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A Message from the Tatra

Geographical Information Systems and Remote Sensing in Mountain Environmental Research

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GEOECOLOGICAL INFORMATION SYSTEM OF THE UKRAINIAN MARAMOROSH

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Abstract. The geoecological information system of the Ukrainian Maramorosh (GEIS) utilizes principles of geoecology to organise data about a landscape and to model its properties. The landscape is interpreted as a geoecosystem consisting of pedogeomorphic, hydroclimatic, and biocenotic features. The single vector layer of pedogeomorphic units contains information about geology, landforms, and soils. It is manually compiled using existing analogue topographic, geomorphological, and geological maps as well as special geoecological field observation data on relationships between landforms, soils, and vegetation within selected sites. The raster layer of biocenotic units is derived from supervised classification of a satellite image and further enhanced using pedogeomorphic data and geoecological information about the relations between vegetation and landforms/soils. The GEIS data layers minimize uncertainty propagation in overlay analysis and allow production of compatible systematic maps (geomorphological, pedological, geobotanical) that are both complementary to each other and supportive of more accurate, integral representation of the landscape than were the original, nonharmonized systematic maps.

Keywords: *Biocenotic units, geoecology, geoecosystem, pedogeomorphic units*

INTRODUCTION

The Ukrainian Maramorosh mountain region occupies 356 km^2 in the SW part of the Ukrainian Carpathians and embraces the left side of the White Tysa (Tisza) basin (*fig. 1*). Although the larger area of this physiographic region belongs to Romania, the Ukrainian part is an autonomous hydrological unit; the national border runs along the Tysa watershed line. The area has a significant elevation span (330–1938 m); complex geological structure (flysch, lava, limestone, conglomerate, and metamorphic formations); complicated geomorphology including steep gravitational slopes, nival and relict glacial landforms; and diverse biocenotic cover represented by deciduous, mixed, and coniferous forests as well as by subalpine shrubs and alpine meadows. Remoteness from the major transportation lines and the absence of large settlements make this region perfect for nature conservation and recreation. The Carpathian Biosphere Reserve controls this area of 89.9 km^2. (Dovhanych 1998). Intensive timber harvesting that mostly does not meet modern environmental standards also takes place in the region.

The high natural complexity and value of the area make it a good test ground for geoecological studies, particularly with the help of a geographic information system (GIS) and remote sensing (RS). Because the GIS serves as a tool of geoecological exploration, and principles of geoecology are utilised in its database structure and modelling

