Environmental Evaluation of the System of Protective Forest Plantations in Urban Landscapes Volgograd Agglomeration Using Gis-Technologies

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Abstract. The article discusses issues related to the study of sanitary protection zones as the main natural barriers to reduce the impact of functioning urban enterprises, also studied the system of protective forest plantations located along linear objects (rail and road transport). At the present stage, a comprehensive ecological-forest-reclamation analysis of protective plantations is impossible without the use of GIS-technologies, which makes it possible to assess the degree of their preservation and assess their environmental protection function. Studies have shown that the territory allotted for the sanitary protection zones of selected enterprises as large polygons does not meet the requirements imposed on them, since they have a high degree of degradation. The state of the system of protective plantings along linear objects can also be assessed as satisfactory, and significant degradation of woody vegetation can be observed as a result of an increase in traffic load. According to the results of the research, we concluded that allow management decisions to be taken to restore the system of protective afforestation in urban landscapes of the Volgograd agglomeration.

1. Introduction

The implementation of protective functions of green spaces directly depends on their condition, especially their safety [17, 19]. An important element of the proper implementation of the joint venture greenery main tasks of the urban environment protection from pollution, is to match their taxational and of characteristic design. Determination of existing levels of plant degradation makes it possible to assess the loss of their protective effectiveness [5, 7, 12, 13].

Geoinformation mapping is a modern method of determining the taxation characteristics of green spaces, revealing a steady correlation of the state with their location in space based on space information and digital elevation models [6, 15, 21, 22, 23].

Key tasks were chosen for the research:

1. Selection of study area, large sites and test sites, the model for the development of plantations safety cards in urban landscapes Volgograd agglomeration.
2. Application of the geographic information mapping method for mapping the safety of green spaces in urban landscapes.
3. Detection of image parameters dependencies of green space in spaceshots taxational of their characteristics.

4. Field calibration of green space preservation in urban landscapes of the Volgograd agglomeration.

2. Materials and Methods

Ground studies of the state of greenery were carried out by the method of selective enumeration taxation of the stand on the test plots of green plantings with the establishment of temporary sample areas. It established: the height and diameter of the trunk of trees at a height of 1.3 m, the current annual increments of height and diameter, the condition of the trees in the sample plots.

In determining the state of the stand in plantations, the plantation state index was used, the value of which was used to determine the category of plantations in accordance with the scale of assessment of forest stands by the healthy, weakened, greatly weakened, drying out and dry categories. [8, 9, 16]. To obtain quantitative data trees were recalculated, each tree was assessed on a viability scale, and then an integral assessment was made to the plantation at each specific site.

The object of research was green plantings in urban landscapes of the Volgograd agglomeration, which were located on the territory of sanitary protection zones of city-forming enterprises and along linear objects (railway and automobile transport).

In the course of the study, a preliminary analysis was made of the economic activities of leading enterprises in relation to such parameters as: the volume of output, the level of exposure to atmospheric air and the presence of a sanitary protection zone established in accordance with regulatory requirements and norms.

The studies were conducted in 2013-2015. In the course of which two large enterprises were selected, located on the territory of the Volgograd agglomeration (Volgograd Aluminum Plant and Volgograd Oil Refinery) [1, 11, 17].

All the necessary work to ensure environmental protection on the territory adjacent to the companies, including the improvement and maintenance of the functions of sanitary protection zones, carried out at the expense of the company, carrying out pollution [12, 24].

Depending on the width of the sanitary protection zone, the following green area is taken: up to 300 m - 60%, up to 1000 m - 50%, from 1000 to 3000 m - 40%, more than 3000 m - 20%.

The identification of the correspondence of these zones sizes and the parameters of green plantings to the approved ones is an important element of environmental monitoring and allows the controlling bodies to react in a timely manner to deviations of the zone characteristics from the established parameters in order to prevent environmental damage [13, 20].

