



DOI 10.23859/estr-240418

EDN GPURFE

UDC 630*181.2:630*425

Article

Forest plantations changed under Sterlitamak industrial center conditions (Southern Urals, Republic of Bashkortostan) during the period 2013–2023: causes and practical significance

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Abstract. The results of assessing the relative living condition of woody plants of the Sterlitamak Industrial Center based on permanent test areas conducted in 2013, 2023 are presented. It is shown that over a 10-year period, against the background of a decrease in the annual volumes of industrial pollution of the environment, the condition of tree plantations changed from the category "weakened" (65%) to the "healthy" one (84%). In the conditions of the industrial zone, the hanging birch turned out to be the most resistant to a complex of extreme natural and man-made factors. At the same time, a significant improvement in the living condition of birch plantations was also noted for the residential and recreational zone. A similar pattern of positive changes in the condition was noted for linden, oak, poplar, spruce and larch. The periodic determination of the relative living condition of tree plantations allows us to form an idea of the changes occurred under prolonged anthropogenic effects, to identify prospects for preservation of existing plantations and to justify the measures for their reconstruction.

Keywords: landscaping, vital condition of trees, industrial pollution, temperature, precipitation

Funding. The work was performed using the equipment of the Agidel collective use center as a part of state assignment No. 123020700152-5 FMRS-2023-0008 "Sustainability of forest-forming tree species and ecological and biological adaptations taking into account anthropogenic transformation of landscape and natural complexes".

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To cite this article: Tagirova, O.V, Kulagin, A.Yu., 2025. Forest plantations changed under Sterlitamak industrial center conditions (Southern Urals, Republic of Bashkortostan) during the period 2013–2023: causes and practical significance. *Ecosystem Transformation* 8 (1), 48–65. <https://doi.org/10.23859/estr-240418>

Received: 18.04.2024

Accepted: 09.06.2024

Published online: 21.02.2025

DOI 10.23859/estr-240418

EDN GPURFE

УДК 630*181.2:630*425

Научная статья

Изменение состояния древесных насаждений Стерлитамакского промышленного центра (Южное Предуралье, Республика Башкортостан) за период 2013–2023 гг.: причины и практическое значение

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Аннотация. Представлены результаты оценки относительного жизненного состояния древесных растений Стерлитамакского промышленного центра на сети постоянных пробных площадей, проведенные в 2013 г. и в 2023 г. Показано, что за 10-летний период на фоне снижения объемов годовичного поступления промышленных загрязнителей в окружающую среду состояние древесных насаждений улучшилось, сменившись с категории «ослабленное» (64.9%) на категорию «здоровое» (83.7%). В условиях промышленной зоны наиболее устойчивой к комплексу экстремальных природных и техногенных факторов оказалась береза повислая; при этом для селитебно-рекреационной зоны также отмечено существенное улучшение жизненного состояния березовых насаждений. Аналогичная картина положительных изменений состояния отмечена для липы мелколистной, дуба черешчатого, тополя бальзамического, ели обыкновенной и лиственницы Сукачева. Периодическое определение относительного жизненного состояния древесных насаждений позволяет отследить динамику изменений в условиях длительного действия антропогенных факторов, определить перспективы сохранения имеющихся насаждений и обосновать мероприятия по их реконструкции.

Ключевые слова: озеленение, относительное жизненное состояние деревьев, промышленное загрязнение, температура, осадки

Финансирование. Работы выполнены с использованием оборудования центра коллективного пользования «Агидель» в рамках плановых исследований по бюджетной теме № 123020700152-5 FMRS-2023-0008 «Устойчивость лесообразующих древесных видов и эколого-биологические адаптации с учетом антропогенной трансформации ландшафтно-природных комплексов».