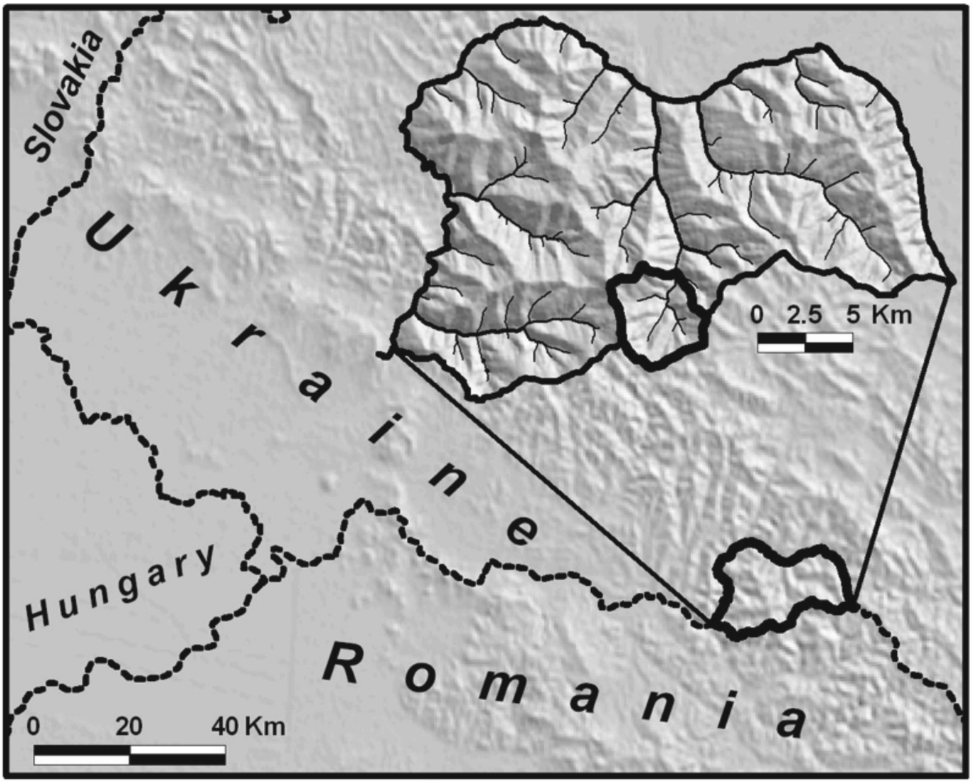

Figure 1. Location of the Ukrainian Maramorosh region and location of the model area within the region (delimited by thick black lines).

procedures, the area is designated as a geoecological information system (GEIS). It is expected that the GEIS of the Ukrainian Maramorosh will help to explore the possibilities of geoecological approach in the interpretation of environmental information and, thus, will serve as a prototype for other similar GIS projects. It is also supposed that the GEIS will contribute to the sustainable management of the area and, being a public domain, will increase societal awareness about the high natural value of the region. The third planned utilisation of the GEIS is in university courses on geoecology and land resource assessment.

The studies in the Ukrainian Maramorosh are carried out at two spatial levels. The whole region (356 sq. km) is to be covered by a dataset with an accuracy of a 1:100,000 map. The database for this spatial level is in the process of preparation. A model area of 17.4 sq. km, which is a catchment of the Kvasnyi Potik upper flow, is represented by a dataset that has an accuracy of a 1:25,000 map (the coarsest map scale available). The model area occupies the most elevated part of the region and bares all the main features of the latter (*fig. 2*). Further material deals only with the model area.

Figure 2. View on the most elevated part of the Ukrainian Maramorosh – Pip Ivan massif (photo by O. Telep, 1998).

METHODOLOGY

Theoretical background

There are somewhat different interpretations of the term "geoecology" (Huggett 1995; Bokov et al. 1996; Leser 1997; Blumenstein et al. 2000). However, the majority of the authors agree that geoecology is the science of geoecosystems as combinations of different environmental components that are studied from the standpoint of their interrelations in geographical space and time. Unlike landscape ecology, which is frequently perceived in the Anglo-Saxon science as a spatial bioecology of vertebrates (e.g., Forman 1995), geoecology focuses more on holistic, or even abiotic, aspects of interactions between the environmental components (Leser 1997, Moss 2000). While spatial boundaries of bioecosystems as objects of bioecology and biocentric landscape ecology are defined by the changes in the vegetation cover (landcover), the mosaic of geoecosystems is mainly based on landforms (Rowe and Barnes 1991). The concept of multiplicity of landscape structures (Hrodzynskyi 1993), which, in particular, envisages delimitation of diverse complementary spatial structures of geoecosystems gives the possibility to bridge the biocentric and abiocentric approaches and might be useful for the development of holistic theory of geoecology / landscape ecology. In this respect, GIS is the tool that makes this merger practically possible.

The idea of synthetic representation of different environmental properties in a GIS with the help of a single polygon layer of "integrated terrain units" has existed for some time (e.g., Aronoff, 1989). However, this approach is based on a rather mechanistic compilation of the units from different thematic maps (AIS, no date) and thus can be error-prone. Also, it does not anticipate usage of continuous geospatial data sets, such as DEMs and climatic surfaces. The alternative is to handle several vector and raster layers representing different properties of geoecosystems that can be merged according do different geoecological models, depending on the objectives of the application. Unlike the data sets of a conventional GIS, these layers are harmonized and organized according to geoecological notions and thus yield minimal uncertainty propagation in multiple overlays.