The sanitary protection zones from residential and public zones accommodated trees and bushes bandwidth greater than 50 m, if the width is not more than 100 m, the bandwidth of the received toils and not less than 20 m.

Rules of placement of various objects in close proximity to residential houses are determined by construction norms and rules [2, 3, 13, 25]. The requirements of these norms for the layout and building of the flow areas are regulated by the design of new ones and the reconstruction of existing ones.

In residential areas, residential buildings can be placed both separately and groups of houses, objects of social, cultural and consumer services of the population, etc. Some objects of public, business and municipal purpose with the area no more than 0.5 hectares, the enterprises which are not having harmful impact on environment are allowed to place outside borders of their sites. The size of the sanitary protection zone for objects that are not a source of pollution should be more than 25 m.

The greatest removal of harmful substances is characteristic of chemical, petrochemical and metallurgical companies, and therefore the sanitary-protective zones of the Volgograd Aluminum Plant and the Volgograd Oil Refinery (Figures 1, 2), whose production is classified as first class, have been selected [4, 14].

The total area of the Volgograd Aluminum Plant sanitary protection zone, including its area (124.18 ha) is 811.77 m. Without the area of the enterprise, the area of the sanitary protection zone is 687.59
ha. According to the requirements [26] when the sanitary protection band width from 1000 to 3000 m, the area allotted for the green area has to be not less than about 40%, it is 51% in fact [18].

3. Results and Discussion

Studies of the spatial distribution of green space on an isolineous elevation map (Figure 3) in the landscape of the test site of the Volgograd Aluminum Plant showed that the plantings are planted taking into account the relief and with reference to the isolines of the height of the relief, which ensures the distribution of runoff without water erosion [4, 18].

According to the results of research, a map of the safety of green spaces in the sanitary protection zone of the Volgograd Aluminum Plant was developed. (Figure 4).
Space shots studies have shown that the total area with the crowns of the trees is stored 123.67 ha, representing 35.2% of the planting area [4].

Due to the fact that the stands are of different ages, of different species and with different planting schemes, part of the crowns in the plantations are closed and form a canopy, in another part of the crowns are open. Therefore it cannot be said that the state of degradation is caused by the degradation of the stand crowns in plantation.

On the territory of the Volgograd refinery, the total area allocated for green plantings is 117.86 hectares, including the roadside plantations located in this zone. Thus, the total landscaping of the sanitary protection zone on the land allocated for plantings is only 8.3%, instead of 40% according to the approved standards. At the same time, the territory of the plant under study intersects with the territory of another enterprise - the chemical enterprise JSC “Kaustik” (however, there are no green areas in the area of enterprises crossing).

Geoinformation researches of actual safety of plantings on these areas have shown the extremely high level of their degradation. To assess the spatial distribution of the degradation of green space, a conservation map has been developed (Figure 5) [18].
Figure 5. Map of safety of green space in the sanitary-protective zone of the Volgograd refinery Green – Tree crowns; Orange – Lacunas and aisles.

The range of plantations safety is from 8 to 90%, average safety is 42.04%, standard deviation is 20.29%. At the same time, 30 plantations of 42 are less than 50% safe and only 12 are more than this value. 

In this study we took the roadside plantings into account. It has been established that 71% of green plantings in the sanitary protection zone of the Volgograd oil refinery are in the stage of disintegration, and only three areas - plantations No. 21, 31, 32 are more than 80% intact. The safety of planting number 19 is less than 8%.

Plantings number 31 and 32 are young, the area of crowns is small, in this regard, their safety was taken into account as the ratio of the number of remaining trees to the total number of seats.

With a total area of sanitary protection zone of 1424.14 hectares, the area allotted for plantings is 118.31 hectares, with a norm of 569.66 hectares. In fact, the crowns of preserved trees in plantations occupy an area of only 37.84 hectares (2.7%) and do not protect the territory from pollution [18].

