Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Assessment of the degree of landscaping in Astana, Kazakhstan and recommendations for its development

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ABSTRACT

The problem of the formation of environmentally friendly urban areas is relevant for various regions of the world. In different climatic conditions, approaches to its solution differ in efficiency and speed of their implementation. The purpose of this work is to assess the degree of landscaping in Astana and present recommendations for its development. The work analyzed data on the existing vegetation cover of Astana, Kazakhstan in 2021. The results of soil phytotoxicity were presented. The area was estimated based on remote sensing data and GIS technologies, followed by an integral assessment of the state of green spaces in Astana, including the determination of survival rate, forest pathological state, and a comprehensive assessment of the state of green spaces. Based on the results of the study, emergency measures were proposed related to individual plant species and situations in parks. The authors indicated what activities need to be carried out for further assessment of landscaping. The landscaping method proposed by the authors can be used to assess the landscaping of other cities in a continental climate.

Keywords: Landscaping, Trees, Ecological situation, Urbanization, Kazakhstan.
Article type: Research Article.

INTRODUCTION

The purpose of urban landscaping is to create and consolidate the main environmental, ecologizing and stabilizing qualities of any territory (Keshtkaran 2019; Krasilnikova *et al*. 2021). Green spaces, forests and vegetation are the only component of nature (creating and regulating) the human habitat (Santangelo *et al.* 2018; Nassif *et al.* 2023). They release oxygen and biologically active substances, absorb carbon dioxide, nitrogen, sulfur and other pollutants, precipitate dust, that is, make the atmosphere suitable for humans (Pereira & Baró 2022). Academician V.I. Vernadsky considered vegetation to be the most active part of nature, which assimilates solar energy, nutrition elements, moisture and turns them into organic matter and accumulated energy (Levit & Krumbein 2000). The construction of the capital of Kazakhstan is being carried out at an accelerated pace in combination with the rapid quantitative growth of the population of Astana, the issue of qualitative improvement of the ecological situation in the city, one of the aspects of which is landscaping, is becoming very relevant (Sullivan & Chang 2017). The existing system of landscaping of the capital, in addition to the insufficiency in the area, has an important drawback – it does not fully take into account the ecological state of the territory of Astana, does not take into account the assimilation-productive, environment-forming ability of vegetation. It is necessary to imagine the territory of the city as a combination of several ecosystems – a river, a steppe, and so on – creating a complex urban socio-ecosystem. The multicomponence, complexity, dynamism of the urban socio-ecosystem requires using a systematic ecological and landscape approach for the study and assessment of the territory. The main requirement of such an approach to the development and using territories is a

Caspian Journal of Environmental Sciences, Vol. 21 No. 3 pp. 585-594 Received: Dec. 06, 2022 Revised: March 28, 2023 Accepted: May 17, 2023
DOI: 10.22124/CJES.2023.6937

Publisher: University of Guilan,

comprehensive assessment and zoning of urban areas (Riascos 2017). In many developed countries, a comprehensive assessment of territories has been carried out for these purposes and ecological atlases of cities have been developed or are being developed (Zakrutkin *et al.* 1999; Wang *et al.* 2022). Each component of an ecosystem is regarded simultaneously as an ecosystem component and an ecological resource. Thus, the problem of landscaping the urban landscape is multifaceted and very important for the residents of the city. In the case of Astana, it is necessary to develop an ecological atlas, which would be considered when planning the landscaping of the city. The present study, was aimed at creating such an atlas. The purpose of this work is to assess the degree of landscaping in Astana and present recommendations for its development.

MATERIALS AND METHODS

Location and Period of the Study

The assessment of the degree of landscaping in Astana was carried out in 2021 using the resources of the Saken Seifullin Kazakh Agrotechnical University, Kazakhstan.

Model for Assessing the Landscaping of Astana

The model of assessing the landscaping of Astana is shown in Fig. 1.