Developing the idea of Solntsev (1960) about different nature and organization of landscape components, the geoecosystem can be perceived as a combination of the three main groups of properties (components): 1. Pedogeomorphic (landforms and geomorphic process, parent rock, soil); 2. Hydroclimatic (radiation, thermal, and moisture regimes); 3. Biocenotic (vegetation, zoo population). These groups of geosystem's properties can be represented by respective geospatial datasets.

Techniques

Software

ArcGIS and Erdas Imagine packages were used in this study.

Data sources

Geospatial data were prepared from paper maps in the scale 1:25,000 available for the study area. These were topographic, geological and geomorphological maps as well as a rather outdated map of forestry taxation. The other data sources are field observations conducted during August 2000 and an Aster VNIR image of October 2001 (15x15 m spatial resolution, green, red and near-infrared bands).

Database structure

The database includes georeferenced scanned copies of the source paper maps and the satellite image as well as other derivative vector and raster overlays. The latter include topographic features such as vector layers of elevation points, stream network, and contour lines (5-to–25 m intervals), which were used to produce a 10x10 m digital elevation model (DEM) and the derivative surfaces – slope, aspect, curvature, hillshade. Thematic features are represented by a point layer of geoecological field observation sites together with a polygon layer of train areas; a polygon layer of pedogeomorphic units; and a raster layer of biocenotic/vegetation units (*fig. 3*).

The vector layer of ***geoecological field observation sites*** has point geometry and an extended attribute database, which contains information about relatively small areas (about 20 m in radius) described during field studies. The attributes contain detailed data on geomorphology, soil properties, and biocenology (phytosociology) including information on species composition, morphology of vegetation layers, and habitat characteristics. Text descriptions are supplemented by digitised photographs of respective

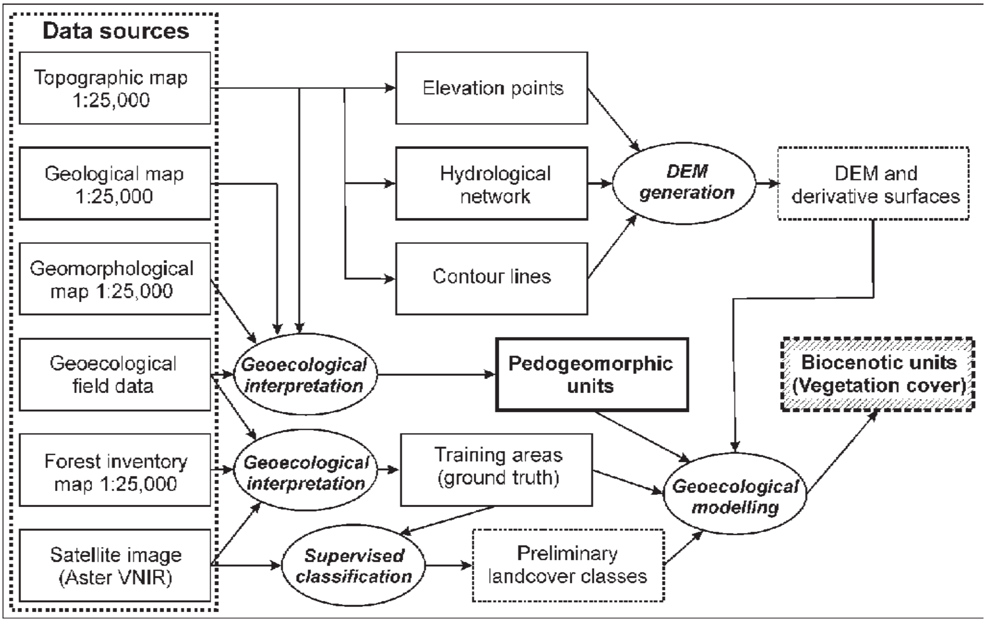

Figure 3. The structure of the database and the procedure of the data generation.

vegetation cover and soil profiles. The observations were done according to existing methodology (Miller 1974) with some minor improvements. The superimposition and comparison of the field observation data with the forest taxation map and the satellite image gave grounds to delineate training areas, which then were used for the supervised classification of the image.

