Remote monitoring of factors determining the environmental safety of urban areas

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Abstract. On the example of the cities of Central Russia, a spatial assessment of the environmental safety factors of the urban environment based on the materials of remote sensing of the Earth was carried out. The data source was multichannel satellite images taken from the Landsat-8 and Sentinel-2 satellites for the period from 2015 to 2022. To assess the dynamic characteristics over a twenty-year period, satellite images of the studied territories from the Landsat-7 satellite for the period from 1999 to 2001 were used. To assess the level of anthropogenic load exerted on the studied territories, 4 zones were identified – with a strong anthropogenic load; with an average anthropogenic load; natural framework; hydrological objects. The largest territory is occupied by areas with an average anthropogenic load, which includes low-rise buildings, agricultural landscapes. Most of this area falls on agricultural fields located near the city. The specific weight of the natural framework is from 8 to 12% of the study area, which is not sufficient to ensure environmental safety. The assessment of the dynamic characteristics of anthropogenic load in all the studied territories shows an increase in zones with a strong anthropogenic load due to the reduction of territories with an average anthropogenic load, which is explained by socio-economic reasons for the development of these territories. As a positive aspect, it is necessary to highlight the increase in the natural framework zone on the territory of the Voronezh city district over a twenty-year period.

1 Introduction

The urban environment of modern urbanized territories is a complex multicomponent system, the functioning of which is carried out both under the influence of interrelated factors and conditions, and autonomous (often conflicting with other factors) substances. Sustainable development of residential landscapes is possible only with a compromise interaction of all its elements [1,2].

The main and non-alternative condition for sustainable development is to improve the quality of life of the population, but in achieving this task, attention should be paid to another important factor - the environmental safety of the territory. Thus, the derivative of the growth of the intellectual industrial potential in the second half of the 20th century in the developed

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countries of the world was the pollution of the urban environment with anthropogenic pollutants, which led to the emergence of environmentally caused diseases of the population [1, 3, 4].

Ensuring the ecological safety of the urban environment involves working with large arrays of spatial and temporal data, the collection and analysis of which in the Russian Federation is successfully carried out by both environmental services and ecologists-practitioners, using mainly methods of ground-based environmental monitoring [1, 5, 6]. The large-scale development of satellite technologies currently observed makes it possible to use Earth remote sensing data to monitor the factors affecting the ecological safety of the territory [2].

Technologies for remote monitoring of the environment are more cost-effective compared to ground-based methods of environmental control, allow significant savings in time resources by conducting more studies over the same time interval [1, 7, 8]. At the same time, it should be noted that the accuracy of the studies performed is higher for ground-based monitoring technologies [2, 9, 10].

Thus, the described conditions determine the relevance of using remote monitoring data in assessing the environmental safety of the urban environment, and their comparison with ground-based monitoring data makes it possible to make scientifically based management decisions [2].

The purpose of this study is to assess the environmental safety factors of the urban environment based on the materials of remote sensing of the Earth on the example of the cities of Voronezh, Lipetsk, Belgorod.

To achieve this goal, the following tasks were solved:
- Collection of Earth remote sensing data of the cities of Voronezh, Lipetsk, Belgorod, as well as suburban areas for a twenty-year period.
- Interpretation of space images of the studied cities was carried out with the identification of objects of environmental risk.
- An assessment of the anthropogenic load of residential landscapes of the studied cities was carried out.
- Studied the spatial characteristics of the natural frame of urban areas and suburban areas.

2 Materials and Methods

To study the ecological safety of the urban environment in urban areas of Central Russia (on the example of the cities of Voronezh, Lipetsk, Belgorod), data from the ScanEx RDC GeoMixer portal were used. This portal is a web-based geoinformation platform for a wide range of tasks that allows you to work with geodata. The multi-channel space images received on the portal, taken from the Landsat-8 and Sentinel-2 satellites for the period from 2015 to 2021, are summarized in the archive. Satellite images of the archive containing the most relevant information for 2021 are presented in Table 1.

To assess the dynamics of the anthropogenic load of urban areas on the example of the cities of Voronezh, Lipetsk, Belgorod over a twenty-year period, the created archive was supplemented with archival multi-channel space images taken from the Landsat-7 satellite for the period from 1999 to 2001 (Table 2). Archival space images were obtained from the USGS portal - the US Geological Survey.

Processing and subsequent thematic interpretation of the obtained space images of the area was carried out in the Scanex Image Processor software package, which allows for the thematic classification of images using various algorithms.

This software package has high performance, which allows solving common problems of thematic interpretation of space images.
In addition, a number of problems related to the storage, analysis and visualization of Earth remote sensing data were solved using the ArcGIS software package [2].

Table 1. Actual space images used to assess the environmental safety of the urban environment.

<table>
<thead>
<tr>
<th>Date of shooting, time</th>
<th>Satellite</th>
<th>Image code</th>
<th>Visible cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.08.2021, 8.17</td>
<td>Landsat-8</td>
<td>LC817602420212</td>
<td>Voronezh</td>
</tr>
<tr>
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<td></td>
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<tr>
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<tr>
<td></td>
<td></td>
<td>28LGN00</td>
<td></td>
</tr>
<tr>
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<td>LC817602320211</td>
<td>Lipetsk</td>
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<td></td>
<td></td>
<td>36LGN00</td>
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<td>20LGN00</td>
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</tr>
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</table>

Multispectral space images collected in the archive provide an opportunity for spatial thematic interpretation of the urbanized territory of the cities of Voronezh, Lipetsk, Belgorod using different color synthesis options.