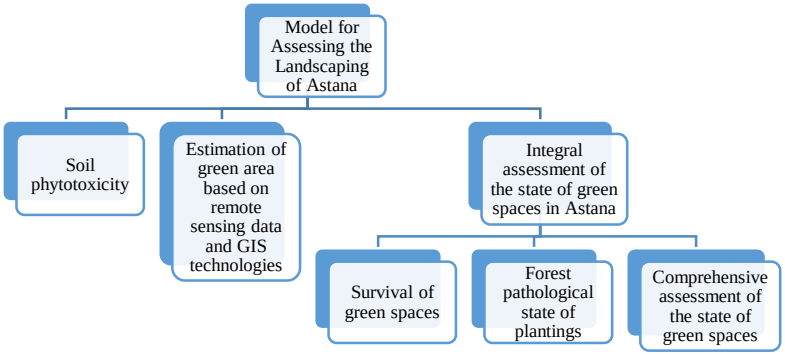

Fig. 1. Model for assessing the landscaping of Astana.

1. Soil phytotoxicity

At the first stage of the study, the features of the reaction of phytotests were studied to assess the quality of the soil cover in various functional zones of Astana using the bioindication method (Aidarkhanova *et al.* 2015). Values of coefficients of soil phytotoxicity in various ecological zones of Astana: sites 1 and 4 – roadside garden squares (beside the highway), sites 2 and 3 –city parks, site 5 – adjacent territory within the city limits of Astana.

2. Estimation of green area based on remote sensing data and GIS technologies

At the second stage, an assessment of the green area of Astana for 2021 was carried out based on remote sensing data and GIS technologies. To calculate the vegetation index NDVI, the following spectral channels of the Sentinel-2 satellite from a free source were used in the work eos.com/landviewer: NIR – reflection in the near infrared region of the spectrum; RED – reflection in the red region of the spectrum.

3. Integral assessment of the state of green spaces in Astana

The integral assessment of the state of green spaces in Astana included the determination of survival rate, forest pathological state, and a comprehensive assessment of the state of green spaces.

Survival of green spaces

1) For the examination of plantings, the most typical and largest objects (parks, garden squares, and streets) of Astana were selected with the measurement of the main taxation indicators and the assessment of the condition of plants, dividing them into healthy, dubious, and dead.

2) For the conditions of the green zone, the collection of experimental data was carried out on permanent test plots, which were planted according to the soil suitability groups in the best-preserved plantations. The survival rate was calculated in the same way, with the total counted number of plants replaced by the total number of all

planted plants. In the process of work, the survival rates were summarized in one table for 16 breeds most used in landscaping in this region.

Forest pathological state of plantings

The forest pathological examination of the state of green belt plantings in Astana was carried out on an area of 7,839 ha to identify trees and shrubs damaged by pests and affected by their diseases. The predominant tree and shrub species in the plantations of the green belt of Astana are deciduous (birch, elm, poplar, maple, sucker, willow, hawthorn, currant, bird cherry) and coniferous (pine).

Comprehensive assessment of the state of green spaces

For an integral assessment of the state of green spaces in common use, the coefficient of integrated environmental assessment (CIEA) was calculated.

Study object

The assessment of the degree of ecological state was carried out in the following public green spaces in Astana:
- Parks: Defenders of the Fatherland, Lovers, Aray, Zher-Uyik;
- Garden squares: Zelenstroy, Tashenova Street, Chess Players, Arbat, Football Players, Baiterek, Musical Fountain, Palace of Schoolchildren, Yesil, New Square, Flower Clock, Congress Hall, Bauyrzhan Momyshuly, Islamic Cultural Centre;
- Avenues: Ablai Khan Avenue, the National Guard area, Sary-Arka Avenue;
- Other sites: Main Square, Vodno-zelonyy Boulevard, KazMunayGas, KazKomertsBank, Ishim Embankment.

Data Analysis

To calculate the NDVI index for Astana in the ArcGIS software (Oliveira *et al.* 2020), we used a raster calculator (Fig. 2) using the formula 1 from the downloaded spectral channels.

$$NDVI = \frac{NIR-}{NIR+}, \qquad (1)$$

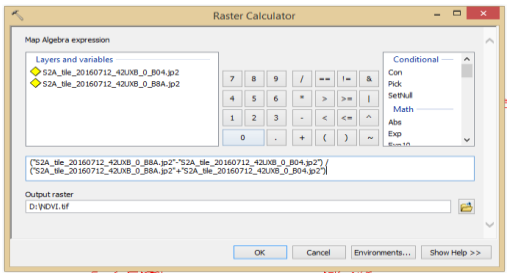

Fig. 2. Raster Calculator in ArcGIS software.

