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Model of Position-Dynamic Structure of River Basins.

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ABSTRACT

In this work, we have presented semi-automated means of modeling of position-dynamic structure (PDS) of river basins' landscapes with application of geo-informational systems (GIS). Results of modeling were tested on the basin of one of headwaters. The structure of the model includes landscape lines, layers, sub-regions and regions. The model takes into account conditions of formation of landscape's PDS in mountain and plain parts of river basins.
Keywords: landscape, position-dynamic structure, river, river basin, GIS modeling.

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INTRODUCTION

Position dynamic model of river basins is based on detachment of landscape outlines with single-types flows of substances and energy, which allows reflecting organization of river basin representatively, and to develop the series of actions of natural resource management and preservation of quality of water resources, which is especially topical at basin approach to natural resource management.

The main principles of analysis of basin landscape structure are presented in many works of foreign [1, 2] and domestic [3-5] scientists. Basin landscape structure is represented by territorial units (bands, layers, sub-regions and regions), which are formed because of hydro-functioning [6]. In modern works, dedicated to study of landscapes GIS are widely used: at mapping or classification of landscapes [7, 8], at soil-landscape [9, 10] and landscape-geochemical [11] modeling.

While analyzing position-dynamic structure (PDS) of landscapes GIS is used for automated detachment of small watersheds in river basin on the base of analysis of digital elevation model (DEM) and hydrologic modeling [12]. Analysis of DEM allows automating detachment of position-dynamic units – elementary slopes [13, 14]. In practice, results of landscape modeling may be used for assessment of erosive danger at development of projects of automated erosion-preventive arrangement of watersheds [15], for solving hydro-ecological problems [16], as well as for development of strategy of regional geo-planning [17].

Landscapes of Crimean river basins were investigated by A.N. Oliferov, V.A. Bokov, Ye.A. Pozacheniuk, Z.N. Timchenko et al. [18-23]

This article contains the method of composing a model of river basins with PDS landscape with application of GIS technologies. This technology was used for implementation of model for river basin of Malyi Salgir, which is located at northern macro slope of Crimean Mountains.

MATERIALS AND RESEARCH METHODS

Base materials for learning PDS of river basins are topographic, soil and geologic maps, vegetation maps, materials of remote sensing and field investigations. At composing the PDS scheme of the river basin program complex ArcGIS 10.1 and ArcHydro application were used, which allow viewing morphometric peculiarities of the territory, detach basin structure and perform a range of analytical procedures. Development methodology of PDS model was tested at investigation of river basin of Malyi Salgir, which flows from karst source at a height of 700 m. River length is 22 km, the square of the basin is 96.1 km^2. Preliminary stage of development of PDS model of river basin is justification of scale of cartographical landscape units. At studying of PDS of Crimean small rivers and water flows of the 1st and 2nd order (according to classification of V. Filosofov – A. Straler), operational scale of 1:50000 was adopted.

THE MAIN PART

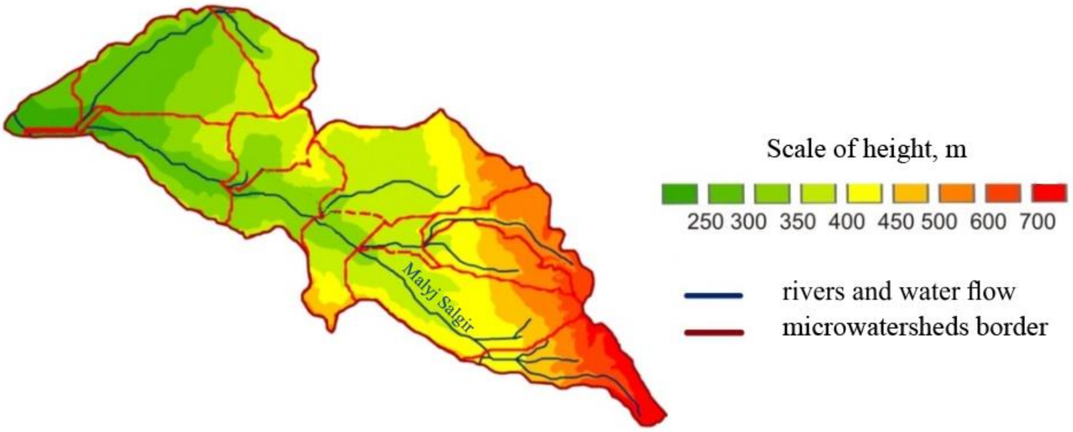

Figure 1: Detachment of micro-watersheds in the Basin of Malyi Salgir River

The method of development of PDS model included several stages. The first stage consisted in creation of map of basin territorial structure. Analysis of basin structure was performed on the base of DEM. Raster schemes of cumulative flow were built, and the orders were assigned to each link of erosive net according to the scheme of Filosofov – Straler. Creation of basin structure is finished with definition of borderlines of micro-watersheds and river basins with the help of ArcHydro application (Figure 1).

