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Environmental Assessment of Basin Geosystems Based on the Landscape Approach

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The article presents the methodology of environmental assessment of the state of a river basin based on the landscape approach using geoinformation systems. This study implements the landscape approach to evaluation, when types of terrain, i.e. the natural geographical systems, act as the spatial-operational units, which ensures the objectivity of the obtained results. The main land use categories are used as the factor of anthropogenic pressures. With this purpose, a spatial database of the functional use of the studied territory, based on the results of a satellite image analysis, was created.

Key words: Environmental assessment, watershed, Anthropogenic pressures, landscapes, geoinformation systems, RSD.

The basin of the Kazanka River is located at the junction of two landscape areas: Its major part (the whole right bank of the river, the midstream and upstream waters) belong to the boreal landscape area, and the right bank (the interstream area between the Kazanka and Mesha Rivers in the midstream and downstream waters) belongs to subboreal northern semihumid landscape area. The major part of the basin is located in the Kazan uphill area with the Transural pine and spruce forest (where pines and spruces prevail) and broad-leaved and spruce nemoral-herb and partially broad-leaved forests (with lindens and oaks) on the dark grey forest and sod-podzolic soil[1].

The area is located in the boreal landscape zone, sub-taiga landscape zone. Geographically, it is located in the northwest of the Republic of Tatarstan (in the Regions of the Zapadnoye Predkamye). The territory of the area lies between the border of Tatarstan with the Mari El Republic in the west, and the Malaya Mesha River in the east. The northern border goes along the watershed of the right slope of the Kazanka River valley. The southern border starts near the City of Kazan from the creek of the Kazanka River and goes along the watershed of the Kazanka and Mesha Rivers until the head of the Nyrsa River in the East. The main part of the area relates to the Vysokogorsk and Arsk administrative districts. In the west, it partially includes the territories of the Zelenodolsk and Atninsk districts, and in the east – of the Sabinsk, Pestrechinsk, and Tyulyachinsk districts. The total square of the landscape area is 2,473 km^2 [2].

Currently, a wide range of geoinformation methods is applied at studying landscapes and adverse processes influencing on them, including the anthropogenic processes[3], as well as at carrying out environmental evaluation of landscapes [4].

Research methodology and results. Let us consider the landscape structure of the Kazanka River basin. Directly within the boundaries of the

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basin, we determined the quantitative ratio of landscapes (terrain types).

Analysis of these data (Table 1) gives reasons to say about the dominance in the landscape structure of the basin of middle and lower parts of slopes with light-gray forest and sod-podzolic soils lying on the deluvial-soliflual clay loam (33.5 and 13.8%, accordingly). They are followed by natural-territorial complexes at the watershed parts of slopes with light-gray forest soils in the eluvial-deluvial deposits (9.5%) and floodplain landscapes formed on alluvial sod-saturated soils (8.2%)[1].

For quantitative analysis of the land management in the territory of the Kazanka River basin, a geospatial database of the functional use of the territory was created. The Landsat-5 satellite image shot in August 2009 was used as the source material. The image was made by the TM (Thematic Mapper) multispectral scanning system operating in seven spectral ranges of the visible, near, medium infrared and thermal infrared parts of spectrum. This image is of medium resolution (30 m), which corresponds to the scale of 1:100,000. Thus, it is best suitable for identification of the main land use types on the regional level of generalization[5].

In the first phase, visual interpretation of the satellite image was conducted, which resulted in a list of main types of the territory usage and provided a set of interpretive attributes, by which the considered land categories are identified. The classification of the Canadian Forest Protection Service[6] supplemented with account of the local peculiar features was taken as the basis.

Identification of the land use types was carried out in different ways

Forests, water basins, and hayfields and pastures were identified using the "Definiens Ecognition" object-oriented image analysis software (Fig. 1). The object-oriented analysis method assumes initial selection on the image of the objects (segments) of areas of relative uniformity of color (texture and brightness). Only after that, the classification of these objects is carried out by the conventional spectral-brightness characteristics and the geometric parameters (shape, size, orientation, etc.), the context parameters (entry into larger objects or areas, proximity to objects of a certain class, etc.), and the texture parameters[7]. Such a system allows processing not only satellite images, but also other types of remote sensing data. For example, it is well suited for the separation and removal of artifacts in digital elevation models[8].

For the most accurate selection of different types of land use, it is advisable to apply different levels of image segmentation and individually select the indicators. The indicators must be typical of the respective object, and at the same time should not have wide scatter of values within the same class. This will allow avoiding typical mistakes at classification: association of objects of other types with the target class; association of objects of the target class with other classes.