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Для цитирования: Тагирова, О.В., Кулагин, А.Ю., 2025. Изменение состояния древесных насаждений Стерлитамакского промышленного центра (Южное Предуралье, Республика Башкортостан) за период 2013–2023 гг.: причины и практическое значение. *Трансформация экосистем* 8 (1), 48–65. <https://doi.org/10.23859/estr-240418>

Поступила в редакцию: 18.04.2024

Принята к печати: 09.06.2024

Опубликована онлайн: 21.02.2025

Introduction

The sustainable development of industrial centers is conditioned by the interrelation of ecology, economy and society. The ecological component ensures the formation of a comfortable environment, which is aimed at the sustainable long-term functioning of the urban ecosystem. Favorable environmental conditions contribute to the concentration of the population in a particular region, an increase in the number of able-bodied people and the economic development of the territory. The economic component is associated with comfortable conditions for society, including the availability of jobs, decent wages and social security. As economic growth and production volumes increase, coupled with the need for sustainable development, it is imperative to reduce the negative impact of anthropogenic factors on the environment. At the present stage of development of industrial cities, targeted financing of environmental protection measures is carried out. In particular, the reconstruction of industrial enterprises, the installation of modern sewage treatment plants, the transition to the best available technologies, the reclamation of disturbed landscapes, reforestation and protective afforestation, and landscaping are key links in optimizing environmental management and improving people's lives (Glebova et al., 2000).

Tree plantations on the territory of industrial centers ensure the formation of a comfortable urban environment (Bukharina et al., 2007; Bushueva and Srodnykh, 2022; Ibragimova et al., 2014; Kulagin and Tagirova, 2015). Woody plants perform gas-accumulating functions (Kulagin and Sergeychik, 1982; Nikolaevsky, 1979; Tarabrin, 1980) and act as a phytfilter, accumulating toxic compounds in conifers, leaves, wood and bark of plants (Alpaidze and Salukvadze, 2023; Garifzyanov, 2011; Giniyatullin et al., 2023; Kabanova et al., 2021; Kulagin, 1974). It should be noted that the successful performance of environmental protection functions by tree plantations is based on the phenomenon of resistance to extreme growing conditions (Ibragimova et al., 2016; Kulagin, 1974, 2003; Kulagin and Sergeychik, 1982).

By now, it is widely believed that the process of drying out of tree stands in conditions of industrial pollution is irreversible and leads to the death of individual trees and plantings as a whole (Kirilyanov et al., 2014; Zverev, 2012). This is the basis for recommendations on sanitary logging in weakened stands (Klochkov, 1991; Pankratov, 2021; Sazonov et al., 2023; Zalesov and Lugansky, 1993), as well as recommendations on the reclamation of contaminated soils (Tyukavina and Korepin, 2023). It is known that formed adaptive complex of woody plants is characterized by ecological features of species (Kulagin, 2009; Tagirova and Kulagin, 2019), and individual structural and functional adaptations of various levels of the organization are implemented throughout the ontogeny of plants (Sensuła et al., 2015; Usmanov et al., 2001). The successful growth of woody plants in changing environmental conditions occurs due to adaptation during a particular growing season, but, in fact, it lasts for decades. A vivid example of ensuring the survival of woody plants in conditions of water scarcity and increased atmospheric gas pollution is the late summer deciduous fall of poplar, birch, linden and other species, as well as a reduction in the life expectancy of needles in pine, spruce and other coniferous species with perennial needles (Feklistov et al., 2005; Kulagin, 1974; Kuzmin and Karpyuk, 2022; Tyukavina

and Korepin, 2023). It has been established that in the case of mass reproduction of leaf-eating pests (Bui et al., 2020, 2021; Vorobyova et al., 2020) or with accidental releases of industrial pollutants into the atmosphere (Menshchikov et al., 2004), the assimilation apparatus almost completely dies. However, due to their regenerative abilities, woody plants are able to restore their leaves, needles, and consequently, biological productivity in the current growing season (Kulagin, 1991, 2000, 2003). It has been shown that in conditions of long-term petrochemical pollution, against the background of a decrease in gross emissions due to the regeneration of the crown and leaves, the vital condition of birch stands improves (Tagirova, 2024).

This work is devoted to the study of the peculiarities of growth and changes in the state of tree plantations in the dynamic conditions of the Sterlitamak Industrial Center (Southern Urals) in the period 2013–2023 in order to substantiate practical measures for the conservation and creation of tree plantations in residential, recreational and sanitary protection zones.

Material and methods

The city of Sterlitamak was founded in 1766 as the Sterlitamak Saltwater Marina, and was granted acity status in 1781. The Sterlitamak Industrial Center (SIC) is located in the forest-steppe zone of the Russian Plain, in the subzone of a typical forest steppe. The relief is represented by sloping plains, gentle valley slopes, composed of clays of Neogene age with mixed grass-grass steppes, oak forests, arable lands on leached chernozems. The relief elements include floodplains, low and medium erosion-accumulative terraces of river valleys with old lakes, swampy meadows, forests and shrubs on alluvial, swampy, dark gray forest and chernozem soils (Atlas..., 2005; Bashkortostan..., 1996). The city is mostly located on the flat territory.

