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Assessment of the state of green areas in Tarusa

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Abstract. The research is devoted to a comprehensive study of the state of green plantations in the town of Tarusa, the Kaluga Region, aimed at assessing the ecological condition of the landscapes and developing recommendations for their sustainable development. The work involved an inventory of flora, an assessment of the state of trees, shrubs, lawns, and flower beds in various functional zones (transport, residential, public, industrial), and the NDVI method was applied to analyze the dynamics of vegetation cover. The results of the study revealed significant degradation of green spaces: 36% of trees and 55% of lawns are in an unsatisfactory condition, and 59% of plant species are found fragmentarily. Based on the data obtained, measures for the optimization of urban landscaping are proposed, including sanitary pruning, planting of resistant species, and control of invasive plants. The practical significance of the work lies in the possibility of using the results for urban planning and environmental monitoring not only in Tarusa but also in other small historical towns.

Keywords: anthropogenic load, urban environment, sustainable development, NDVI

Authors' contribution. *E.A. Parakhina* — conceptualization, methodology, project administration, supervision. *V.A. Brundukova* — investigation, formal analysis, writing and editing of the manuscript, visualization. All authors have read and approved the final version of the manuscript.

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Оценка состояния зеленых насаждений г. Таруса

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Аннотация. Исследование посвящено комплексному изучению состояния зеленых насаждений города Таруса Калужской области, направленному на оценку экологического состояния ландшафтов и разработку рекомендаций для их устойчивого развития. Проведены инвентаризация флоры, оценка состояния деревьев, кустарников, газонов и цветников в различных функциональных зонах (транспортной, селитебной, общественной, промышленной), а также применен метод NDVI для анализа динамики растительного покрова. Результаты исследования выявили значительную деградацию зеленых насаждений: 36 % деревьев и 55 % газонов находятся в неудовлетворительном состоянии, а 59 % видов растений встречаются фрагментарно. На основе полученных данных предложены меры по оптимизации городского озеленения, включая санитарную обрезку, посадку устойчивых видов и борьбу с инвазионными растениями. Практическая значимость работы заключается в возможности применения результатов для градостроительного планирования и экологического мониторинга не только в Тарусе, но и в других малых исторических городах.

Ключевые слова: антропогенная нагрузка, урбанизированная среда, устойчивое развитие, NDVI

Вклад авторов. *Парахина Е.А.* — концептуализация, методология, администрирование проекта, руководство исследованием. *Брундукова В.А.* — проведение исследования, формальный анализ, создание рукописи и ее редактирование, визуализация. Все авторы ознакомлены с окончательной версией статьи и одобрили ее.

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Заявление о конфликте интересов. Авторы заявляют об отсутствии конфликта интересов.

Заявление об использовании технологий искусственного интеллекта. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовались.

Заявление о доступности данных. Все данные, полученные в ходе этого исследования, включены в опубликованную статью.

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Introduction

The city of Tarusa is a small area and population town of the Kaluga region, administrative center of the Tarusa district.[1] Area of the district — 715 km^2, Square of Tarusa — 12 km^2. As of 31.12.2021, the population of the Tarusa district is 15,384 people, the town of Tarusa — 9,918 people.[2]

Conservation of the region's natural heritage and sustainable development are important tasks. Urban ecosystems are being formed in cities, which have complex structures and are under constant anthropogenic influence. Towns, such as Tarusa, require considerable attention because of their vulnerability, including environmental vulnerability. Little attention is paid to the study of urban ecosystems in towns [1–8].

The main geomorphological features of the town's landscapes: hills, gullies and ravines, the Oka River floodplain. The climate is moderately continental.

The development of tourism is leading to a growing anthropogenic impact. Increased recreational use, land development and natural landscape changes require a comprehensive analysis of the town's ecological state. The study of green beds, which play a key role in maintaining the ecological balance of an urban ecosystem, is particularly important [9–11].

The aim of this study is to assess the current state of the Tarusa ecosystems and develop recommendations for their sustainable development. The following tasks were carried out as part of the work:

1) Analysis of plant species composition and distribution of each species by functional area.

2) Assessment of the quality condition of trees, shrubs and grasses using field methods and NDVI calculation.

3) Development of measures to optimize urban greening.

Studies were conducted in 2023–2025. For the first time, a comprehensive inventory of the green spaces of Tarusa has been carried out, areas of greatest environmental stress have been identified and adaptive solutions for their restoration have been proposed.