The vector dataset of ***pedogeomorphic units*** is the result of geoecological synthesis of several information sources. Geoecological interpretation of the topographic, geological and geomorphological maps, which is also based on the field experience, afforded delimitation of the landform polygons with certain combinations of morphography, morphogenesis, and parent rock material. These landforms were used to spatially interpret basic soil characteristics obtained during field studies at the observation sites and hence to supplement the dataset with the soil information. The polygon attribute table contains entries on morphography, average slope and curvature, morphogenesis, geomorphic processes, soil genetic type, soil depth and rockiness. Pedogeomorphic units are grouped into regions representing pedogeomorphic complexes. The polygon dataset also bears line topology conveying special linear geomorphic features – ridge crests, scarp edges, etc. This vector layer substitutes several traditional thematic datasets (those on geology, geomorphology, and soils) offering harmonised information about the features and thus yielding minimal spatial uncertainty.

The raster layer of ***biocenotic units (vegetation cover)*** was obtained via geoecological interpretation of the Aster satellite image. First, the training areas were defined using field data, forestry inventory map, and the image (see *fig. 3*). However, signatures of some vegetation classes (e.g., willow-alder growth, maple-beech forest, alpine meadow, and after-forest secondary meadow) were very much alike. Therefore, maximum likelihood classification of the image did not mange to discriminate some of the vegetation classes. To further process the dataset, information about geoecological relationships between the vegetation and landforms/soils was used – namely, Solntsev's (1960) idea about the controlling role of pedogeomorphic factors in local geospatial differentiation of the climate and vegetation. The field observations and regional literature sources (Deyl 1940, Malynovskyi 1980) provided necessary additional information to describe geoecological relationships – i.e., between vegetation, soil, and landforms. The data on the landform and soil distribution were taken form the layer of pedogeomorphic units. Subsequent geoecological modelling in the GIS environment resulted in the improved layer of biocenotic units.

RESULTS AND DISCUSSION

The obtained datasets of pedogeomorphic and biocenotic units more accurately convey spatial differentiation of the landscape, when compared with the available set of original thematic systematic maps that are compiled by different authors and do not consider various geoecological interrelations/correlation between the landscape components – i.e., systematic information (about landforms, soils, vegetation) is harmonised in the geoecological database. The datasets have compatible geometry and attribute information. This is especially important for the subsequent spatial modelling (e.g., sectoral resource assessment), because will yield minimal uncertainty propagation in GIS overlay operations. The GEIS allows production of vivid thematic maps with synthetic and complementary contents (*figs. 4* and *5*), which give impression about the interdependencies between different landscape features.

It was found out that the layer of pedogeomorphic units can have a limited use in the interpretation of the spatial distribution of natural potential vegetation (NPV) – significant elevation spans (up to 800 m) within relatively homogeneous fluvial landforms of ridge slopes produce distinct differentiation of ecoclimatic conditions and thus cause heterogeneity of the NPV. Usually, lower parts of the slopes have beech formations as NPV, while their upper parts – spruce formations. Ecoclimatic interpretation of DEM data should be used as a supplement to the pedogeomorphic information to model spatial distribution of the NPV.

It should be also mentioned, that manual compilation of the layer of pedogeomorphic units from several "feature" maps is a time-consuming, intellectually intensive, and potentially error-prone job, which can be justified in case, when the maps are not available in the digital form (our case). Application of reductionistic geoecological models, like the idea of a controlling pedogeomorphic factor in vegetation distribution, for the enhancement of the landcover classification may lead to somewhat speculative results in case of limited ground-truth information and/or "crisp" (non-overlapping) classification categories.