Industrial enterprises are concentrated in the northern part of Sterlitamak. Enterprises of the chemical and petrochemical industries act as the main pollutants of the environment. The volume of total emissions of pollutants amounted to 42.1 thousand tons, or 80.7% of emissions from stationary sources. In the period from 2008 to 2022, there was a decrease in total emissions into the atmosphere from stationary and mobile sources on the territory of the SIC (Fig. 1). In particular, the amount of emissions of sulfur dioxide and nitrogen oxides into the atmosphere has significantly decreased (Fig. 2). As a result, the anthropogenic impact on the environment is decreasing, and the environmental situation is stabilizing (Gosudarstvennyi doklad..., 2023).

In addition to the negative effects of industrial pollutants, extremely low and extremely high temperatures, as well as temperature fluctuations in long-term dynamics negatively affect the state of woody plant plantations (Fig. 3). At the same time, some stabilization of forest conditions is determined by the fact that the amount of precipitation in the SIC has been increasing since 2010 (Fig. 4).

On the territory of the SIC, permanent test areas (TA) were laid in tree plantations (Fig. 5), the species composition of the plantations was analyzed, the taxation indicators of stands were determined (Andreeva et al., 2002) and the relative vital condition (RLC) of woody plants (with additions for deciduous woody plants) was estimated by the number of trees (L_n , %) (Alekseev, 1989). This paper presents the results of research conducted in 2013 (Ibragimova et al., 2014; Tagirova and Ibragimova, 2013) and in 2023.

During the research, attention was paid to plantings containing common spruce *Picea abies* (L.) Karst, Sukachev larch *Larix sukaczewii* Dyl., hanging birch *Betula pendula* Roth, small-leaved linden *Tilia cordata* Mill., pedunculate oak *Quercus robur* L., and balsamic poplar *Populus balsamifera* L.

When assessing the main diagnostic parameters of the vital condition of trees, the following signs were characterized: crown density (% of normal density), the presence of dead branches (% of the total number of branches on the trunk), the degree of damage to the needles (leaves) by toxicants, pathogens and insects (the average area of necrosis, spotting and overeating in % of the leaf area).

Tree height was determined using a Nikon Laser Forestry Pro range finder (Japan), and the diameter of the trees was measured with a Haglof measuring fork (Sweden). The age of the stands in the test area was determined using a Suunto augmentation drill (Finland) at a height of 0.4 m.

Standard statistical processing methods were used to process the actual material (Microsoft Excel 2020, Adobe Photoshop 2020).

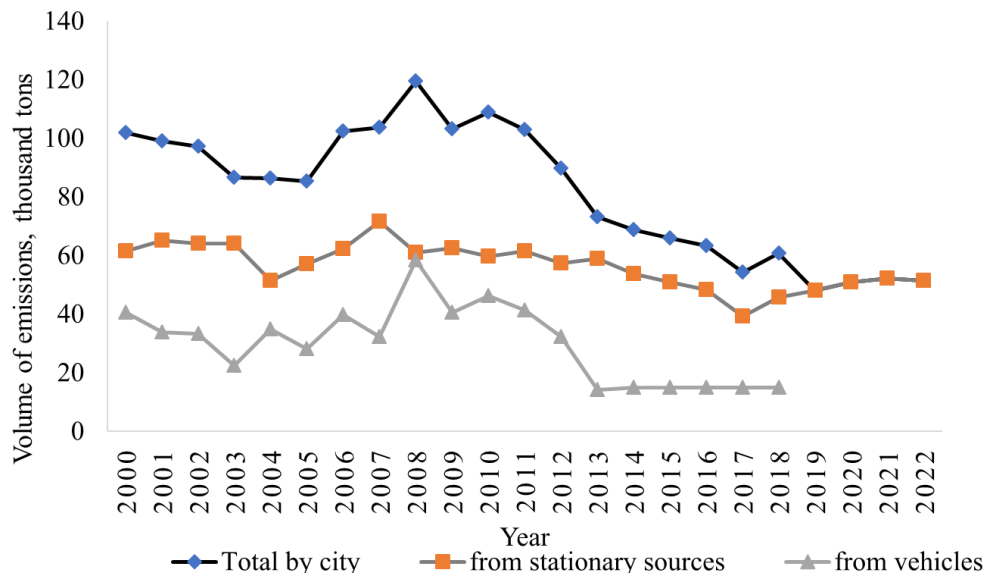


Fig. 1. Emissions of pollutants into the atmosphere from stationary and mobile sources on the territory of the Sterlitamak Industrial Center in 2000–2022, thousand tons (Gosudarstevnyi doklad..., 2023).