The second stage consisted in creation of morphometric maps (maps of slopes and exposition). Slope differentiation define position-dynamic peculiarities of landscapes. At modeling of PDS basin of Malyi Salgir river, gradation, composed according to [24, 25]: 1°, 3°, 5°, 7°, 10°, 15°, 30° and more, has been adopted. Building of the map of slope exposition was performed according to four quadrantal bearings. Maps of slopes and expositions were built according to DEM, with the usage of Spatial Analyst instrument (Figure 2).

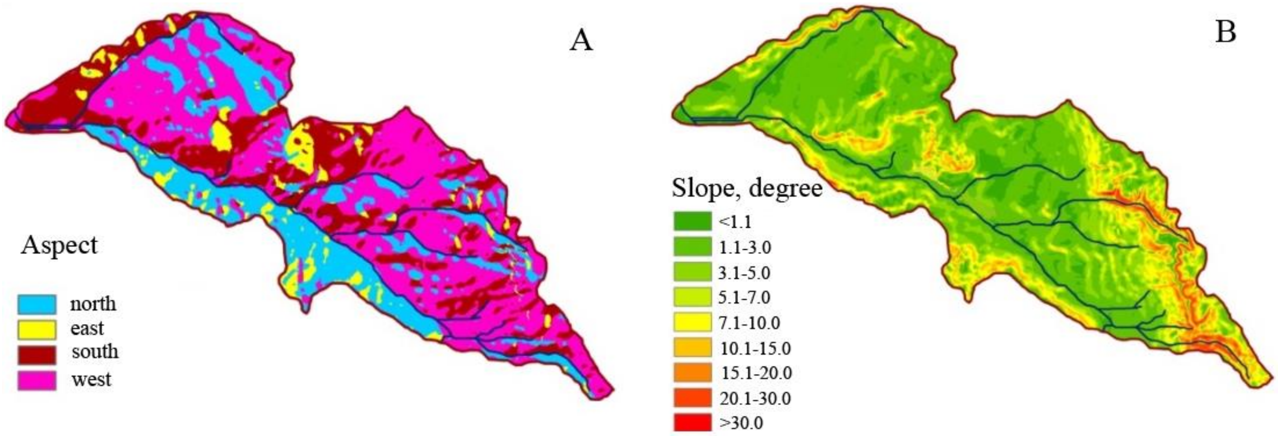

Figure 2: Morphometric maps of basin Territory of Malyi Salgir River: A – expositions; B – steepness