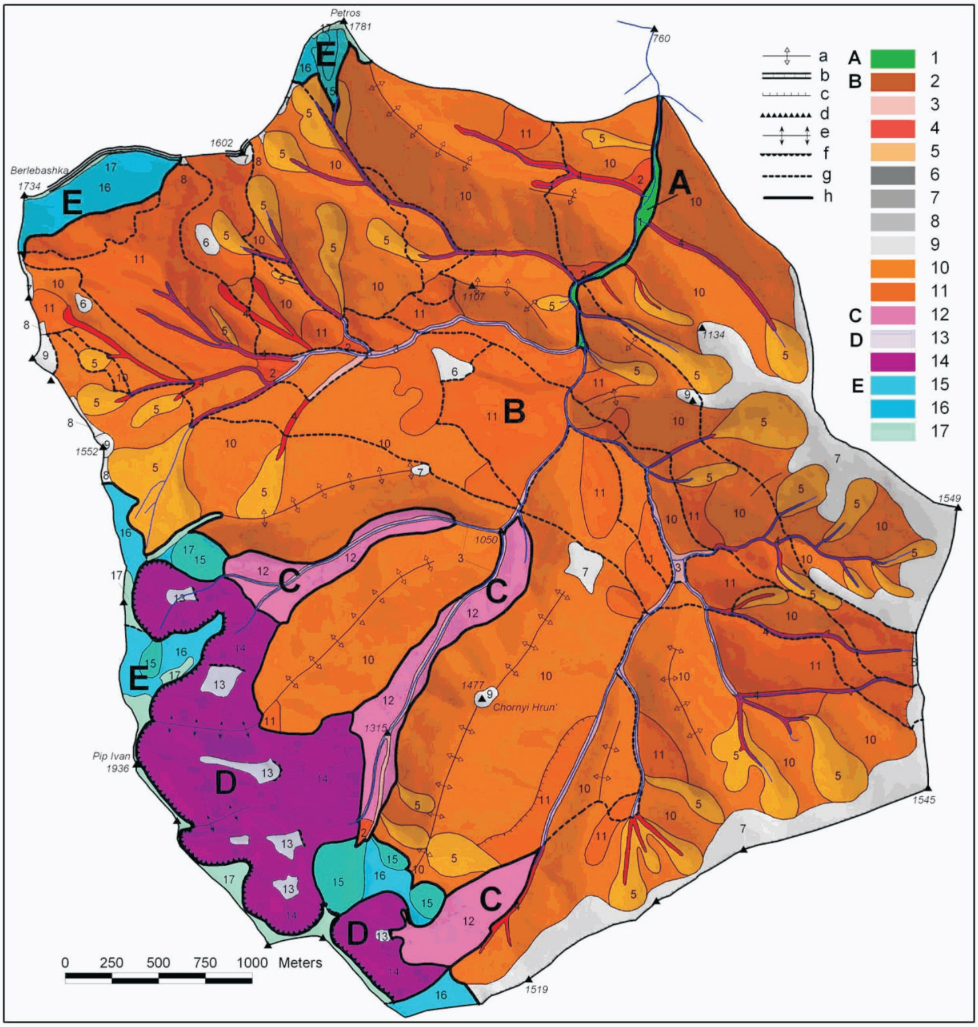

Figure 4. Kvasnyi Potik headwater basin. Pedogeomorphic complexes. Explanations: **A.** Fluvial accumulation landforms with alluvial brown soils; **B.** Fluvial and gravitational landforms with mountain-forest brown soils; **C.** Relict glacial and fluvial landforms with mountain-forest brown soils; **D.** Relict glacial, gravitational, and nival landforms with sod-brown mountain soils; **E.** Nival and gravitational landforms with sod-brown mountain soils. **a.** "Hog-back"-type ridges and spurs; **b.** Tension cracks; **c.** Landslide disengagement walls; **d.** Cirque scarps; **e.** Arète; **f.** Rock terraces; **g.** Petrologic boundaries; **h.** Boundaries of pedogeomorphic complexes.