[1] Information about Tarusa. *Administration (executive body) of the city settlement "The town of Tarusa".* Available from: https://tarusagorod.ru/informaciya-o-taruse.html (accessed: 05.09.2025).

[2] Tarusa district. *Administration of MR "Tarusa district".* Available from: https://tarusa.gosuslugi.ru/o-munitsipalnom-obrazovanii/ (accessed: 05.09.2025).

Research methods

The integrated assessment of urban ecosystems was carried out through the most active component — plants. Within the town of Tarusa, functional areas were allocated:

1) Transport — condition of roadside lawns, as well as wood-shrub plants (if present) was analysed;

2) Residential — the object of assessment was green vegetation of residential areas: lawns, flower beds, shrubs and trees;

3) Public — the condition of all elements of landscaping was assessed: park lawns, decorative flower beds, tree plantations;

4) Industrial — the condition of plants located within industrial areas was analysed.

Test sites were laid in all functional zones (Figure 1).

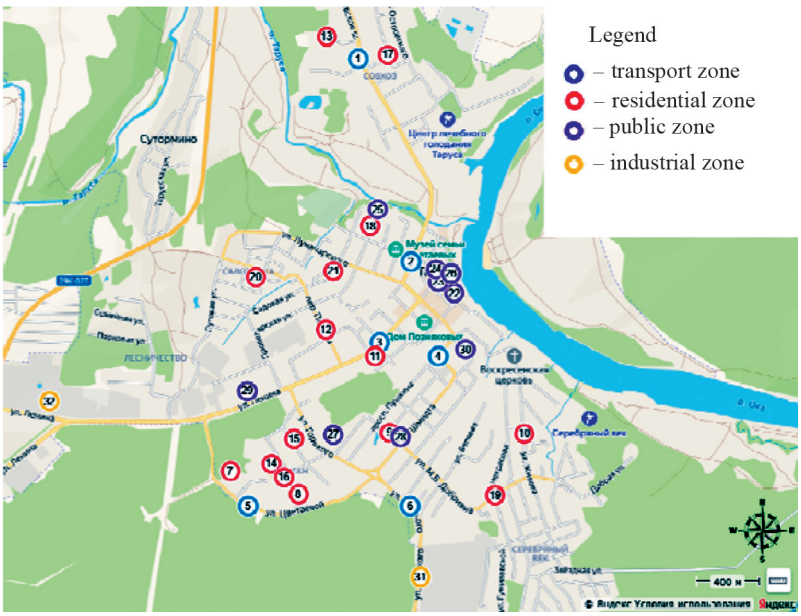

Figure 1. The layout of the points for assessing the state of urban vegetation in Tarusa

Source: compiled by Brundukova V.A. based on: Green space assessment point map. Available from: https://yandex.ru/maps/20208/tarusa/?ll=37.166359%2C54.729619&mode=usermaps&source=constructorLink&um=constructor%3Aac874c981addcc86ecf594f1e9a04be60a42d95cc967e405aed55b9c3a0fc64f&z=13 (accessed: 03.08.2025).

The evaluation was based on a point system in accordance with the order dated December 15, 1999 № 153 "On the approval of regulations for the creation, protection and maintenance of green spaces in cities of the Russian Federation." According to the methodology of the order, green spaces are evaluated by a three-point rating system: 3 points — good condition (no damage, normal development); 2 points — satisfactory condition (minor damage, reduced viability); 1 point — unsatisfactory condition (severe damage, oppression); 0 points — object not found on site.

A list of species diversity of higher-vascular plants encountered at test sites was compiled. For each species, its characteristics are given: morphological features, growth zones, frequency of occurrence. This yielded data on the flora of the area under study [12].

In order to identify the patterns of spatial distribution of species, a taxonomic assessment was carried out and the extent of each species' prevalence was analyzed.

Assessment of the quality condition of plants was carried out in the growing seasons 2023–2025 according to the methodology approved by order dated December 15, 1999, No. 153 "On the approval of regulations for the creation, protection and maintenance of green spaces in cities of the Russian Federation."[3] Remote methods were also used. NDVI (Normalized Difference Vegetation Index) was calculated. NDVI is calculated by the formula

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}},$$

where NIR — reflected infrared radiation, and RED — reflected red radiation.