In accordance with these requirements, the algorithm of identification of these types of functional use of the territory, which is a tree of sequential processes, has been developed[9].

At creating an algorithm, it is important to think well on the sequence of classes separation so that, having excluded classified objects from further processing of the image, you could simplify the identification of the remaining classes. It should be noted that in the developed algorithm, the process of identification of each type of land management includes a set of procedures:

1. image segmentation;
2. class separation;
3. "gaps" removal (if necessary);
4. classification results generalization;
5. uniting the neighboring objects of the same class into single ranges.

The rest categories of land use were vectorized manually with the Easy Trace software. Special attention was paid to decryption of the lands of settlements, as the territory of the City of Kazan was included in the basin boundaries. Besides, depending on the category, these lands influence to various degrees on the landscapes, which is important at further evaluation[10].

All vector layers, which were obtained by automated processing and manual vectorization, were corrected in accordance with the rules of topology.

In the result of the work, a spatial database on the main types of land use in the basin was obtained, and their areas (for polygonal objects) and lengths (for linear objects) were calculated. (Table 2). In the same manner,

Table 1. Distribution of the terrain types in the Kazanka River basin

The genetic type of deposits	The morphogenetic type of the terrain	Soil types	Square	
			ha	%
Alluvial	I and II benches of small rivers	Sod-podzolic	4,160	1.49
		Light-gray forest soil	803	0.29
		Gray forest soil	394	0.14
		Alluvial sod-saturated soil	566	0.20
	IV and VI benches of large rivers	Sod-podzolic	10,060	3.59
		Sod-carbonate leached and degraded soil	69	0.02
		Light-gray forest soil	1,279	0.46
		Gray forest soil	82	0.03
	III benchof large rivers	Sod-podzolic soil	1,244	0.44
		Light-gray forest soil	144	0.05
	I and II benches of large rivers	Sod-podzolic soil	6,882	2.46
		Light-gray forest soil	179	0.06
		Alluvial meadow-boggy soil	192	0.07
	Slopes of benches of large rivers	Sod-podzolic soil	2,923	1.04
		Sod-carbonate leached and degraded soil	105	0.04
		Light-gray forest soil	491	0.18
		Alluvial meadow-boggy soil	344	0.12
	Flood basin	Alluvial sod-saturated soil	22,850	8.16
Eluvial-deluvial soil	Watersheds	Sod-podzolic soil	3,897	1.39
		Light-gray forest soil	9,435	3.37
		Gray forest soil	364	0.13
	Near watershed parts of slopes	Sod-podzolic soil	9,991	3.57
		Sod-carbonate leached and degraded soil	57	0.02
		Light-gray forest soil	26,590	9.49
		Gray forest soil	1,089	0.39
	Medium parts of slopes	Sod-podzolic soil	87	0.03
Deluvial-soliflual soil	Medium parts of slopes	Sod-podzolic soil	17,790	6.35
		Sod-podzolic typical soil	782	0.28
		Sod-carbonate leached and degraded soil	444	0.16
		Light-gray forest soil	75,920	27.11
		Gray forest soil	5,513	1.97
		Dark-gray forest soil	1,004	0.36
	Lower parts of slopes	Sod-podzolic soil	13,710	4.90
		Sod-carbonate soil	1,264	0.45
		Sod-carbonate leached and degraded soil	655	0.23
		Light-gray forest soil	38,590	13.78
		Gray forest soil	4,468	1.60
		Dark-gray forest soil	2,366	0.84
		Degraded humus	232	0.08
		Alluvial sod-saturated soil	684	0.24
Deluvial-soliflual soil lying on the alluvial soil	IV and VI benches of large rivers	Sod-podzolic soil	6,495	2.32
		Light-gray forest soil	2,353	0.84
		Gray forest soil	1,225	0.44
	III bench of large rivers	Sod-podzolic soil	1,932	0.69
		Light-gray forest soil	5	0.00
	Slopes of benches of large rivers	Sod-podzolic soil	138	0.05
		Light-gray forest soil	156	0.06
		Gray forest soil	44	0.02

the thematic map of the functional land use was built (Fig. 2).

This was followed by quantitative evaluation of existing anthropogenic pressures on the landscapes of the Kazanka River basin. The following methodology based on GIS technology was used[1].