After calculating the spectral index, an NDVI raster with a scale from -1 to 1 was obtained. The index values range from -1 to 1, which correspond to certain types of coatings (Table 1).

Table 1. NDVI index values.

NDVI	Type of cover
0.8 – 1.0	Very strong, dense vegetation (for example, tropical or broad-leaved healthy forest)
0.67 – 0.8	Powerful, dense vegetation (forest)
0.4 – 0.5	Sparse tree and shrub vegetation
0.2 – 0.4	Shrubs and pastures
0.09 – 0.2	Open soil
-0.1 – 0.1	Rock, sand, snow
-0.42 – 0.33	Water body
-0.55 – -0.5	Anthropogenic cover (concrete, asphalt)
0	Cloud in the picture

The survival rate of each breed was calculated using the following formula:

$$S\ (\%) = \frac{Nh.+50\%d. \times 100}{Ntot.}$$

where S (%)*:* survival percentage, Nh.: number of healthy plants, d.: number of dubious plants, Ntot.: total number of plants counted.

Integral assessment of the state of public green spaces. In the work, the coefficient of integrated environmental assessment (CIEA) was used, which is calculated as the sum of the products of the state scores (SS) by correction coefficients (CC) divided by the sum of the CCs of all vegetation elements according to the formula:

$$CIEA = \frac{(SS.s. \times 1 + SS.sh. \times 0.4 + SS.l. \times 0.2 + SS.fb. \times 0.1)}{\sum CC\ \mathbf{s,sh,l,fb}}$$

The values of correction coefficients (CC) was conditionally accepted for each of the vegetation elements: **s**tands -1.0, **sh**rubs-0.4, **l**awns-0.2 and **f**lower **b**eds -0.1.

The gradation of the characteristics of the condition of trees of common use of Astana by the weighted average value is shown in Table 2.

Table 2. Characteristics of the state of trees by weighted average.

№	Degree of attenuation	Condition
1	Does not exceed 1.5	The planting is healthy
2	1.6-2.5	Weakened
3	2.6-3.5	Severely weakened
4	3.6-4.5	Shrinking
5	More than 4.5	The deceased

The study and assessment of the condition of public green spaces in Astana were carried out according to the scale of categories of tree condition (Table 3).

Table 3. Scale of tree condition categories.

Tree condition categories	Signs of tree condition categories	
	Coniferous	Deciduous
1-no signs of weakening	The crown is thick, the needles (foliage) are green, the growth of the current year's shoot is of normal size for this breed, age and growing conditions.	
2-weakened	The crown is sparse, the needles are light green, the growth is reduced, but not by more than half, individual branches are withered.	The crown is sparse, the foliage is light green, the growth is reduced, but not by more than half, individual branches are withered, single water shoots.
3-severely weakened	The crown is openwork, the needles are light green, the growth is weak, less than half of the usual, the branches shrink to 2/3 of the crown.	The crown is openwork, the foliage is light green, the growth is weak, less than half of the usual, the branches shrink to 2/3 of the crown, abundant water shoots.
4-shrinking	The crown is strongly openwork; the needles are gray, yellowish or yellow-green; the growth is very weak or absent; the drying of more than 2/3 of the branches.	The crown is strongly openwork; the foliage is small, sparse, light green or yellowish; the growth is very weak or absent; drying over 2/3 of branches.
5-fresh dead wood	Needles are gray, yellow or red-brown, partial falling of bark.	Foliage is sluggish or absent, partial bark falling off.
6-old dead wood	There are no live needles (foliage), bark and small twigs have completely crumbled, stem pests have flown out, there is a mycelium of wood-destroying mushrooms on the trunk.	

RESULTS

Soil Phytotoxicity

The results of determining the phytotoxicity of soils are shown in Fig. 3.

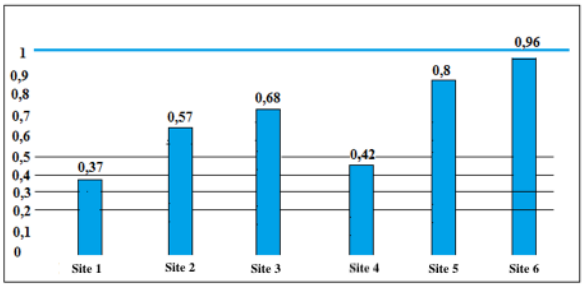

Fig. 3. Soil phytotoxicity coefficients by plots.