CONCLUSIONS AND RECOMMENDATIONS

As demonstrated on the example of the small catchment in the Ukrainian Maramorosh, principles of geoecology are useful for harmonising thematic systematic geospatial environmental information. However, wider application of the geoecological approach in the construction of environmental GIS may require further improvements in the methodology. It looks expedient to develop an algorithm for the automatic, or semiauto-

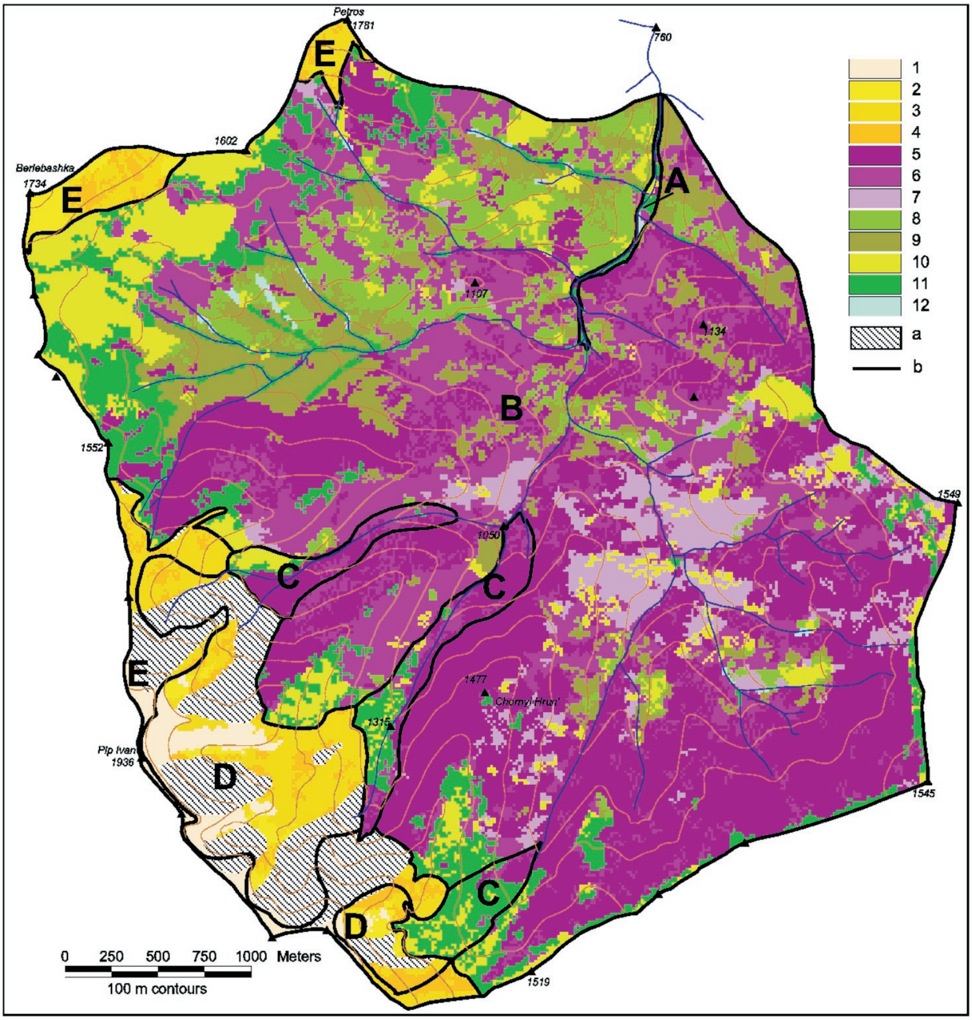

Figure 5. Kvasnyi Potik headwater basin. Biocenotic units. Explanations: **1.** Alpine meadows; **2.** Secondary subalpine meadows; **3.** Subalpine meadows with shrubs (*Alnus viridis, Juniperus sibirica, Pinus mugo)* and spruce low light forest; **4**. Subalpine shrubs (*Alnus viridis, Juniperus sibirica, Pinus mugo*) and spruce low light forest; **5**. Spruce forests; **6**. Spruce forests with developed understorey; **7.** Spruce low forest; **8.** Beech and maple forests; **9.** Mixed forests (beech, fir, maple, spruce); **10.** Secondary after-forest meadows; **11.** After-forest succession with deciduous shrubs (*Rubus ideaus, Alnus viridis*); **12.** Shrubs and low forest with *Alnus incana* and *Salix*. **a.** Areas of intensive shading (not classified); **b.** Boundaries of pedogeomorphic complexes (see *fig. 4*).