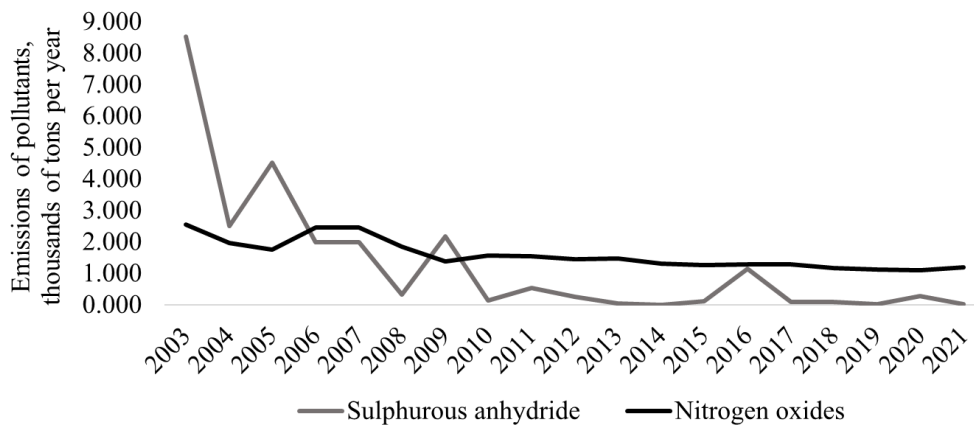


Fig. 2. Emissions of sulfur dioxide and nitrogen oxides into the atmosphere on the territory of the Sterlitamak Industrial Center in 2003–2021, thousand tons (Gosudarstevnyi doklad..., 2023).

Results and discussion

In the course of our previous studies, the following zones were identified within the SIC: an industrial zone (TA No. 1 and TA No. 2), a residential and recreational zone (TA No. 3–8), as well as a southern zone located on the territory of the Sterlitamak forestry (TA No. 9) (Fig. 5) (Ibragimova et al., 2014; Tagirova and Ibragimova, 2013).

Changes in the taxation indicators of forest plantings for the period 2013–2023 are presented in Table 1, and the RLC parameters are shown in Table 2. Changes in RLC over a ten-year period are recorded based on assessing the state of model trees. The representation of woody plant species in plantings in individual territories differs due to the use of a small number of species in the creation of forest crops, plantings in gardens and squares in the 1960s.

TA No. 1

An assessment of the condition of 13 poplar trees was carried out in the sanitary protection plantings at TA No. 1, located north of Sterlitamak Petrochemical Plant JSC. As compared to 2013, the recorded decrease in the average tree diameter (Table 1) was associated with a large felling to ensure safety (high probability of windbreak).

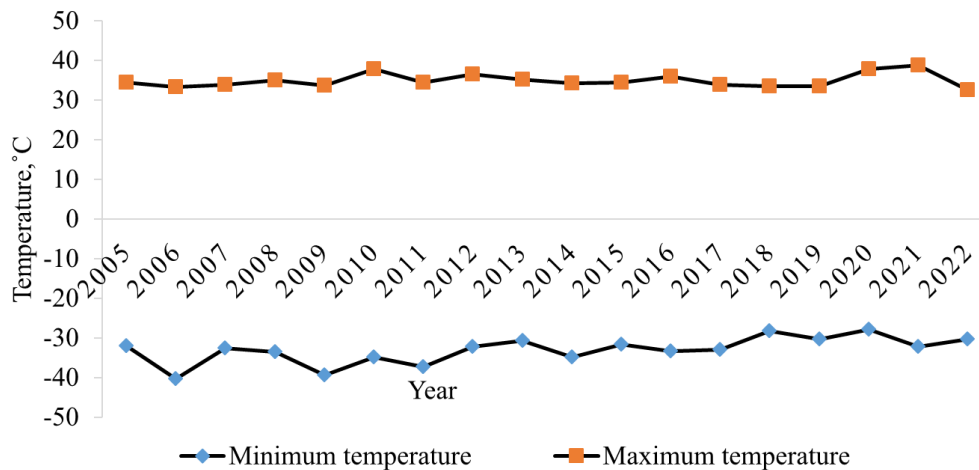


Fig. 3. Dynamics of temperature changes in the territory of the Sterlitamak Industrial Center in 2005–2022, Celsius degrees (<https://rp5.ru/>).