Table 2. Archival space images of the area used to analyze the dynamic characteristics of environmental safety factors in the urban environment.

<table>
<thead>
<tr>
<th>Date of shooting</th>
<th>Satellite</th>
<th>Image code</th>
<th>Visible cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.08.2001</td>
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<td>LE717602420012</td>
<td>Voronezh</td>
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</table>

Multispectral space images collected in the archive provide an opportunity for spatial thematic interpretation of the urbanized territory of the cities of Voronezh, Lipetsk, Belgorod using different color synthesis options.

When deciphering environmental risk objects that have the greatest anthropogenic load on urbanized territories, industrial enterprises and other man-made objects were identified [1, 2]. Their deciphering signs are very diverse, but by some indirect signs, it seems possible to identify this group (Figure 1).
For example, increased brightness in the visible range of the spectrum indicates disturbed soils, on which, as a rule, industrial and technogenic objects are located [18]. NDVI analysis of territories where industrial and man-made objects are located will show zero or negative values due to a decrease in brightness in the near infrared range [1, 2].

So, if we compare the territories where gypsum or limestone is mined, then in comparison with the territories where clay is mined, the brightness in the visible zone of the spectrum will be higher [1, 2].

Interpretation and spatial assessment of the zones of the natural frame of the urban environments of Voronezh, Lipetsk, Belgorod, as well as suburban areas, was carried out using the NDVI analysis method [1, 2].

3 Results

As a good deciphering feature in medium-resolution images (which include images summarized in the archive), it seems possible to note large industrial buildings, utility and storage facilities, and transport infrastructure. These objects usually occupy large areas, and the artificial materials from which they are built show high brightness in the visible channels of the spectrum and in the mid-infrared range [1, 2]. At the same time, their brightness will be low in the near infrared zone of the spectrum [1, 2]. Place the figure as close as possible
after the point where it is first referenced in the text. If there is a large number of figures and tables, it might be necessary to place some before their text citation.

With a detailed analysis of satellite images inside industrial zones, it seems possible to determine the type of production by a number of features [1, 2].

Thus, a large number of internal railways and large industrial buildings with a high degree of probability indicates the location of machine-building industries in this territory. An extensive network of pipelines and distillation columns are deciphering features of oil production and petrochemistry enterprises [1, 2].

Metallurgical enterprises (for example, NLMK Group on satellite image LC81760232021173LGN00 dated June 22, 2021) are characterized by thermal anomalies (compared to the rest of the surrounding area), as well as the presence of dumps [2].

When deciphering industrial and man-made objects, it should be taken into account that, despite the absence of vegetation cover at the enterprise itself, there is usually a sanitary protection zone with a high level of vegetation around it [2].

The integral indicator of the anthropogenic load on the urban environment includes many factors, with special attention should be paid to the natural frame, the correct location of which can significantly minimize the negative impact on the quality of the environment of the industrial and transport complex, improve microclimatic conditions, thereby increasing comfort for the population [2].

### 4 Discussion

The location of the natural frame zones in the city of Voronezh can be traced mainly in the northern part of the suburban area (Ramonsky district of the Voronezh region). An analysis of climatic factors (wind roses) shows that this location has a weaker positive effect on microclimatic conditions. As a recommendation for this territory, we can propose to increase the natural frame zones for the southwestern suburbs (Semiluksky district of the Voronezh region).

As the main recommendation for the city of Lipetsk, it is possible to propose an increase in the territory of the natural frame between industrial and residential ecological and functional zones.

The most optimal location of the natural frame zones can be identified on the territory of the city of Belgorod.

### 5 Conclusions

The study of environmental safety factors based on the materials of remote monitoring of the cities of Voronezh, Lipetsk and Belgorod made it possible to spatially assess the level of anthropogenic load exerted on the study areas by identifying 4 zones - with a strong anthropogenic load; with an average anthropogenic load; natural framework; hydrological facilities.

Spatial zoning based on the materials of thematic interpretation of satellite images of the territory of the studied cities and suburban areas showed that most of the areas are occupied by areas with an average anthropogenic load, which include low-rise buildings, agricultural landscapes. Most of this zone falls on agricultural fields located near the city. This fact testifies to the significant contribution of agricultural activity to the economic potential of the studied territories.

The specific gravity of the natural frame is from 8 to 12% of the study area, which is not sufficient to ensure environmental safety.
An assessment of the dynamic characteristics of the anthropogenic load in all the studied territories shows an increase in areas with a strong anthropogenic load due to a reduction in areas with an average anthropogenic load, which is explained by socio-economic reasons for the development of these territories. As a positive aspect, it should be noted the increase in the natural frame zone in the urban district of the city of Voronezh over a twenty-year period, which is the reason for the successful implementation of a number of environmental programs by the regional authorities.

Acknowledgments

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References