During the study it can be concluded that the surface area available for forest plantations in the buffer zone of the Volgograd Oil Refinery plant does not comply with the requirements of SanPiN 2.2.1 / 2.1.1.1200-03.

In determining the status categories and characteristics taxational green space in the buffer area Volgograd Aluminium plant trial for observing the area was also isolated for 3 years.

At the same time, there is a decrease in the number of trees classified in the “healthy” and “weakened” categories and is increasing in the “severely weakened”, “shrinking” and “dry” categories. I.e., the process of degradation of healthy plantations is at a rate of 7-8% per year, which indicates the poor condition of the plantations as a whole. [10]

An experimental data analysis obtained the taxation of tree plantings shows that in the plantings of the sanitary protection zone of the Volgograd aluminum plant, degradation processes are observed, the
condition of trees in the plantings is deteriorating, the growth of trees is slowing and the thickness of the tree increases (up to 16.7%) and dry (up to 13.9%) trees.

Thus, the study of the state of the stand in various areas of the city of Volgograd allowed to establish the following patterns:
- the best characteristics for all data of the taxation studies showed natural stands;
- artificial plantations on almost all sample plots are in a state of decay, more than 50% of the stand in them are in a state of shrinkage or have shrunk;
- artificial plantations planted near natural plantations (floodplain or bayrachny) have better taxation characteristics in comparison with plantations located in other places;
- there is a decay of plantings in the sanitary protection zones of enterprises. The sanitary-protective zone of the Volgograd aluminum plant is relatively better organized, where the safety of the stand is about 35%;
- It may be noted that there is practically no possibility of performing protective functions by green areas of the sanitary protection zone of the Volgograd Oil Refinery. Crowns area of the surviving trees from plantations established at rates of 570 hectares (40% of the sanitary protection zone) is only 37.84 hectares (2.7%) and dissolved while providing protection from contamination adjacent areas [4, 10,18].

It is urgent to take measures to restore green spaces in accordance with the established norms, which, in accordance with the legislation, are entrusted to the polluter enterprise.

In addition to the sanitary protection zones of large enterprises, protective plantings along linear objects, which are of particular importance for the efficient operation of the Volgograd agglomeration transport network, were chosen as test plots [4]. The area of forest plantations of natural and artificial origin is very small, and in conditions of high rates of urbanization, the system of green forest plantings is subjected to intensive anthropogenic load [10].

The studies were conducted on the territory of the northern and southern part of the Volgograd agglomeration with a choice of test plots of the green forest plantings system located along the roads and railways.

During the study required to determine the safety of protective forest stands along roads and railways, key areas were selected (Table 1 and 2, respectively).

**Table 1.** Results of visual evaluation green forest plantings state along roads on test sites [10].

| Plot number, an object coordinates | Breed composition | Height, m | Diameter, cm | Sanitary condition, % |
|-----------------------------------|------------------|-----------|--------------|----------------------|
| N 48°46‘07.07“; E 44°24‘12.26” (Aviators Highway) | 6 Fraxinus excelsior | 5 | 15 | Healthy 20 | Dry top 70 | Shrunken 10 |
| Plot 2, N 48°46‘16.59“; E 44°23‘46.20” (Aviators Highway) | 4 Acer negundo | 4 - 5 | 13 | Healthy 50 | Dry top 50 | Shrunken - |
| Plot 3, N 48°35‘50.37“; E 44°12‘56.68” (highway, Gorny village) | 5 Fraxinus excelsior | 5 | 13 - 15 | Healthy 20 | Dry top 70 | Shrunken 10 |
| Plot 4, N 48°40‘47.38“; E 44°22‘15.68” (Portovskaya str., Gorkovsky district) | 5 Acer negundo | 3 - 5 | 13 | Healthy 30 | Dry top 55 | Shrunken 15 |
| Plot 10 Ulmus pumila | 10 Ulmus pumila | 4 | 15 | Healthy 40 | Dry top 40 | Shrunken 20 |
| N 48°40‘47.38“; E 44°22‘15.68” (highway, Gorny village) | 8 Ulmus pumila | 3 - 3.5 | 25 | Healthy 10 | Dry top 60 | Shrunken 30 |
Table 2. The results of visual assessment of the state of green forest plantings along the railways in the test areas [10].