A comparative analysis of the phytotoxicity of soils in various ecological zones (the territory of a city park, a roadside garden square, or a personal plot) showed certain differences in the reaction of test objects. Seed germination of the test object in most samples ranged from 37 to 80%, while in the control, it was 96%. The results of the experiment showed that the water extracts of the soils in Astana are characterized by heterogeneity. The range of phytotoxicity of the studied soils did not exceed 16%. The main contribution to soil pollution in the urban environment was made by vehicles. The phytotoxicity of the roadside garden square soil was characterized by a significant deviation from the control. Motor traffic in this ecological zone and, in general, in the city limits formed areas of local air pollution. An analysis of the results of the performed experiment characterized the phytotoxicity of the soil as a heterogeneous structure for all surveyed ecological zones. Insignificant deviations from the control in terms of soil phytotoxicity were characteristic of the territory of city parks and personal plots. The value of the coefficient of the soil phytotoxicity in the surveyed experimental plots was in the range of 16-43%. In roadside highways, there was a significant disturbance of the soil cover, as indicated by bioindicative signs.

Assessment of the Landscaping Area of Astana for 2021 Based on Remote Sensing Data and GIS Technologies

The resulting NDVI raster of Astana is shown in Fig. 4, and the scale of the NDVI index for Astana in Fig. 5. We obtained values ranging from 0.42745098 – 0.592156863 highlighted on the NDVI raster with orange class, corresponding to sparse and sparse woody and shrubby vegetation. According to statistics, the area of this class was 201.1 km^2 (20110 ha), which occupied about 28% of the administrative territory of the city.

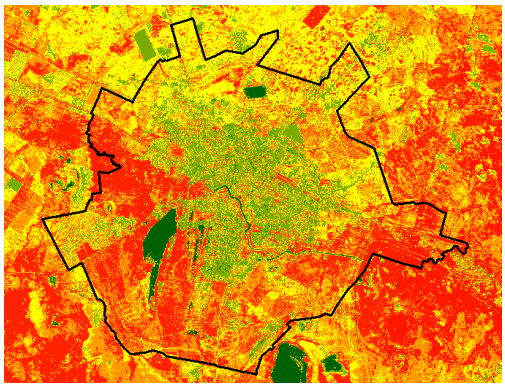

Fig. 4. NDVI index with overlapping borders of Astana.

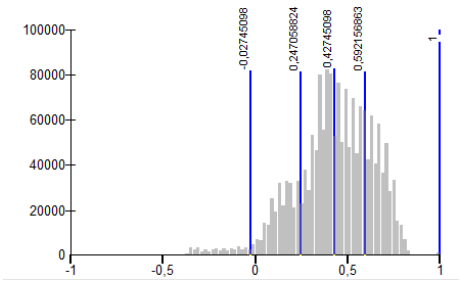

Fig. 5. NDVI index scale for the city of Astana.

The value of 0.592156863 – 1 highlighted on the raster with a red class, corresponding to dense vegetation. According to statistics, the area of this class was 173.8 km^2 (17376 ha), occupying about 24% of the administrative territory of the city. Thus, the total area of landscaping of Astana in 2021 was calculated: 374.9 km^2 (37486 ha), comprising about 52% of the administrative territory of the city.

Survival rate of green spaces

The survival percentage of green spaces in Astana is presented in Table 4. Standard survival rate and preservation are represented by the following indicators: normal – 70; good – 60.4; weak (low) – 30.4. In general, survival and preservation have good indicators.

Forest pathological examination of the state of plantings

According to the results of the forest pathological examination of plantings, the 30 most harmful species of phytophagous insects were identified (Table 5). Diseases caused real harm to green zone plantations: mainly various types of spotting (maple tar spot, septoria, poplar Marssonina leaf spot, birch leaf blight), infectious and non-infectious marginal leaf necrosis and finally pine shute. These diseases cause significant damage to young plants and reduce the decorative qualities of mature trees and shrubs, while rot diseases mainly affect old trees. Possible active methods of protecting green spaces include physical, mechanical (agrotechnical), biological, and chemical. Chemical control is allowed only in extreme cases, with the mass reproduction of pests and the mass spread of diseases, with the obligatory observance of the established regulations and safety measures.