1. Scores were assigned to different types of land use through expert evaluation, reflecting the degree of direct or indirect

Table 2. Distribution of the land use according to the results of decryption

Areal objects			
Land use category		Area, ha	Area, %
Agricultural land	Mowing and grazing land	41,090	14.6
	Crop land	159,400	56.7
Forest	Leaf and mixed forest	28,480	10.1
	Coniferous forest	9,989	3.6
	Deforestation and glades	2,049	0.7
Settlements	Urban area	9,269	3.3
	Industrial zones and construction sites	4,147	1.5
	Rural area	17,440	6.2
	Cottage settlements	4,434	1.6
	Green area	1,348	0.5
	Airport	239.4	0.1
	Military ground	762.3	0.3
Water reserve land	Basins	2,245	0.8
Total	280,892.7	100.0	
Linear objects			
Land use category	Length, km		
Transport land	Highway	403.3	
	Ground road	1,127.0	
	Railroad	108.4	
Water reserve land	Rivers	1,650.0	

Table 3. Score pressures of various types of land use of the land on the geosystems

Land use category		Score of pressures
Agricultural land	Hayfields and pastures	2
	Crop land	4
Forestry land	Leaf and mixed forest	1
	Conifer forest	1
	Openings and cleared strips	4
Land intended for building	Urban developments	5
	Industrial and construction areas	5
	Rural settlements	4
	Holiday settlements	3
	Green areas	2
	Airport	5
	Tank training battlefield	5
Water reserve land	Basins and rivers	1
Transport lands	Highway roads	5
	Unsurfaced roads	4
	Railway road	5

impact of this type of land management on the geosystem (Table 3). Scores take values from 1 to 5, ascending as the impact increases (from low to high).

2. Based on maps of land use in the studied territory (see Fig. 10.6), a raster layer of the anthropogenic pressures was created, in the cells of which scores of the pressures are recorded in accordance with Table 3. The cell size of the raster is 30 × 30 meters.
3. The average value of the scores of the raster cells' pressures corresponding to this division was used as the evaluation of the anthropogenic impact on the landscape

Table 4. Score sustainability of different landscapes (type of terrain) to anthropogenic impact

Terrain type	Stability score
Watershed, bench systems	1
Slope systems	2
Flood basins	3

Fig. 1. Example of water basins separation

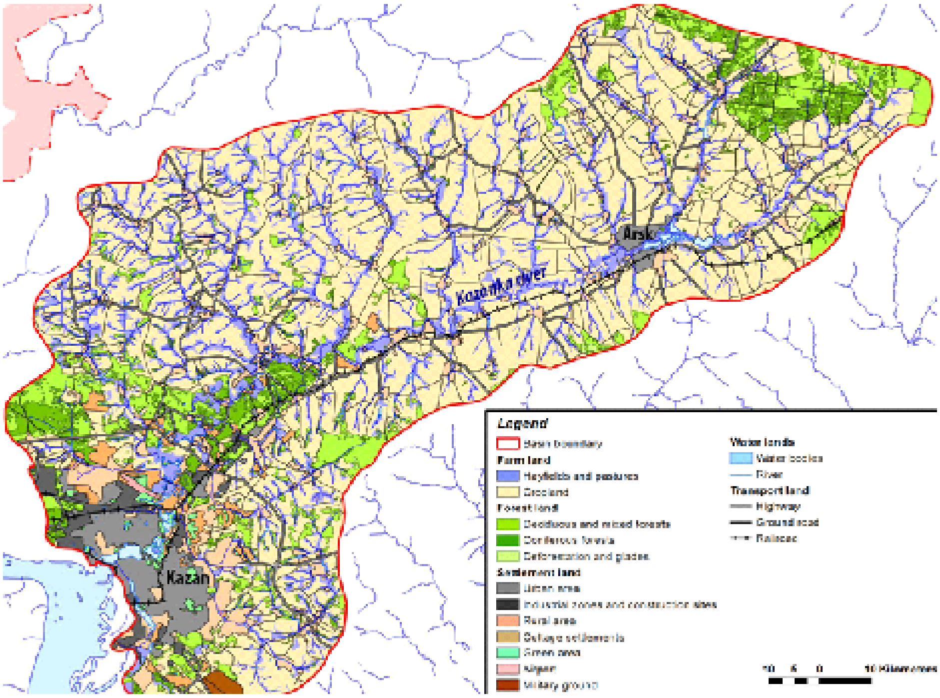

Fig. 2. The map of land use in the Kazanka River basin

division. The resulting map of anthropogenic pressures on the landscape is shown in Figure 3a.