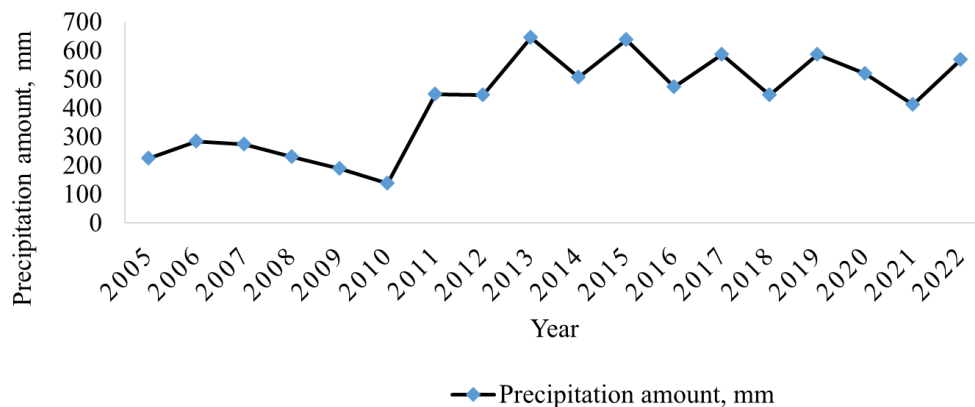


Fig. 4. Dynamics of precipitation amounts on the territory of the Sterlitamak Industrial Center in 2005–2022, mm (<https://rp5.ru/>).

In this area, RLC of poplar plantations is classified as "weakened" ($L_n = 62\%$). Crown density is 20–85%. The presence of dead branches on the trunk is from 1% to 45%. The degree of leaves damage is from 15% to 20%. Dryness is not pronounced. It is found that 2 trees belong to the "healthy" category, 8 trees are "weakened", 1 tree is "severely weakened", 2 trees are "dying", none of trees belong to the category "dry".

TA No. 2

A total of 46 trees were assessed in the sanitary protection plantings of TA No. 2, located north of Bashkir Soda Company JSC. Their average diameter was 32 cm, the average height – 25 m, and the average age – 43 years.

In this territory, the RLC of poplar plantations (21 trees) belongs to the "weakened" category ($L_n = 57\%$). The crown density is 45–80%. The presence of dead branches on the trunk is from 1% to 45%. The degree of damage to the leaves makes up 5–10%. Dryness is noted. Fourteen trees belong to the category "weakened", five to "severely weakened", two to "dying", and no trees belong to "healthy" and "dry" categories.

In TA No. 2, birch (25 trees), according to RLC, belongs to the category "healthy" ($L_n = 89\%$). The crown density is 65–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. Sixteen trees are considered "healthy", nine – "weakened", and no trees belong to "severely weakened", "dying" or "dry" categories.



Fig. 5. A map diagram of the city of Sterlitamak with the location of permanent test areas (Ibragimova, et al., 2014; Tagirova and Ibragimova, 2013).

TA No. 3

On the territory of the Gagarin Park of Culture and Recreation (TA No. 3), the condition of 81 trees has been assessed. The average diameter is 39 cm, the average height is 20 m, and the average age is 48 years.

In this territory, the relative living condition of poplar plantations (12 trees) belongs to the category "healthy" ($L_n = 93\%$). The crown density is 55–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. Nine trees belong to the "healthy" category, three to "weakened", and no trees to "severely weakened", "dying" or "dry" categories.

RLC of birch plantations (47 trees) belongs to the "weakened" category ($L_n = 77\%$). The crown density is 55–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. All in all 16 trees belong to

Table 1. Brief description of changes in the main indicators of tree plantations in the Sterlitamak Industrial Center for 2013–2023.

