

Assessment of the dynamics of urbanized areas by remote sensing

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Abstract. This research looks at the results of a study of spatial ecological zoning of urban territories using the NDVI-analysis of actual multi-channel satellite images from Landsat-7 and Landsat-8 in the Voronezh region for the period 2001 to 2016. The results obtained in the course of interpretation of space images and processing of statistical information compiled in the GIS environment "Ecology of cities Voronezh region" on the basis of which carried out a comprehensive ecological zoning of the studied urbanized areas. The obtained data on the spatial classification of urban and suburban areas, the peculiarities of the dynamics of weakly and strongly anthropogenically territories, hydrological features and vegetation.

1. Introduction

The increasing pace of urbanization and industrialization in addition to positive effects lead to an increase in anthropogenic impact on the environment. Therefore, the magnitude of environmental risk, and reduced social comfort to the population of large cities. In Russia and most other developed countries this problem is particularly acute since the mid-twentieth century with a high rate of development of industry, oil and petrochemical industries, due to the increased power of thermal power plants, vehicles, etc.

The increasing geochemical contamination of the environment in the population of many large industrial cities of the manifest of environment-related diseases. The attention of environmentalists focused on the study of mechanisms of formation of zones of technogenic pollution and the search of effective ways of improvement of the urban environment [1-3].

A natural frame around the urban settlements is a key determinant of environmental comfort in urbanized areas. Operational spatial assessment of the ecological framework and anthropogenically territories is conducted according to remote sensing [4-6]. This method allows to assess the dynamics of urbanized areas and environmental quality.

The application of satellite imagery data greatly enhances the study of the environmental factors. The development of remote sensing techniques has greatly simplified the process of mapping land and water resources, soil, forests, agricultural crops and urban infrastructure, assessment of crop and much more.

In Russia and other countries of methods of remote sensing are highly relevant and are widely used for assessing spatial dynamics of urban territories. Using geographic information systems allow us to efficiently develop ecological basis for the organization of urbanized areas [7-10].

2. Equipment and devices used in studies

Classification of the studied spatial objects performed by means of NDVI (Normalized Difference Vegetation Index) of relevant multichannel space images Landsat-7 and Landsat-8. Investigated spatial correlations of weakly and strongly anthropogenically territories, hydrologic objects, green space (natural frame). The first slice of data was obtained by satellite images 2001 for the cities and towns of Voronezh, Liski, Rossosh', Pavlovsk, Borisoglebsk (Voronezh region) and their 10-kilometer buffer zones. Another slice of data was obtained for the same areas from satellite imagery of 2016. Thus was obtained the assessment of changes in different areas over a fifteen-year period.



Spatial classification of objects according to the method of NDVI cities of Voronezh and Liski was conducted using satellite images: LE71760242001222KIS00 of Landsat 7, August 10, 2001, LC881760242016240LGN00 of Landsat-8, August 16, 2016; for towns of Rossosh and Pavlovsk was conducted using satellite images: LE71750252001215SGS00 of Landsat-7, August 3, 2001, LC81750252016233LGN00 of Landsat-8 August 20, 2016; for Borisoglebsk town and its suburban area was conducted using satellite images: LE7174024001224KIS00 of Landsat-7, August 12 2001, LC81740242016242LGN00 of Landsat-8, August 29, 2016.

3. Results and Discussion

The results of the spatial dynamics of urban territories on the example of *Voronezh city* are presented in figures 1 and 2. The analysis of the spatial zoning of Voronezh and its suburban ten kilometer areas (a total of 1246 km²) using NDVI, showed that the majority of the study space (40-50 %) applies to weakly anthropogenically area.

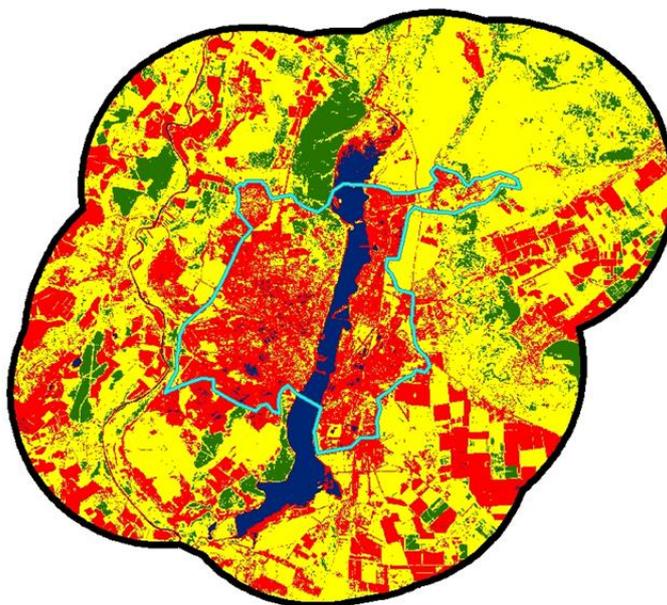


Figure 1. The spatial zoning of Voronezh and its suburban ten kilometer zone (NDVI method by satellite image LE71760242001222KIS00 of Landsat-7, August 10, 2001) color coding is according to table 1

