborated at the Ivan Franko University some time before [6] and slightly changed by the author of this paper. The point attribute table contains items on:

1. Observation point id (number format); 2. Author of the description (character format); 3. Date (date format); 4. Altitude above sea level (number format); 5. Slope (number format); 6. Aspect (character format); 7. Soil genetic type (character format); 8. Soil profile depth (number format); 9. Soil stoniness (character format); 10. Type of forest habitat according to Alekseyev-Pohrebniak (character format); 11. Tree stand composition formula (character format); 12. Tree stand canopy density (number format); 13. Tree stand age (number format); 14. Actual vegetation association (character format); 15. Potential natural vegetation (character format); 16. Link to text file with a complete description of the site (character format – file name); 17. Link to graphics file with photos of the site and of the soil profile (character format – file name).

Such a structure of the attribute database enables quick search of necessary field information via SQL as well as easy access to complete field records and colour photographs stored in a form of plain text and graphics files (Fig. 2).

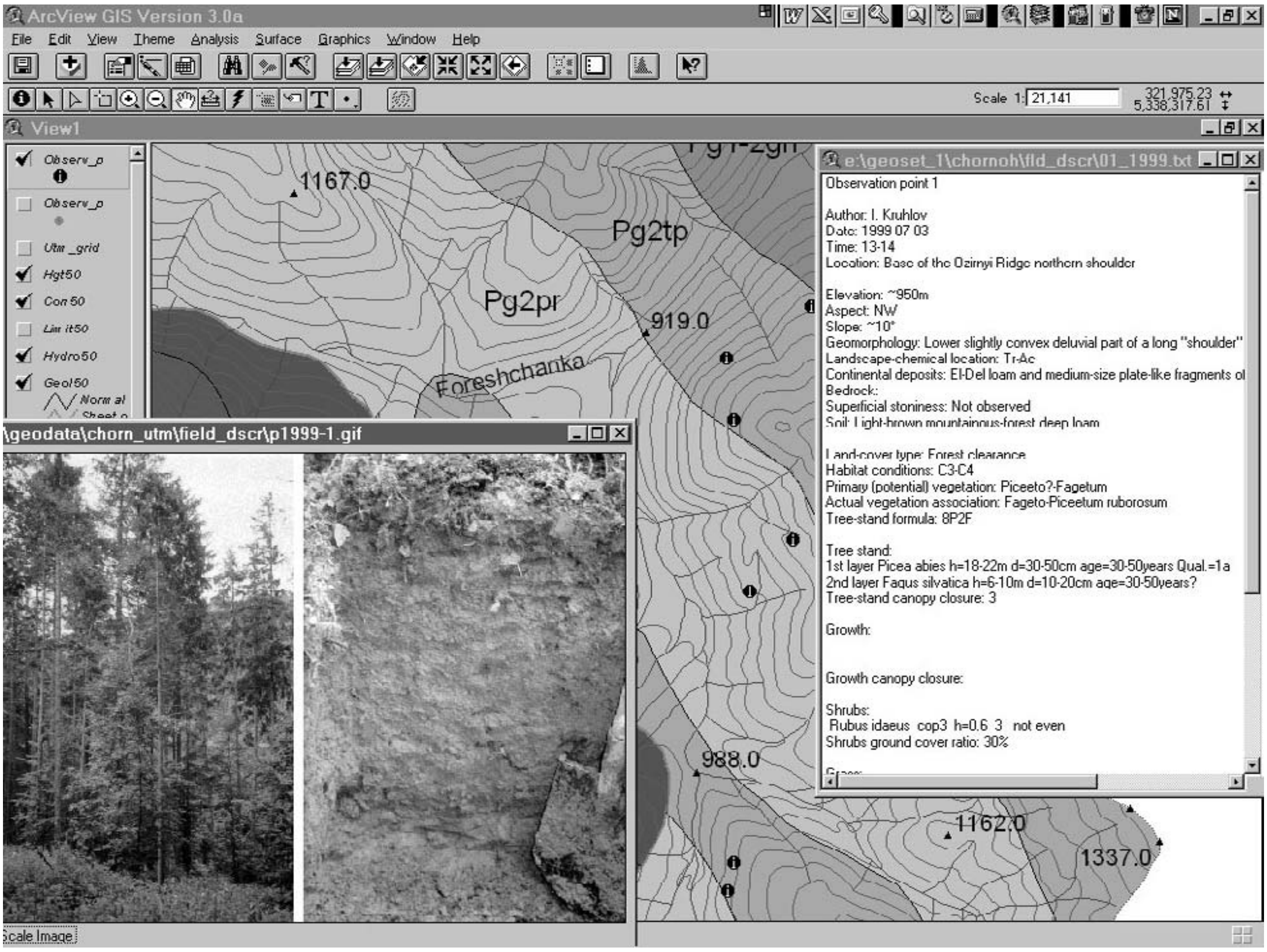

Fig. 2. Access to field landscape-ecological records via "Hot Link" in ArcView GIS