| Plot number coordinates an object | Breed composition | Height, m | Diameter, cm | Sanitary condition,% |
|-----------------------------------|------------------|-----------|--------------|----------------------|
|                                  |                  |           |              | Healthy | Dry top | Shrunken |
| Plot 5, N 48° 49'59.63", E 44° 21'43.64" (in the direction of Gumrak station - Konny st.) | 10 Ulmus pumila  | 3 - 4      | 9.6 - 11.2   | 80      | 15      | 5        |
| Plot 6, N 48° 50'00.58", E 44° 21'37.60" (in the direction of Gumrak St.- Ancient rampart st.) | 7 Ulmus pumila  | 3 - 4      | 9.6 - 11.2   | 40      | 30      | 30       |
|                                  |                  | 3 Fraxinus excelsior | 4      | 11 - 13     | 60      | 40      | -        |
| Plot 7, N 48° 49'59.27", E 44° 21'43.93" at the intersection of the railway (in the direction of Gumrak St.- Ancient rampart St.) and the R-220 road. | 5 Ulmus pumila  | until 3    | 8.6 - 10     | 60      | 10      | 30       |
|                                  |                  | 5 Fraxinus excelsior | until 3 |           | 60      | 30      | 10       |

Table 3. Results of distant assessment of a condition of green forest plantings along highways on test sites [10].

| Plot number | Total area, m² | Lacuna plots area, m² | Preservation plot,% |
|-------------|----------------|-----------------------|---------------------|
| Plot 1      | 8925.66        | 1952.29 (21.87%)      | 78.13               |
| Plot 2      | 8237.85        | 1977.43 (24%)         | 76                  |
| Plot 3      | 94049          | 42259 (45.1%)         | 44.9                |
| Plot 4      | 13449          | 6529 (41.4%)          | 48.6                |

Table 4. Results of distant assessment of a condition of green forest plantings along railways on test sites [10].

| Plot number | Total area, m² | Lacuna plots area, m² | Preservation plot,% |
|-------------|----------------|-----------------------|---------------------|
| Plot 5      | 15044.78       | 685.71 (4.6)          | 95.4                |
| Plot 6      | 29786.64       | 2865.46 (9.6)         | 90.4                |
| Plot 7      | 43359.8        | 2088.45 (4.8)         | 95.2                |

After the carried-out taxation assessment data with use of methods of remote sensing were received and the safety of test sites is defined (table 3 and 4 respectively).

In the course of cameral processing and the use of the method decryption of space high resolution images, it is possible to draw the following conclusions:

1. The safety of the analyzed areas may deteriorate as a result of an increase in traffic load (for example, an extension of the highway).
2. The condition of plantings can be assessed as satisfactory, the degradation of woody vegetation can be traced (about 40% of woody vegetation is dry-top), and there are practically no cuttings (sanitary felling).

3. Key areas located along the railway, are in a more healthy state compared to areas along the author of the automobile roads, which can be explained by the lower intensity of the transport load, the physiographic features of the objects of study. For example, a large number species of young tree (mainly ash) are noted on site 7, which indicates a self-restoration of disturbed sites in this area.

It must be concluded that the selected sites are at the stage of degradation and are in dire need of relevant agroforestry operations carrying out. To increase the sustainability of forest plantations, it is necessary to increase the species composition of green forest plantings.

After analyzing the selected key areas located along the urban linear objects, we can conclude that it is advisable to carry out a set of measures to improve the safety of green forest plantings [4, 18].

Thus, a geoinformational assessment of a condition of green plantings gives the chance to estimate interrelations of objects, their interposition and interaction, to understand a situation in this region, to make the right choice and is better to be prepared for a decision making.

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