Table 4. Survival rate (%) by tree species.

№	Name of tree species (+ species name in the green zone)	In the city			Green space					Average value
		Autumn planting	Spring planting	Planting trees with a clod	Years after planting (years)					
					1	2	3	4	5	
1	Siberian peashrub	-	-	-	78.0	75.7	62.5			70.5
2	Silver birch	62	65	70	69.0	37.3		32.1	30.4	35.9
3	Bessey cherry	-	-	-	72.0	70.6	65.1	61.6		66.2
4	Siberian elm	75	80	85	76.7	73.4	57.1		41.0	64.8
5	White dogwood	75	80	-	74.1	68.3	57.0	56.4		66.7
6	Tatarian honeysuckle	75	78	-	68.0	63.6	59.4	58.3		63.1
7	Purple willow	75	80	85	79.8	75.6	63.6	52.3		71.8
8	Boxelder maple Plant	75	80	80	79.2	77.3	76.0	74.8	61.4	77.1
9	Russian olive	75	80	-	81.2	77.2		71.0	69.4	72.1
10	Rowan	65	70	70					69.6	66.0
11	Golden currant	75	80	-	79.7	75.7				70.7
12	Scotch pine	65	60	70	38.2	31.9				30.8
13	Black poplar	75	80	85	60.4		60.0			60.0
14	Chokecherry + bird cherry	65	70	80		58.6	48.3			50.2
15	Siberian crab apple	75	79	80	79.0					70.0
16	Green ash	70	78	80	64.0	56.0	54.0			58.1

In addition, in the plantations of the green zone, a complex of miner insects has formed, which includes species different in their biological and ecological characteristics leading to outbreaks of mass reproduction for a long time (leaf-mining sawflies, elm leaf-mining fleas, etc.).

Results of the comprehensive assessment of the ecological condition (CAEC) of green spaces

The results of the comprehensive assessment of the degree of the ecological state of public green spaces in Astana are presented in Table 6.

Table 5. Types of pests in plantings of the green belt of Astana.

Tree species	Types of plant pests
Scotch pine, *Pinus sylvestris* L.	Great web-spinning pine-sawfly, *Acantholyda posticalis* Mats; red-headed pine sawfly, *Acantholyday erythrocephala* L.; pine resin-gall moth, *Retinia resinella* L.
Silver birch, *Betula pendula* Roth.	Birch leafminer, *Fenusa pumila* Kl; birch leafminer *Scolioneura betulae* Zadd.; birch sawfly *Croesus septentrionalis* L.; birch sawfly *Cimbex femorata* L., *Biston* sp.
Laurel poplar, *Populus laurifolia* Ldb.	Poplar leaf beetle, *Malasoma populi* L.; poplar sawfly, *Trichiocampus viminalis* Fall.; small poplar borer, *Saperda populnia* L.; hornet moth, *Aegeria apiformis* Cl.; *Pemphigus pactucarius* Pass.; poplar spiral gall aphid, *Pemphigus spirothecae* Licht.; puss moth, *Dicranura vinula* L.; poplar grey, *Acronycta megacefala* Schiff.
Siberian elm, *Ulmus pumila* L.	*Psylla ulmi* L.; *Trichiocampus eradiatus* Htg.; *Exaereta ulmi* Schiff., *Biston* sp.
Redhaw hawthorn, *Crataegus sanguinea* Pall.	Pear slug *Coliroa limacina* Retz.; black-veined white *Aporia crataegi* L.; *Cfcfecia crataegana* Hb.
Siberian violet-willow, *Salix acutifolia* Willd.	Poplar leaf beetle *Melasoma populi* L.; willow gall sawfly *Pontania proxima* Lepel.; *Argyroploce sflicella* L., *Rhogogaster viridis* L.
Russian olive, *Elaeagnus angustifolia* L.	Artichoke aphid *Capitophorus elaegni* Guercio.; grape wood borer *Chlorophorus varius* Mull.

Table 6. Assessment of the degree of the ecological state of public green spaces in Astana.