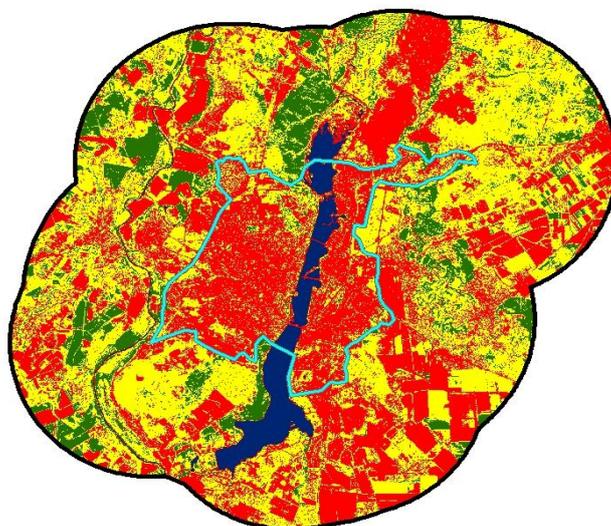


Figure 2. The spatial zoning of Voronezh and its suburban ten kilometer zone (NDVI method by satellite image LC881760242016240LGN00 of Landsat-8, August 16, 2016 color coding is according to table 1

Names and descriptions of the classification units indicated by different colors in figures 1, 2 and are given in table 1.

Table 1. The color symbols in figures the spatial zoning of Voronezh city and its suburbs (NDVI method)

Color	Classification of territory	Description
Blue	Water objects	Rivers, lakes, reservoirs and other hydrological objects
Green	Dense green vegetation	The territory constituting the nature frame – forests, gardens, squares, natural tracts and other lush green vegetation
Yellow	Weakly anthropogenically territories	Open soil, agricultural land, weak green vegetation
Red	Strongly anthropogenically territories	Anthropogenic structures – buildings, roads and other objects. The classification groups of (excluding residential ecological-functional zone) are considered as objects of ecological risk

The main share of weakly anthropogenically territories is formed by the agricultural fields of the Ramonsky, Novousmanskyy and Semiluksky administrative districts, which adjoin of Voronezh (figures 1, 2). The share of natural frame is 8-10% of total square of the study area. The green areas located mainly in its northern part, which significantly reduces their positive impact on the microclimate of the urban area. It is connected with the fact that movement of air masses over the city happens mainly in the northeast direction [11]. Strongly anthropogenically territories that are considered as objects of ecological risk, primarily located in the central part of the city and in the small urban settlements of the suburban zone (figures 1, 2).

The analysis of the spatial dynamics of the various zones for a 15 year period found little (within the error of the technique) reduction of water objects, increase of 8% strongly anthropogenically territories. Such tendency is caused by active construction of housing estates in city boundaries of Voronezh and

adjacent satellite towns – Bobyakovo, Somovo. There was a slight increase in the natural frame (less than 5%) that is associated with the implementation of federal and regional programs for the reconstruction of the forested areas. Weakly antropogenically territory of Voronezh and its suburbs ten-kilometer zone decreased by 10% due to the increase in strongly antropogenically and natural frame.

The analysis of the spatial dynamics of the *town Liski* and its suburban area (a total of 770 km²) shows a slight reduction in hydrologic objects and an increase of 5% weakly antropogenically territories is caused by active construction of new residential complexes.

Unlike the Voronezh city, the most part of Liski and its suburban zone consists of a strongly antropogenically territories. It is caused by existence of the large city-forming enterprise – Locomotive depot Liski southeastern railway. During the last 10 years, active construction of new residential and industrial complexes is underway. Over a fifteen-year period, the territory of the natural frame of Liski has increased by more than 10%. Placing green spaces from the windward southeast side of the town contributes to improving the microclimatic conditions of its territory.

The dynamics of urbanized territories according to the data of multi-channel space images in the period 2001-2016 is presented in table 2

Table 2. Dynamics of urbanized areas according to multi-channel space images (2001-2016)

Objects/squares	2001				2016			
	SAT,%	WAT,%	NF,%	HO,%	SAT,%	WAT,%	NF,%	HO,%
Voronezh 1246 km ²	32	55	9	4	40	44	12	4
Liski 770 km ²	41	51	7	1	45	38	16	1
Rossosh' 827 km ²	35	40	24	<1	37	44	19	<1
Pavlovsk 521,15	30	44	25	1	45	35	19	1
Borisoglebsk 639,19	31	54	14	<1	36	34	29	<1

SAT – strongly antropogenically territories; WAT – weakly antropogenically territories; NF – natural frame; HO – hydrological objects

Spatial analysis of the territory of the *town Rossosh'* (the center of the chemical industry in the Voronezh region) and its suburban zone (totaling 827 km²) showed a predominance of weakly antropogenically territory. It is caused by domination of low floor building and development of homestead economy. In 2001 strongly antropogenically territories were located mainly outside city line. The active construction of multi-storey residential buildings already by 2016 led to an increase in highly antropogenically territories by 15%.