Although the theme of ***petrogenic units*** is not completed yet, it is possible already to discuss some general issues using partly experience of the previous research [3, 4]. The geometric part of the vector layer is formed by polygons of genetic landforms. The polygons are derived via manual interpretation of the topographic map with consideration of other data on geomorphology, continental geological deposits and soils. They are obtained from field observations and existing surveys [e.g., 8]. The attribute database will contain information of morphography, morphogenesis, continental deposits genetic type, continental deposits texture, primary soil genetic type, type of forest habitat, potential natural vegetation (sub)formation.

The vector polygon theme of ***landcover units*** will be automatically produced from a classified satellite image. This might be the available "Salut" image after the procedure of supervised classification. For this purpose a polygon vector layer of training areas is being produced from the point overlay of field observation sites. Preliminary results promise possibility of delineation of broad-leaf (beech, alder), coniferous (spruce and fir-spruce) and mixed (beech-fir-spruce) forests, shrub / growth formations and meadows. The classification is complicated by low spectral resolution of the image, by spectral distortions caused by contrast illumination of the steep slopes of different aspects, and by the outdated situation represented on the image (about 15 years ago).

It is planned to supplement the thematic database with a vector layer of ***catchment units***. This data set is frequently used in hydrological and topoclimatic modelling. Although it might be derived automatically from the DEM, manual interpretation of the contour map proved to give better accuracy. Systematic description of the initial thematic database is given in Table 2.

Table 2

Structure of initial thematic database

#	*Name*	*Format*	*Attribute data*	*Source*
1	Bedrock geology	Vector, lines & polygons	Geological boundaries, stratigraphy, petrology	Geological map 1:50,000
2	Field observation sites	Vector, points	Complete record on geomorphology, soil & vegetation (text & graphics)	Field survey
3	Petrogenic units*	Vector, polygons	Landforms, continental deposits, soils	Topographic, geological, geomorphological maps, field observations
4	Landcover units*	Vector, polygons	(Sub)formations of vegetation / other landcover	Classified satellite image
5	Catchment units*	Vector, polygons	Strahler rank, Shreve rank	Topographic map
6	Classified satellite image*	Raster, 5x5m	Landcover classes	Composite satellite image, field observation sites (training areas)

*Themes not completed yet

The initial landscape-ecological database described above, together with other spatially-referenced data collected in the future (e.g., on topoclimate, channel hydrology), will be used to produce more complicated and more integrated models of the Prut headwater basin.

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2. *Hrodzynskyi, M.D. 1993. Principles of landscape ecology. Lybid, Kyiv. 224 p. (In Ukrainian.)*
3. *Krouglov, I. 1997. Landscape-ecological information system for Lviv: Data base design and modeling. pp. 125-130. In: Proceedings Conf. "Cadastre, Photogrammetry and Geoinformatics". June 1997. Lviv, Ukraine.*
4. *Krouglov, I. and Bozhuk, T. 1997. Landscape-ecological information system for the Ukrainian Marmarosh. pp. 1-5. (Appendix.) In: Proceedings Conf. on Economic and Environmental Development. October 1997. Nyiregyhaza, Hungary.*
5. *Kruhlov, I. 1999. Structure of the urban landscape. Acta Fac. Rer. Nat. Universitatis Ostraviensis: Geologie-Geographie: 175: 71-89.*
6. *Miller, H.P. 1974. Landscape studies of mountainous and pre-mountainous areas. Lviv University Publisher. Lviv. (In Russian.)*

7. *Stoyko, S.M. (Ed.) 1982. Flora and vegetation of the Carpathian Reserve. Naukova Dumka, Kyiv. (In Ukrainian.)*
8. *Swiderski, B. 1937. Geomorfologia Czarnohory. Warszawa.*
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ABSTRACT

The region – a core area of the Carpathian National Park – is notorious for its scenic landscape, interesting geomorphology and diverse biocenological cover retaining many extinctive species. The geographical database for the area is being built on the principles of landscape ecology. Its topographic part is represented by vector and raster themes derived from a topographic map and a satellite photograph. The core of the thematic part of the database will be formed by two integrated vector themes – of petrogenic and of landcover units. They will substitute traditional systematic layers on geomorphology, quaternary geology, soil cover, potential and actual vegetation. To date the themes of bedrock geology and field observation sites are completed.