№	Green space objects	Status in points by vegetation category				CAEC (average)
		Tree	Hedge	Lawn	Flower	
1	Defenders of the Fatherland Park	1.3	1.5	1.5	1.0	1.4
2	Zelenstroy Garden Square	1.3	-	-	2.0	1.4
3	Tashenova Street Garden Square	1.5	-	2.0	1.0	1.5
4	Chess Players Garden Square	1.8	1.0	1.0	1.5	1.5
5	Arbat Garden Square	1.3	-	2.0	-	1.4
6	Main Square	1.7	1.0	1.0	1.5	1.4
7	Lovers Park	1.6	1.5	1.5	1.0	1.5
8	Football Players Garden Square	1.5	1.0	1.0	1.5	1.3
9	Ablai Khan Avenue, the National Guard area	1.5	-	-	-	1.5
10	Baiterek Garden Square	1.7	1.3	1.5	1.0	1.5
11	Musical Fountain Garden Square	1.7	-	1.0	1.0	1.5
12	Vodno-zelonyy Boulevard	1.6	-	-	1.5	1.5
13	KazMunayGas	1.4	1.0	1.0	1.0	1.2
14	KazKomertsBank	1.9	1.0	1.0	1.0	1.5
15	Islamic Cultural Center Garden Square	1.6	1.0	1.5	1.0	1.4
16	Ishim Emnankment	1.9	1.0	1.0	1.2	1.5
17	Aray Park	1.8	1.0	1.0	1.5	1.5
1	Zher-Uyik Park	1.9	1.5	2.0	1.0	1.8
2	Palace of Schoolchildren Garden Square	2.0	1.5	1.5	2.5	1.8
3	Yesil Garden Square	1.8	-	1.5	-	1.8
4	New Square Garden Square	2.3	1.5	1.0	1.0	1.9
5	Flower Clock Garden Square	1.9	-	-	1.5	1.9
6	Congress Hall Garden Square	1.8	-	2.0	1.0	1.8
7	Baurzhan Momyshuly Garden Square	2.1	1.0	2.0	1.5	1.8
8	Prospekt Sary-Arka	1.9	-	-	1.5	1.9

As shown in Table 6, out of the 25 surveyed objects, 17 are classified as healthy (CAEC of 1.5 or less) and eight as weakened (CAEC of 1.6 or more).

DISCUSSION

In order to rationally place plantings, it is necessary to know the contamination of soils, soils and waters throughout the territory (Shikhova 2019). The assessment of soil phytotoxicity carried out in the present study showed that the main part of the city's territory is unsuitable for the growth of woody and shrubby plants. There is another problem caused by the occurrence of variegated clay close to the surface of the earth. This clay, firstly, contains a lot of salts, and secondly, it is water-resistant (Turdakhunov *et al.* 2014). The water that enters the soil – thawed, rain – reaches the layer of this clay, is saturated with salt – sometimes up to 34 g L^{-1} – and rises up through the capillary system of the soil. Therefore, the soils of more than half of the city's territory are, to varying degrees, saline. Unsuitable and unsuitable lands prevail in Astana, which, of course, complicates the work on landscaping, requires special measures to improve drainage, create individual planting sites, selection of resistant plants and systematic care with irrigation. As the results showed, the survival rate and preservation of green spaces in Astana are stable. Weak and low survival rates are observed only in two species: silver birch and Scotch pine. The phytosanitary condition of green spaces in Astana is generally characterized as satisfactory, except for coniferous species (spruce and pine), where the main pests are spruce false shield, pine aphid, pine hermes and coniferous mites, which affected the condition and growth of coniferous species. In addition, the most destructive diseases are rust and shute. The comprehensive assessment of the ecological state in public green spaces of Astana indicate the need for the following activities:

a) In the case of the tree category of vegetation, restoration and care work is required at the following sites: Chess Players Garden Square, Main Square, Lovers Park, Baiterek Square, Musical Fountain Garden Square, Vodno-zelonyy Boulevard, KazKomertsBank, Islamic Cultural Center Garden Square, Ishim Embankment, Aray Park, Zher-Uyik Park, Palace of Schoolchildren Garden Square, Yesil Garden Square, New Square Garden Square, Flower Clock Garden Square, Congress Hall Garden Square, Bauyrzhan Momyshuly Garden Square, Sary-Arka Avenue;

b) in the case of the lawn and flower categories of vegetation, restoration and care work is required at the following sites: Tashenov Street Garden Square, Arbat Garden Square, Zher-Uyik Park, Congress Hall Garden Square, Bauyrzhan Momyshuly Garden Square, and the flower garden in the Palace of Schoolchildren Garden Square.