To calculate the NDVI index pace images Landsat 8 were used, which were subsequently processed in the QGIS environment. Visualization of the results is performed using a color gradient: from red (minimum values of vegetative activity) to green (maximum values). Based on calculated data, all the territory was classified according to NDVI threshold values into classes: dense vegetation, thin vegetation, open soil, water objects, artificial surfaces [13].

Results and discussion

In the course of work, field studies were carried out on 32 test sites in the town of Tarusa, covering different functional groups. An annotated list of the flora, including all identified species and their characteristics, has been drawn up on the basis of these data. The results clearly show the state of vegetation under anthropogenic conditions and allow to assess the degree of transformation of urban ecosystems [2].

As a result of the assessment at 32 test sites there were 71 species of higher-vascular plants recorded. The spruce tree dominates among woody plants (*Picea abies* (L.) H. Karst.), marked on 7 sites, and also ash-leaved maple tree (*Acer negundo* L.) and small-leaved linden tree (*Tilia cordata* Mill.), the frequency of occurrence was 6 sites. Among the grass plants, it was most frequently noted woolly burdock (*Arctium tomentosum* Mill.) — on 7 sites. 59% of the species occur only once on sites.

[3] *Order of the State Committee of the Russian Federation for Construction and Housing-Communal Complex dated December 15, 1999 No. 153 "On the approval of regulations for the creation, protection and maintenance of green spaces in cities of the Russian Federation."* Available from: https://normativ.kontur.ru/document?moduleId=1&documentId=49758&ysclid=mq0owj5to069896350 (accessed: 12.07.2025).

In the systematic structure of the flora of Tarusa, according to the data obtained, the leading position is occupied by families *Rosaceae*, *Salicaceae* и *Aceraceae*. This is broadly consistent with studies in other towns: In Kineshma, the major families are *Rosaceae* (42 species) and *Salicaceae* (20 species), but in Dubna — *Rosaceae* (40 species) and *Salicaceae* (22 species) [6; 7]. The predominance of these families reflects general trends in flora formation under urbanized conditions of temperate zone.

The vegetation of Tarusa is characterized by the predominance of trees over shrubs and lianas, which is typical for urban dendroflora of Central Russia. Kineshma is also dominated by trees, although the proportion of bushes there is higher [14]. In Dubna, on the other hand, there is greater diversity of bush forms, which may be due to their wider use in private-sector natural vegetation [15].

The common problem for Tarusa, Kineshma and Dubna is the introduction of invasive species into natural communities. In Kineshma, 12 species are invasive (for instance, *Acer negundo* L., *Populus alba* L., *Fraxinus pennsylvanica* Marsh.) [14]. In Dubna, aggressive behavior is noted by *Acer negundo* L., *Amelanchier spicata* (Lam.) K. Koch, *Hippophae rhamnoides* L. and other species [15]. In Tarusa, according to the observations made, invasive species are also actively settled (for instance, *Acer negundo* L., *Solidago canadensis* L.), which requires constant monitoring and control of their spread.

The resilience of urban ecosystems depends not only on species diversity, but also on plant quality condition. The analysis of the data obtained during the study resulted in a summary table with an assessment of their quality condition (Table 1).

This approach allowed the assessment of the condition of tree-bush vegetation, flower beds and lawns to be unified for subsequent analysis and comparison.

Table 1. **Plant quality condition in Tarusa**

Site number	Quality condition of the trees	Quality condition of the shrubs	Quality condition of the lawns	Quality condition of the flower beds
1	0	0	1	0
2	2	0	1	0
3	3	2	1	0
4	0	1	2	0
5	1	3	2	2
6	1	1	1	0
7	0	0	2	0
8	1	1	2	0
9	0	2	1	0
10	0	3	2	1

Table 1, ending

Site number	Quality condition of the trees	Quality condition of the shrubs	Quality condition of the lawns	Quality condition of the flower beds
11	0	2	0	2
12	0	1	1	0
13	1	1	1	0
14	1	1	1	1
15	1	2	1	0
16	1	0	1	0
17	1	0	1	0
18	3	2	1	0
19	1	0	1	0
20	0	1	2	1
21	3	0	2	0
22	0	3	2	3
23	0	2	2	2
24	0	2	0	2
25	0	2	3	2
26	1	0	1	1
27	0	0	1	1
28	0	1	1	1
29	0	2	2	1
30	1	0	1	0
31	2	0	2	0
32	0	0	1	0

Source: compiled by V.A. Brundukova.