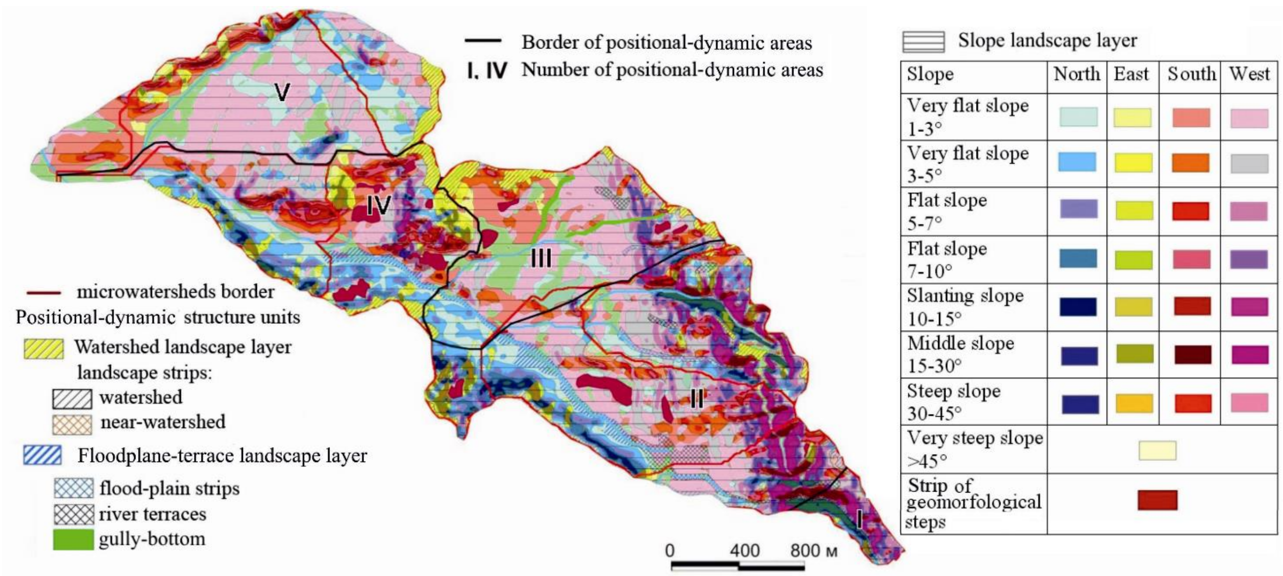

Figure 3: The scheme of position-dynamic structure of Malyi Salgir River

Then, framework lines of the landscape were detached, disposition of which influence the intensity of substance and energy flows, the speed of water erosion of soils and other processes. We detached watersheds' dividing lines, valley lines, shoulders, bottoms of slopes, hinge lines for selected micro-watersheds (with the help of building transversal hypsographical profiles from watersheds to valley lines). Information about soil and vegetation was obtained from corresponding maps, complemented with application of satellite images and confirmed at field researches.

The third stage implied detachment of territorial units of PDS and creation of the model. Using obtained volume of special data on micro-watersheds, we detached landscape bands, layers and regions.

Borders of landscape bands go across framework lines of the landscape; within their limits steepness of slope, soil and character of micro-relief must be relatively homogeneous. That is why maps of steepness and sloped that had been earlier obtained, were combined by means of overlay and geo-morphologically homogeneous units w of PDS landscape were detached. Thus, at the territory of the basin we automatically detached 6300 landscape outlines of various morphological types (Figure 3).

In spite of the fact that square of basin of Malyi Salgir river is relatively small, it is characterized by diversity of slope landscape bands, in formation of which the main role is played by relief. Conditions of PDS formation in mountain parts of the basin differ from plain ones. Not only valley lines and watersheds, but also general high position in this case present drain-forming landscape borders.

Landscape outlines with close landscape and ecologic conditions are connected with mono-directional fluxes, have common position with reference to hypsographical borders of change of landscape dynamics' factors, and they may be united into landscape layers. At the territory of the basin, in question landscape outlines were logically united into three groups of layers according to their morphological characteristics: watershed, slope and bottomland-bench ones (refer to Figure 3). Watershed layer occupies the highest surfaces and bands of slopes that are located near the watershed. Those are the warmest and driest landscape bands in the basin; erosive processes are low. Slope layer includes bands of various steepness and exposition, which are characterized by medium (5-7°) and strong (>7°) manifestation of erosive processes. Bottomland-bench layer is represented by wetted floodplains and bottoms of hollows. It is characterizedby transit and accumulation of solid and liquid drain, which are formed in upper layers.

According to unidirectionality of horizontal flows, landscape layers are united into position-dynamic sub-region, which is associated with the left or right part of the basin, and which has one macro-exposition. Sub-regions compose the highest unit of PDS – position-dynamic region. For example, according to structure of location of bands and layers at the territory of Malyi Salgir river, we have detached five position-dynamic regions, which reflect basin's location in mountain and piedmont parts of Crimea.

CONCLUSION

Developed model of river basin is a semi-automated system of detachment of PDS of river basins' landscapes, which may be passed on. The model has been tested at studying landscapes of Malyi Salgir river basin (Crimea).

SUMMARY

The model of landscape PDS reflects dependency of natural conditions from terrain elevation, location of landscape outlines with reference to significant borderlines, along which the change of intensity and direction of horizontal substantial and energetic flows occur. The model structure includes landscape bands, layers, bub-regions and regions, We have developed semi-automated system of detachment of PDS of river basins' landscapes, which includes automated operations 9detachment of landscape outlines in GIS) and logic or analytical (unification of outlines into position-dynamic layers and regions) ones. As a result of modeling, we studies PDS of key basin and created complex landscape geographic informational system, which contains information about relief, morphometric peculiarities, hydrography, soil covering, vegetation and characteristics of landscape units, detached at the territory of analyzed area.

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