Zone	TA no.	Location	Species	RLC, L _n , %	
				2013 г.	2023 г.
Industrial	1	North of Sterlitamak Petrochemical Plant JSC	<i>Populus balsamifera</i>	40.5	62.3
	2	North of Bashkir Soda Company JSC	<i>Populus balsamifera</i>	21.3	56.7
			<i>Betula pendula</i>	76.0	89.2
Residential and recreational	3	Yu.A. Gagarin Park of Culture and Recreation	<i>Populus balsamifera</i>	83.3	92.5
			<i>Betula pendula</i>	49.0	77.0
			<i>Tilia cordata</i>	91.0	95.0
	4	“Sodovik” Culture and Recreation Park	<i>Larix sukaczewii</i>	67.0	76.0
			<i>Quercus robur</i>	54.0	76.0
			<i>Betula pendula</i>	44.0	73.2
5	Park on Khudaiberdina St.	<i>Tilia cordata</i>	78.5	93.2	
		<i>Betula pendula</i>	69.5	86.9	
		<i>Picea abies</i>	91.0	92.0	
6	Park named after G.K. Zhukov	<i>Betula pendula</i>	60.0	91.3	
		<i>Tilia cordata</i>	73.0	90.0	
		<i>Larix sukaczewii</i>	94.0	95.6	
7	Park named after S. Yulaev	<i>Picea abies</i>	85.0	93.8	
		<i>Betula pendula</i>	44.0	93.2	
8	Park near the House of Culture	<i>Picea abies</i>	75.0	100	
		<i>Betula pendula</i>	44.0	93.2	
		<i>Betula pendula</i>	73.0	93.2	
Southern	SIC green zone	<i>Populus balsamifera</i>	36.5	48.6	
		<i>Betula pendula</i>	59.5	71.0	
		<i>Tilia cordata</i>	63.5	95.4	
Среднее значение				64.9	83.7

Table 2. Changes in the relative living condition (RLC, %) of trees in the plantings of the Sterlitamak Industrial Center in 2013–2023.

Zone	№ ПП	Location	Species	RLC, L _n , %		
				2013 г.	2023 г.	
Industrial	1	North of Sterlitamak Petrochemical Plant JSC	<i>Populus balsamifera</i>	40.5	62.3	
	2	North of Bashkir Soda Company JSC	<i>Populus balsamifera</i>	21.3	56.7	
			<i>Betula pendula</i>	76.0	89.2	
	3	Yu.A. Gagarin Park of Culture and Recreation	<i>Populus balsamifera</i>	83.3	92.5	
			<i>Betula pendula</i>	49.0	77.0	
			<i>Tilia cordata</i>	91.0	95.0	
			<i>Larix sukaczewii</i>	67.0	76.0	
			<i>Quercus robur</i>	54.0	76.0	
	Residential and recreational	4	“Sodovik” Culture and Recreation Park	<i>Betula pendula</i>	44.0	73.2
				<i>Tilia cordata</i>	78.5	93.2
5		Park on Khudaiberdina St.	<i>Betula pendula</i>	69.5	86.9	
			<i>Picea abies</i>	91.0	92.0	
6		Park named after G.K. Zhukov	<i>Betula pendula</i>	60.0	91.3	
			<i>Tilia cordata</i>	73.0	90.0	
			<i>Larix sukaczewii</i>	94.0	95.6	
			<i>Picea abies</i>	85.0	93.8	
7		Park named after S. Yulaev	<i>Betula pendula</i>	44.0	93.2	
			<i>Picea abies</i>	75.0	100	
8	Park near the House of Culture	<i>Betula pendula</i>	73.0	93.2		
Southern	9	SIC green zone	<i>Populus balsamifera</i>	36.5	48.6	
			<i>Betula pendula</i>	59.5	71.0	
			<i>Tilia cordata</i>	63.5	95.4	
Среднее значение				64.9	83.7	

the "healthy" category, 26 to "weakened", 5 to "severely weakened", and no trees to "dying" or "dry" categories.

Linden (12 trees) is classified as "healthy" ($L_n = 95\%$). Its crown density is 80–95%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. A total of 10 trees belong to the category "healthy", 2 are "weakened", no trees are referred to the "severely weakened", "dying" and "dry" categories.