Analysis of the tree plantations revealed that more than one-third (36%) of all sites are characterized by unsatisfactory tree conditions. Most commonly, woody plants in this condition are found in the residential (7 sites) and transport (2 sites) zones. Satisfactory and good condition are recorded at a significantly lower rate of 6% and 10% respectively, moreover trees with the corresponding quality condition of being scattered across different functional zones. An important factor is the total absence of trees in almost half (48%) of the sample sites surveyed (Figure 2).

The quality condition of bushes, unlike trees, in the territory of Tarusa is better (Figure 3). Although the proportion of sites completely devoid of shrubs is also high (38%), their satisfactory condition is almost three times more common

(28% compared to 6% for trees). These sites are mainly concentrated in the residential and public zones (4 sites each). At the same time, the proportion of plants in unsatisfactory (25%) and good (9%) condition is distributed among different functional zones without any one being strongly dominated.

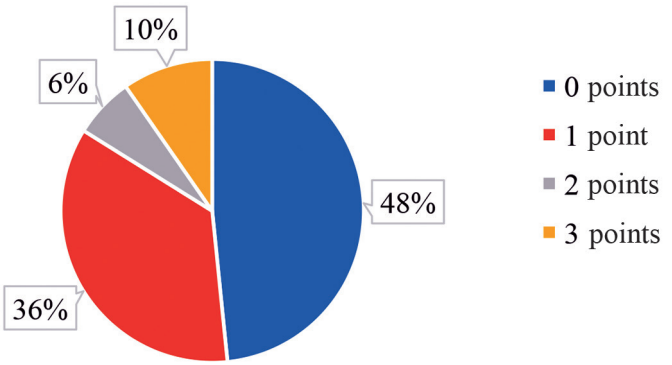

Figure 2. The quality condition of the trees

Source: compiled by V.A. Brundukova.

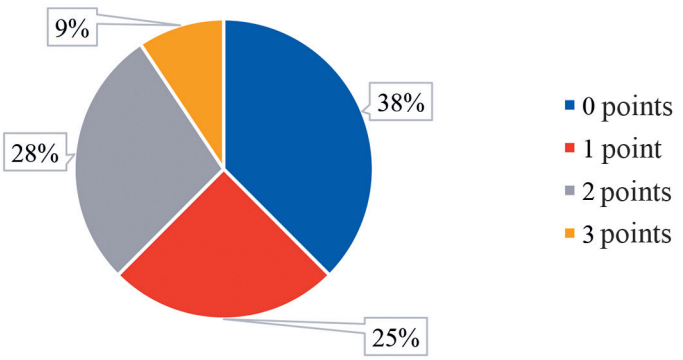

Figure 3. The quality condition of shrubs

Source: compiled by V.A. Brundukova.

Analysis of the quality condition of grass plants on lawns revealed a critical situation: more than half (55%) of sites have unsatisfactory cover, with the problem most acute in the residential zone (9 sites) (Figure 4). Lawns are in a satisfactory condition and less common (36%) and also mostly concentrated in residential areas. The good condition of the lawn was recorded in only one site (3%) in the public zone. Another 6% of zones are completely devoid of lawns.

When assessing the quality condition of flower beds, it is important to note that they are completely absent in 59% of surveyed areas (Figure 5). Of the existing flower beds, most (22% of the total number of test sites) are in unsatisfactory condition and are concentrated in public and residential zones. Only 16% of the flower plants were in satisfactory condition. It is noteworthy that a flower garden in good condition was found on only one site (3%) in the public area, which highlights the severity of the problem.

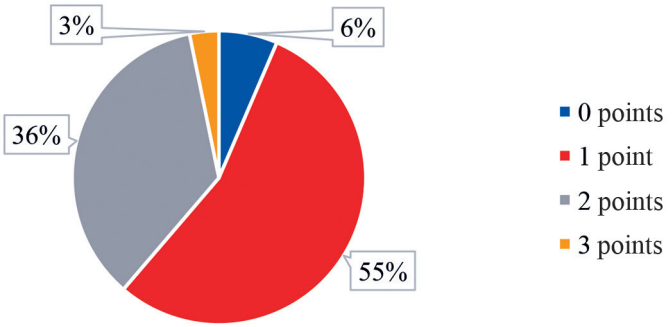

Figure 4. The qualitative condition of lawns

Source: compiled by V.A. Brundukova.