We identified primary activities for restoration work. For the improvement of landscaping in general, there is not enough planning for the assessment of the landscaping system. The urban landscaping system should consist of large arrays, as well as a system of linear and spotted objects along streets, blocks, inside courtyards. This whole system should be connected with green objects of forest park and suburban areas. In Astana, it is necessary to create green corridors along all transport highways and repair the existing spot-linear landscaping system. The most effective in terms of improving the urban environment are large green areas and corridors – from 150 to 600 hectares. Only such arrays have environment-forming and environment-improving functions (Thomé *et al.* 2016). There are no such territories reserved in the General Plan, so it is necessary to resolve this issue by demolishing dilapidated housing and other low-rise economic facilities. A zone of ecological rehabilitation of industrial territories has also been allocated. They should have their own system – protective and environmental-improving. There is also a medium-improving meadow-swamp system around Lake Taldykol and south of the village of Internationally, on the left bank. In the forest park and suburban areas, it is possible to create recreational, sports, tourist facilities. In addition, in large natural protective areas there are also economic ones: environmentally safe facilities for obtaining environmentally friendly food, medicinal and technical products. Rehabilitation of rivers, lakes, creation of protective zones along their shores is also envisaged. This will require an adjustment of the General Plan of Astana. It seems important to create a "Public Greening Fund of the capital" and increase the city budget items aimed at landscaping, allocate grant funding for research and development of the production and technical base for the activities of nurseries. To do this, it is necessary to attract sponsors and conduct competitive procedures for the implementation of landscaping projects and the development of nurseries. When selecting an assortment of tree and shrub species for landscaping, Astana needs to focus on frost-resistant, salt-tolerant and drought-resistant breeds with a high growth class, while priority landscaping with conifers and highly phytoncidal flowering shrubs is required. It is important to pay attention to improving the level of knowledge and skills in landscaping of employees of the landscaping infrastructure in the Kazakh cities and foreign universities of this

profile. At this time, these works are not carried out or are conducted at a very low level. It is necessary to equip the urban landscaping infrastructure with modern innovative specialized equipment, apparatuses and aggregates for landscaping, including equipment for biological and chemical protection of green spaces. When designing and further carrying out work on the creation of green spaces, it is recommended to comply with the goals, principles and requirements of the ecological and economic policy of Kazakhstan.

CONCLUSION

For further accelerated development of landscaping in Astana, it is required: a complete inventory of green spaces and an additional inventory survey of green spaces. The landscaping development project as part of the Master Plan should be linked to the plan for the development of the nursery base and with the development of the necessary design and estimate documentation. We developed a methodology and assessed the degree of landscaping in Astana. Based on our results, we proposed recommendations for the development of the city. The main advantage of our methodology is a comprehensive assessment that considers the different components of the city's ecosystem. The application of the method helped to identify plants (birch, pine) for which it was necessary to urgently take emergency restoration measures. In addition, we were able to develop measures for tree, lawn, and flowering vegetation for the most complex objects requiring emergency intervention. By applying this assessment methodology, the authorities were able to obtain accurate information and effectively make decisions on the formation of environmentally friendly urban areas, which is very important for achieving the principles of sustainable development. The limitations of the study include the quality of the original data. The data published by the Ministry of Environmental Protection (MEP) is based on measurements carried out by Kazhydromet from only 4 or 5 observation points for the whole city, whereas, even according to the old Soviet standards, there should be about 15 stationary and as many mobile ones for Astana. The obtained results significantly contribute to the development of measures for the accelerated development of landscaping in Astana. In the future, it is necessary to conduct additional research to develop environmental atlases of the city.

Author's Contributions

All authors contributed equally to this study.

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Bibliographic information of this paper for citing:

Ospangaliyev, A, Sarsekova, D, Mazarzhanova, K, Dosmanbetov, D, Kopabayeva, A, Obezinskaya, E, Nurlabi, A, Mukanov, B 2023, Assessment of the degree of landscaping in Astana, Kazakhstan and recommendations for its development. Caspian Journal of Environmental Sciences, 21: 585-594.