Larch (5 trees) belongs to the "weakened" category ($L_n = 76\%$). Its crown density makes up 55–75%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. Two trees belong to the category "healthy", two are "weakened", one is "severely weakened", and no trees belong to "dying" and "dry" categories.

Oak (5 trees) belongs to the "weakened" category ($L_n = 76\%$). Its crown density is 55–75%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. One tree belongs to the category "healthy", four to "weakened", and no trees to the categories of "severely weakened", "dying" and "dry".

TA No. 4

On the territory of the "Sodovik" Culture and Recreation Park (TA No. 4) the condition of 47 trees has been assessed. The average diameter is 40 cm, the average height – 22 m, and the average age – 53 years.

RLC of birch (25 trees) belongs to the category of "weakened" ($L_n = 73\%$). Its crown density is 20–5%. The presence of dead branches on the trunk is within 1–55%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. There are 11 trees in total belonging to the category "healthy", 8 trees to "weakened", 4 to "severely weakened", 2 to "dying", and no trees to the category "dry".

Linden (22 trees) is classified as "healthy" ($L_n = 93\%$). Crown density of linden is 75–90%. The presence of dead branches on the trunk is from 0% to 5%. The degree of damage to the leaves ranges from 1% to 10%. Dryness is not pronounced. A total of 17 trees belong to the category "healthy", 5 to "weakened", and no trees to "severely weakened", "dying" or "dry" categories.

TA No. 5

On the territory of the park on Khudaiberdina St. (TA No. 5), the condition of 31 trees has been assessed. The average diameter is 25 cm, the average height is 13 m, and the average age is 45 years.

Birch (16 trees) belongs to the category "healthy" ($L_n = 87\%$). The crown density is 55–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. A total of 10 trees belong to the category "healthy", 5 to "weakened", 1 to "severely weakened", and no trees to "dying" and "dry" categories.

RLC of common spruce (15 trees) belongs to the category "healthy" ($L_n = 92\%$). The crown density is 45–90%. The presence of dead branches on the trunk is from 1% to 25%. The degree of damage to the needles is from 1% to 20%. Dryness is not pronounced. Twelve trees belong to the category "healthy", two are "weakened", one is "severely weakened". There are no trees belonging to "dying" and "dry" categories.

TA No. 6

On the territory of the park named after G.K. Zhukov (TA No. 6), the condition of 97 trees has been assessed. The average diameter is 24 cm, the average height is 14 m, and the average age is 43 years.

RLC of birch (31 trees) belongs to the category "healthy" ($L_n = 91\%$). The crown density is 55–85%. The presence of dead branches on the trunk is from 1% to 15%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. 23 trees belong to the category "healthy", 7 to "weakened", 1 to "severely weakened", and no trees to "dying" and "dry" categories.

Linden (15 trees) is classified as "healthy" ($L_n = 90\%$). The density of the crown is 70–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. All in all 10 trees belong to the category "healthy", 5 to "weakened", and no trees to "severely weakened", "dying" and "dry" categories.

Larch RLC (27 trees) belongs to the category "healthy" ($L_n = 96\%$). Crown density is 55–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the needles is from 1% to 10%. Dryness is not pronounced. All together 24 trees belong to the category "healthy", 2 to "weakened", 1 to "severely weakened", and no trees to "dying" and "dry" categories.

Spruce RLC (24 trees) belongs to the category "healthy" ($L_n = 94\%$). The crown density is 75–85%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the needles is from 1% to 10%. Dryness is not pronounced. A total of 19 trees belong to the category "healthy", 5 to "weakened", and no trees to "severely weakened", "dying" and "dry" categories.

TA No. 7

On the territory of the park named after S. Yulaev (TA No. 7), an assessment of the condition of 40 trees has been made. The average diameter is 35 cm, the average height is 15 m, and the average age is 48 years.

Birch RLC (31 trees) belongs to the category "healthy" ($L_n = 93\%$). The crown density is 75–95%. The presence of dead branches on the trunk is from 1% to 5%. The degree of damage to the leaves is from 1% to 5%. Dryness is not pronounced. Twenty four trees belong to the category "healthy" and 7 to "weakened". There are no trees belonging to severely weakened, "dying" and "dry" categories.