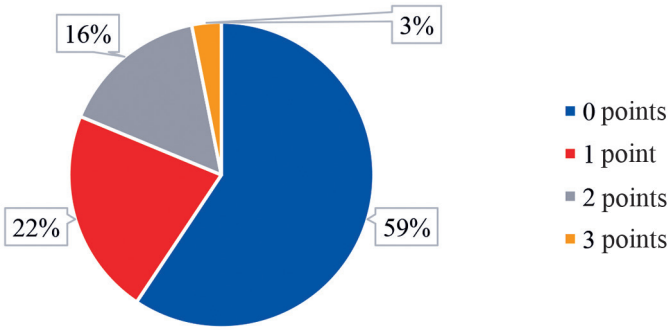

Figure 5. The quality condition of flower beds

Source: compiled by V.A. Brundukova.

Based on conducted studies, an assessment of the quality condition of plants in different functional areas of the town of Tarusa was made.

Transport zone: sections along roads, highways, intersections. High anthropogenic stress due to gaseous pollution, soil salinization, mechanical damage of plants:

– quality condition of the trees: average 2–3 points. In satisfactory condition — *Acer negundo* L., *Tilia cordata* Mill. Slow growth, partial drying of the crown are being noted. In good condition — single plant specimens *Picea abies* L., pollution-resistant;

– quality condition of the shrubs: average 1–2 points. Unsatisfactory condition prevails — Japanese meadowsweet, common ninebark bare-stemmed at the bottom. In satisfactory condition — common lilac, but with rare bloom;

– quality condition of the plants in lawns: average 1–2 points. Decimated, with dominance of weed species (couch grass, plantain);

– quality condition of the plants in flower beds: average 0–2 points. On most sites were not found, rare flower beds with marigolds in satisfactory condition.

High human-induced stress depresses plants, especially along busy roads.

Residential zone: residential districts (private sector, multi-storey development). Moderate recreational load, local pollution:

– quality condition of the trees: average 1–2 points. In satisfactory condition — linden, ash tree in private courtyards. In unsatisfactory — old poplar with hollows, crown dieback;

– quality condition of the shrubs: average 2–3 points. In satisfactory condition — rosehip, honeysuckle. In good condition — decorative planting (spirea, white dogwood);

– quality condition of the plants in lawns: partially dug up, but in the private sector there are well-maintained sites;

– quality condition of the plants in flower beds: mostly in satisfactory condition (peonies, irises).

Condition of the plants varies depending on care. In the private sector — better, in the multi-storey — there is degradation of lawns.

Public zone: parks, public gardens, squares. Active recreational use:

– quality condition of the trees: good condition — lindens, maple trees in park areas;

– quality condition of the shrubs: decorative planting (spirea, white dogwood) in good condition;

– quality condition of the plants in lawns: well-maintained but worn out in places;

– quality condition of the plants in flower beds: flower beds with perennial plants in good condition.

Better quality condition is maintained by care, but recreational stress leads to local degradation.

Industrial zone: the territory of enterprises. Soil and air pollution:

– quality condition of the trees — unsatisfactory condition, necrosis of the bark is observed;

– quality condition of the shrubs — are virtually absent or severely depressed;

– quality condition of the plants in lawns: decimated, with weeds;

– quality condition of the plants in flower beds: absent.

Transport and industry are the most vulnerable zones — plants are being suppressed by pollution. In the residential zone, the condition depends on the level of amenity. The best condition of vegetation in public areas. Based on the results of the study, a map was drawn up reflecting the state of the landscape in the town (Figure 6).

The analysis of time dynamics (Figure 7) highlights several stable trends:

1) clearly expressed annual cycle with peak values (0.6–0.8) in July-August and minimum (0.1–0.2) in January-February, this is due to the change of seasons and the decrease in green vegetation during winter;

2) the amplitude of seasonal oscillations is 0.5–0.6, what is typical for mixed temperate forests;

3) statistically significant ($p < 0.05$) decrease in average annual values NDVI from 0.52 ± 0.03 (2001–2005) to 0.45 ± 0.04 (2019–2023);

4) the largest negative anomalies (–15–20% from the standard) were recorded in 2010, 2015 and 2021.