In 2001, the green structure of Rossosh' was more than 200 km², which is almost 25% of total square of town territory and its suburban zone (827 km²). By 2016 the area of the territory of a natural framework was reduced for 10% that is caused by natural and antropogenic wildfires during the summer period of 2010. As a result these territories have turned into category a weakly antropogenically. The transfer of air masses north-west direction and features of distribution of green space have a beneficial effect on the microclimate of the town. Spatial dynamics of water objects in the Rossosh town and in its suburban zone are located in the limits of error of the technique.

Spatial analysis of territory of the *town Pavlovsk*. The territory of the settlement from the North to the south is crossed by the highway of federal importance of M-4 Don dividing it into two parts: western and east. In the eastern part of the town there are major industrial and communal enterprises, an array of modern individual buildings and agricultural land. In the western part - blocks of residential and public buildings, forest tracts along the Don River, floodplain areas of Osered' River and agricultural lands.

During the period from 2001 to 2016 strongly antropogenically territory has increased by 1.5 times. Significant changes are observed in urban areas along the M4-Don highway, where roadside infrastructure is actively developing. The weakly antropogenically territory, allotted in 2001, is transformed into a highly antropogenically territory by 2016. This fact is explained by the increasing

role of the automobile route and the increased transport load, the peak of which was observed the day before and during the Winter Olympic Games in Sochi (2014).

Increase in a share of strongly anthropogenically territory is observed also in a suburban area of Pavlovsk where mining objects are located. Among them OJSC «Pavlovskgranit» especially actively develops. From 2001 to 2016, the growth of highly anthropogenically territory is due to the reduction of the slightly anthropogenically territory.

It is revealed that a natural framework of Pavlovsk and its suburban zone were reduced by 35 km² that makes about 8% of the explored territory. This fact is caused by the strong fires in the summer of 2010 which have led to loss a valuable forests. Territories of Rossosh' and Pavlovsk belong to a steppe zone with an insufficient amount of precipitation, therefore natural restoration of forests happens here extremely slowly and demands development of special reforestation programs. Almost equal ratio of winds of east and western direction and also location of green plantings to the west from the town in a flood plain of the Don River in general positively influence on the climatic features of the settlement.

Spatial analysis of the territory of *Borisoglebsk*. The Borisoglebsk town district is located in a southeast part of Oka-Don plain on confluence of the Vorona River and Khopyor River. The Borisoglebsk and 24 rural settlements make uniform municipal unit – the town Borisoglebsk's district. Almost a quarter of the territory of the district (26 thousand hectares) is occupied by forests, including oak forests. Through the town are the highways Voronezh-Saratov, Moscow-Volgograd and the railway (line Moscow-Volgograd).

Over a fifteen-year period, the area of strongly anthropogenically territories within Borisoglebsk and its suburban zone increased by 5% of the total area, which is a regularity for the urban territories of the developed countries of the world

The square of weakly anthropogenically territory of Borisoglebsk and its suburban zone for a fifteen-year period decreased by 125 km² due to an increase in the area of green plantations. The spatial dynamics of water bodies in the study area is within the error of the methodology.

Among the cities and town of Voronezh region Borisoglebsk and its suburban area has the largest a natural frame. Spatial dynamics of different areas over a fifteen-year period shows a significant increase (almost 2 times) of square of green space. It is connected with introduction of the ecological program which includes actions for restoration of the forest lands in the southern part of the city, restriction of access of motor transport to the woods, strict control of stay in forests of the population and other. Despite loss of a part of forest fund as a result of the fires in the summer of 2010, the total area of forests continues to increase.

Spatial location of the natural frame around Borisoglebsk has a beneficial effect on microclimatic indicators and the ecological situation in the explored territory.

4. Conclusion

Spatial zoning of urban areas of Voronezh region by NDVI method shows differentiation of the studied territories by the sizes of a natural frame – from 7 to 30%, weakly anthropogenically –34-55% and strongly anthropogenically –30-45% of territories.

The smallest value of the square a natural frame is noted in the regional center – the Voronezh city that is caused by the social and economic reasons. The price of land and its profitability in Voronezh and its suburban zones is significantly higher than in other studied urban sites. Local business elites actively develop suburban areas, which leads to reduction of forests and natural areas. General town plan (2006) provides for the removal of objects of environmental risk in suburban areas. On the one hand it has positive environmental effect, and from another also leads to reduction of the territory of a natural framework.

The greatest area of green plantings of urbanized territories of Voronezh region is in Borisoglebsk. The arrangement of a natural framework concerning the city is important. Priority is the location of the natural framework from the windward side of the town. In the territory of the Voronezh region, the best way for this indicator is the green zones around Liski and Borisoglebsk.

For all the studied urban and suburban areas showed a stable growth trend strongly anthropogenically territories, which is a feature of rapidly developing cities of Russia.

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