Spruce (9 trees) is classified as "healthy" ($L_n = 100\%$). The density of its crown is 80–90%. The presence of dead branches on the trunk is from 1% to 10%. The degree of damage to the needles is from 1% to 10%. Dryness is not pronounced. Nine trees belong to the category "healthy". There are no trees referred to "weakened", "severely weakened", "dying" and "dry" categories.

TA No. 8

An assessment of the condition of 31 birch trees has been made on the territory of the park near the House of Culture (TA No. 8). The relative living condition of the plantings is classified as "healthy" ($L_n = 93\%$). Crown density is 75–90%. The presence of dead branches on the trunk is from 1% to 5%. The degree of damage to the leaves is from 1% to 5%. Dryness is not pronounced. Twenty four trees belong to the category "healthy", 7 to "weakened", and no trees to "severely weakened", "dying" and "dry" categories.

TA No. 9

On the territory of the SIC green zone (TA No.), the condition of 120 trees has been assessed. The average diameter is 33 cm, the average height is 18 m, and the average age is 50 years.

Poplar (51 trees) is classified as "severely weakened" ($L_n = 49\%$). Crown density is 20–60%. The presence of dead branches on the trunk is from 5% to 45%. The degree of damage to the leaves is from 5% to 45%. Dryness is noted. A total of 31 trees belong to the category "weakened", 6 to "severely weakened", 14 to "dying", and no trees to "healthy" and "dry" categories.

The RLC of birch (56 trees) belongs to the category of "weakened" ($L_n = 71\%$). The density of its crown is 25–85%. The presence of dead branches on the trunk is from 5% to 25%. The degree of damage to the leaves is from 5% to 10%. Dryness is not pronounced. All in all 5 trees belong to the category "healthy", 49 are "weakened", 1 is "severely weakened", 1 is "dying". There are no trees belonging to the category "dry".

Linden (13 trees) is classified as "healthy" ($L_n = 95\%$). The crown density is 75–85%. The presence of dead branches on the trunk is 1–10%. The degree of damage to the leaves is from 1% to 10%. Dryness is not pronounced. Eleven trees belong to the category "healthy" and two to "weakened". There are no trees belonging to "severely weakened", "dying" and "dry" categories.

A comparative analysis of the condition of poplar, birch, linden, larch, spruce and oak growing in different zones of the SIC showed that in 2013 the most depressed plantings were in the industrial zone (the condition of poplar was assessed as "weakened" (RLC 56.7–62.3%)) and in the southern part of the SIC (the condition of poplar plantations was assessed as "severely weakened" (RLC 48.6%) and birch – as "weakened" (RLC 71.0%)).

It was found that over a 10-year period the condition of tree plantations improved against the background of a decrease in annual industrial pollution, as well as a slight increase in precipitation and temperature rise. In general, the state of tree plantations with the participation of spruce, larch, birch, linden, oak and poplar in the SIC in 2013–2023 improved: the category "weakened" (64.9%) was changed to the "healthy" one (83.7%).

Conclusions

The Sterlitamak Industrial Center saw a decrease in industrial emissions from 2013 to 2023. It was found that, in general, during the specified period, RLC of woody plants changed from "weakened" to the "healthy" category. It should be noted that such positive changes occurred due to the timely implementation of plant care measures (watering, crowning, logging, etc.) by city services.

It is shown that in the industrial zone of Sterlitamakbirch turned out to be the most resistant to a complex of extreme natural and man-made factors in 2023. Its condition is estimated on average as "healthy" ($L_n = 89.2\%$). The reasons for general improvement of SIC tree plantations over the past 10 years (2013–2023) are the ecological and biological adaptive features of woody plants and their ability to regenerate (sympodial type of crown branching and growth, restoration of the assimilation apparatus after defoliation, etc.) against the background of reduced emissions of industrial pollutants and minor changes in natural and climatic parameters.

It is advisable to justify and make decisions on cutting down, reconstructing and creating plantings in a modern city on the basis of individual trees, taking into account the growing conditions and location of plantings. At the same time, the timeliness and correctness of forest management measures is ensured by the frequency of inspections of plantings.

Improvement and landscaping of territories and green areas of cities must be carried out taking into account the anthropogenic load. Based on the state assessment of plantations for the residential and recreational area, the above-mentioned types of woody plants are recommended for SIC landscaping. The above makes it necessary to take a differentiated approach to the organization of reconstruction, restoration and creation of plantings in modern industrial centers.

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