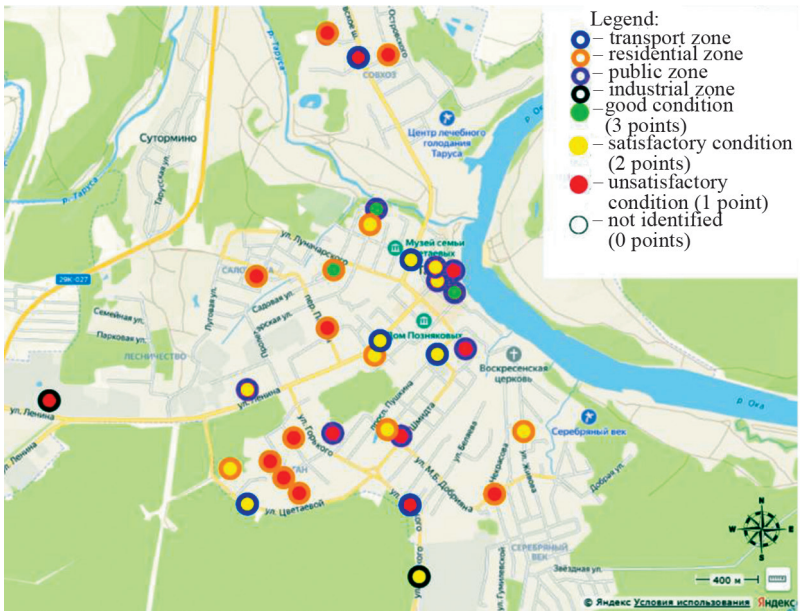

Figure 6. Map of the landscape condition in the town of Tarusa

Source: compiled by V.A. Brundukova based on: Green space assessment point map. Available from: https://yandex.ru/maps/20208/tarusa/?ll=37.166359%2C54.729619&mode=usermaps&source=constructorLink&um=constructor%3Aac874c981addcc86ecf594f1e9a04be60a42d95cc967e405aed55b9c3a0fc64f&z=13 (accessed: 03.08.2025).

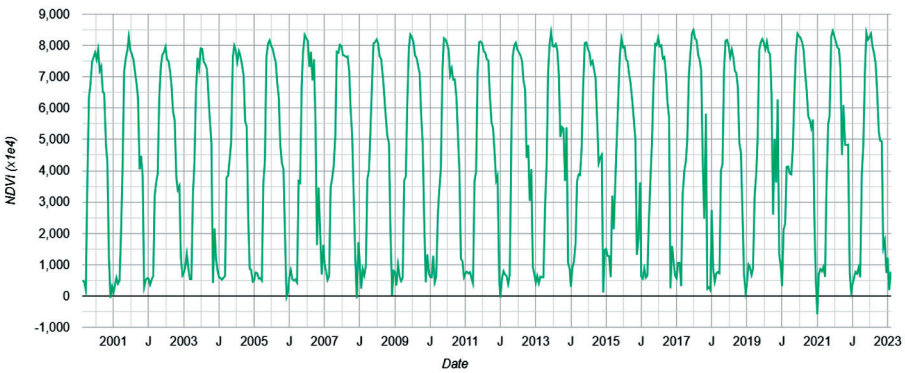

Figure 7. NDVI indicator from 2001 to 2023

Source: compiled by V.A. Brundukova using Interactive NDVI Map: https://digital-dryads.eu/interactive-ndvi/ (accessed: 03.08.2025).

For the quantitative assessment of vegetation cover dynamics in Tarusa, a normalized differential vegetative index (NDVI) was used. Its calculation was based on remote sensing data covering the years 2001 to 2023.

The results indicate a progressive degradation of plant communities in 18–22% of the town territory.

Space image was analyzed using the QGIS program dated 28.06.2024 and NDVI was calculated (Figure 8).