4 It is known that different parts of the paragenetic basin geosystems (watershed - slope - floodplain) have various degree of resistance to anthropogenic pressures, which activate environmentally adverse processes. To take into account the location of the landscape divisions, different types of terrains were assigned points after expert evaluation, which points reflected the degree of their resistance to the anthropogenic impact exerted (Table 4). Scores take values from 1 to 3, ascending as the susceptibility to impact increases (from weak to strong). Figure 3b shows a map of resistance to anthropogenic pressures of the landscapes of the Kazanka River basin.

5. Assessment of anthropogenic pressures on the landscape, which takes into account its resistance to provided impact, was obtained by reducing the pressure by 1 point if the landscape is located on watershed or a bench system, or increasing the pressure by 1 point if the landscape division is located in the floodplain. Scoring pressure of the sloping landscapes was not changed. The final map of anthropogenic pressure on the landscapes with account of their degree of sustainability (susceptibility) to anthropogenic impact is shown in Fig. 3c.

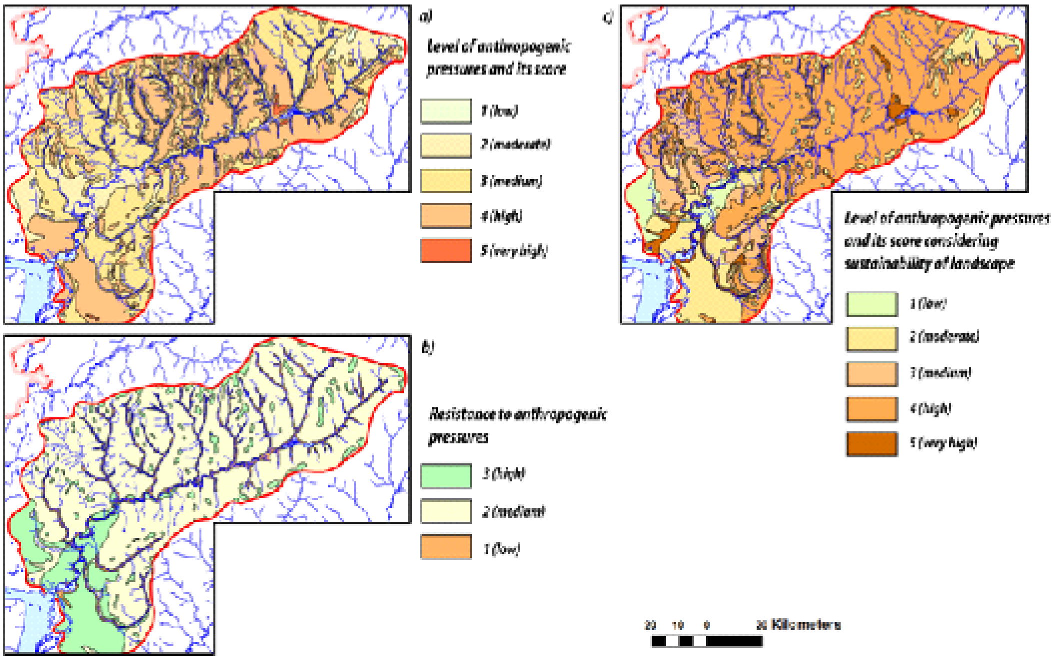

Fig. 3. The score evaluation of the anthropogenic pressures on the landscapes (a), the resistance of the landscapes to anthropogenic impact (b) and the anthropogenic pressures, taking into account the sustainability of landscapes (c) in the Kazanka River basin.

CONCLUSION

A sequence of tasks was solved in the course of the work. Firstly, the analysis of the landscape structure within the study watershed was performed. The technological scheme of the main land use types mapping was developed, which uses Landsat images and the system of object-oriented analysis of images. According to the results of interpretation, a spatial database of functional use of the territory was compiled and an appropriate map was created. At the final stage, using the obtained materials, the anthropogenic pressures on the landscape of the studied area were calculated, and a map of these pressures was compiled.

Summary

The application of geoinformation technology and modern methods of satellite imagery processing in combination with the landscape approach that involves use of natural systems as spatial units, which include comprehensive information on the geology, topography, vegetation, etc., is a convenient tool for prompt and timely data acquisition on the environmental condition of the territory.

Such data are essential both for the natural geographical and environmental studies, and for monitoring purposes, territory planning, and optimization of economic activity in accordance with the concept of stable development.

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