matic, compilation of a single layer of pedogeomorphic units using the digital thematic systematic maps. Provisions should be envisaged for the probabilistic characterisation and evaluation of the vegetation distribution according to pedogeomorphic units. The GEIS lacks hydroclimatic data at this time, which can be also used to increase the reliability of vegetation classification – ecoclimatic characteristics of dominant plant species can be added then as additional parameters for the geoecological interpretation of the landcover data (e.g., Guisan and Zimmermann 2000). The methodology of geoecological harmonisation and interpretation of environmental thematic systematic information will be verified and improved on a medium-scale dataset embracing the whole Ukrainian Maramorosh.

REFERENCES

AIS (Aerial Information Systems). (No date) *Integrated Terrain Unit Mapping*. Redlands, Ca.

Aronoff, S. (1989) *Geographic Information Systems: A Management Perspective*. Ottawa: WDL Publications.

Blumenstein, O.; Schachtzabel, H.; Barsch, H.; Bork, H.-R.; Küppers, U. (2000) *Grundlagen der Geoökologie*. Berlin: Springer-Verlag.

Bokov, V.A.; Yena, A.V.; Yena, V.G. et al. (1996) *Geoekologiya (Geoecology)*. Tavriya, Simferopol.

Deyl, M. (1940) *Plants, Soil and Climate of Pop Ivan: Synecological Study from Carpathian Ukraine*. Opera Botan. Čechica., Praha.

Dovhanych, Ya. O. (ed.) (1998) *Pryrodookhoronnyi Fond Zakarpattya. Dovidnyk. (Nature Protected Fund of Transcarpathia. Reference Book)*. Uzhgorod.

Forman, R.T.T. (1995) *Landscape Mosaics: The Ecology of Landscapes and Regions*. Cambridge: Cambridge University Press.

Guisan A.; Zimmermann N.E. (2000) Predictive habitat distribution models in ecology. *Ecological Modelling* 135, 147–186.

Hrodzynskyi, M.D. (1993) *Osnovy Landshaftnoyi Ekologiyi (Principles of Landscape Ecology)*. Lybid, Kyiv.

Huggett, R. (1995) *Geoecology: An Evolutionary Approach*. London: Taylor and Francis.

Leser, H. (1997) Landschaftsökologie und Geoökologie. Ansätze, Probleme, Perspektiven. *Karlsruher Schriften zur Geographie und Geoökologie* 7, 1–12.

Malynovskyi, K.A. (1980) *Roslynnist' Vysokohir'ya Ukrayinskyh Karpat (Alpine Vegetation of the Ukrainian Carpathians)*. Naukova Dumka, Kyiv.

Miller, G.P. (1974) *LandshaftnyyeIssledovaniya Hornyh i Predhornyh Territoriy (Landscape Studies of Mountainous and Pre-Mountainous Areas)*. Vyshcha Shkola, Lvov.

Moss, M.R. (2000) Landscape ecology: The need for a discipline? In: Richling, A.; Lechnio, J.; Malinowska, E., eds. *The Problems of Landscape Ecology. Vol. VI.* Warsaw; 172–185.

Rowe, J.S.; Barnes, B.V. (1994) Geo-ecosystems and bio-ecosystems. *Bulletin of the Ecological Society of America* 75, 40–41.

Solntesv, N.A. (1960) O vzaimootnosheniyah "zhyvoy" i "myortvoy" prirody (On the interactions between "animate" and "dead" nature). *Herald of Moscow University. Geography Series* 6, 10–17.

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