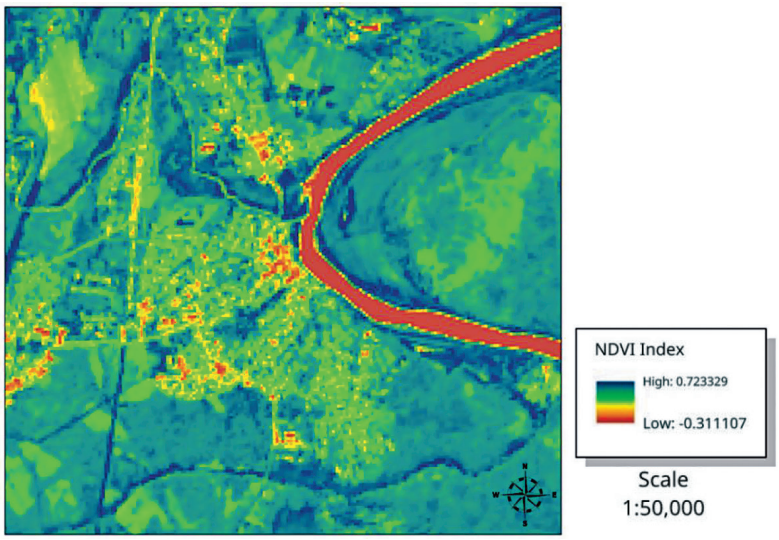

Figure 8. NDVI index on the map of Tarusa

Source: compiled by V.A. Brundukova using the QGIS program.

Analysis of NDVI values revealed significant variation: maximum index value (0.723) corresponds to areas with high photosynthetic activity, such as floodplain and coniferous forests, while at least (–0.311) is characteristic of areas with dense development and bridges. The spatial distribution of different classes of vegetarian activity by town districts is systemized in Table 2.

Table 2. **Distribution into NDVI classes**

Class	Percentage of territory, %	An example in the city
Dense vegetation	15	Northern and eastern suburbs
Sparse vegetation	30	Parks and public gardens
Open ground	25	Agrolandscapes, wastelands
Water bodies	10	The Oka River, Tarusa, ponds
Artificial surfaces	20	City center, roads

Source: compiled by V.A. Brundukova.

There are still dense vegetation strips along the Oka River, indicating a stable floodplain ecosystem. At the same time, sites near the Tarusa River are characterized by low NDVI values (< 0.025) indicating possible silting processes or strong anthropogenic effects.

There is a circular zone of sheared vegetation around the town centre, probably formed as a result of greening programs.

Most problematic are zones in the south of the city with NDVI values in the range 0.025–0.5, where remediation measures such as planting sustainable grass species are needed.

Conclusion

The technique of qualitative assessment of planting on a point ranged system was tested, where 3 — good condition, 2 — satisfactory, 1 — unsatisfactory. As a result:

– trees: 36% — unsatisfactory condition, 6% — satisfactory condition, 10% — good condition;

– shrubs: 25% — unsatisfactory condition, 28% — satisfactory condition, 9% — good condition;

– lawns: 55% — unsatisfactory condition, 36% — satisfactory condition, 3% — good condition;

– flower beds: 22% — unsatisfactory condition, 16% — satisfactory condition, 3% — good condition.

There have been recorded 71 plant species, of which 59% occur only once, indicating fragmentation of ecosystems. The most common species: Norway spruce (*Picea abies*), woolly burdock (*Ārctium tomentōsum*).

The following key issues in Tarusa's landscape have been identified:

Degradation of greenspace.

– 36% of the trees surveyed are in unsatisfactory condition (crown dieback, mechanical damages), and the prevalence of poorly resistant species has also been identified (ash-leaved maple tree) with a lack of native species (oak, linden);

– 55% of lawns have sparse grass with a dominance of weed species (creeping wheatgrass, plantain), and there is also a lack of care for flower beds (22% of sites are in unsatisfactory condition).

Floristic depletion. Disappearance of species typical for the floodplains (grassy, mixed grass) in 40% of surveyed areas. Noticeable spread of invasive plants (for example, Canadian goldenrod).

Imperfect management decisions. Lack of monitoring data on soil, vegetation and water bodies.

The following recommendations can be made to resolve selected issues:

– to carry out a sanitary pruning of 100% of trees in unstisfactory condition;

– to increase the planting of the most common tree species, such as the small-leaved linden and the pedunculate oak;

– to implement grass mixes for urban lawns (meadow fescue, bluegrass) at degraded sites;

– to annually remove invasive species such as Canadian goldenrod and Sosnovsky's hogweed mechanically, and gradually introduce current and best techniques for the disposal of these species;

– to conduct monitoring work to assess the condition of green spaces at least once every three years to allow for the rapid management of species diversity in the town.

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