Features of the development stability of tree plantations of large city industrial zones

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Abstract. Expansion of urbanized areas and activity of technogenic systems led to the emergence and operation of a set of environmental factors that determine the flow of life processes in new conditions. Under the influence of anthropogenic factors including man-made (industry, energy, transport) and economic activities (construction, utilities, recreational load) in the environment, a number of environmental problems arise and develop, aggravated by unfavourable weather conditions for dispersion of harmful impurities in the air, which is especially important for Krasnoyarsk city. Biological monitoring is necessary to assess the environmental consequences of human impact, to ensure the necessary level of environmental quality and the environmental safety of the urban environment. Recently, researchers have been analysing the degree of impact of environmental factors through developmental sustainability (fluctuating asymmetry). This paper shows an assessment of the stability of the development of tree plantations growing in the zone of influence of an aluminium plant and heat and power engineering enterprises. For the study the most common tree species were selected, which are widely used for landscaping cities: apple berry, wild cherry, balsam poplar, elm squat. The representativeness of the data obtained is confirmed by appropriate statistical processing. Morphometric indicators of the lamina (j3, j4, j5) of apple and berry apple trees sensitive to negative environmental factors, intensified under the influence of emissions from an aluminum plant, are revealed. An identical response of indicator species belonging to the same family was found.

1. Introduction

According to the Office of the Federal State Statistics Service for the Krasnoyarsk Territory, the Tyva Republic and the Republic of Khakassia (Krasnoyarsk statatistics), the urban environment has become the main place of residence for 77.2% of the population of the Krasnoyarsk Territory, while 54.4% of the urban population is concentrated in Krasnoyarsk city. Thus, the ecological condition of urbanized areas should be given particular attention.

2. Problem statement

It is known that green plantings of cities and their industrial areas are among the most important means of maintaining the purity and consistency of the atmospheric air. However, they can simultaneously perform the function of environmental quality indicator [1, 2]. At the same time, woody plants play an important bio-indicative role both at the level of the biochemical, physiological,

anatomical, morphological, and floristic, bio-geocenological responses. Plants, overcoming the effects of adverse factors, produce adaptive changes in the structure and processes of life. Thus, under the action of the anthropogenic factor, the area of the leaf plate of woody plants decreases, and the asymmetry of their leaf plates is manifested. The assessment of the degree of asymmetry of leaf leaves of woody plants is currently under discussion [3]. However, it should be noted that a number of authors demonstrate a fairly successful use of this indicator in determining the stability of plant development [4-6]. In this case, the main link in the improvement of urban areas is the choice of sustainable plantations with effective protective and sanitary-hygienic functions, which requires a careful selection of species that successfully develop in altered environmental conditions.

Thus, an urgent task is to assess the influence of varying degrees of anthropogenic impact on the index of fluctuating asymmetry (IFA) of a number of tree species growing under these conditions.

The aim of our study is to identify the stability of the development of an array of green spaces in an industrial area. The subject of our research includes fluctuating asymmetry (FA) of morphometric indicators of leaflets.

3. Materials and methods

Krasnoyarsk, the administrative industrial centre of the Krasnoyarsk Territory, is one of the largest cities in the Russian Federation with a population of over 1 million people. It differs from other large cities in a number of features and a unique urbanized ecosystem with a wide range of industrial enterprises (metallurgy, power engineering, chemical industry). The city is located on the territory of three climatic zones, on the banks of the Yenisei river. Within the city the year-round water surface is open on the river; in winter, there is no ice cover. According to S.V. Mikhailuta et al. despite the fact that the prevailing wind direction is south-west in Krasnoyarsk (38% of the total number), the wind direction is transformed in certain areas of the city due to illiterate development [7]. All of the above factors cause a high level of atmospheric air humidity and the nature of movement and sedimentation of suspended particles, aerosols, which come from emissions from stationary sources and vehicles.

The most common tree species, widely used for urban landscaping were selected as the objects of the study [8]. Thus, apple (*Malus baccata*), wild cherry (*Prunus padus*), balsam poplar (*Populus balsamifera*), elm elm (*Ulmus pumila*), which are dust-holding, gas-resistant species grow in most public gardens, parks, streets and courtyards, sanitary protection zones of industrial facilities in Krasnoyarsk city.

To achieve the goal, in September 2016, plant samples were selected in industrial areas of Krasnoyarsk. According to the amount of emissions that enter the environment from the activities of selected sources, they can be distributed as follows (by increasing load): CHP-3 - CHP-2 - CHP-1 – RUSAL plant (figure 1).

The selection was made in accordance with the requirements of the methods [9, 10] on the west and south sides of the crown (middle part) from ten randomly selected trees of each type (distance from the road not less than 50 m, characterized by a low level of traffic loading). The leaves were pressed between layers of filter paper and dried under pressure. A sample of plant samples included 100 leaves at each point from trees of the same age.

Prepared plant materials were scanned with a resolution of 1200 dpi. 5 people took part in the measurement procedure, while the measurements were carried out on sheet plates without mechanical damage or deformation. During the work, the most standard metric bilateral signs were considered: j_1 is the width of the left and right halves of the lamina; j_2 is the distance from the base of the leaf blade to the end of the vein of the second order; j_3 is the distance between the bases of the first and second veins of the second order; j_4 is the distance between the ends of the first and second veins of the second order; j_5 is the angle between the main vein and the second vein from the base of the leaf.

Statistical processing was performed using Microsoft Excel, Statistica.

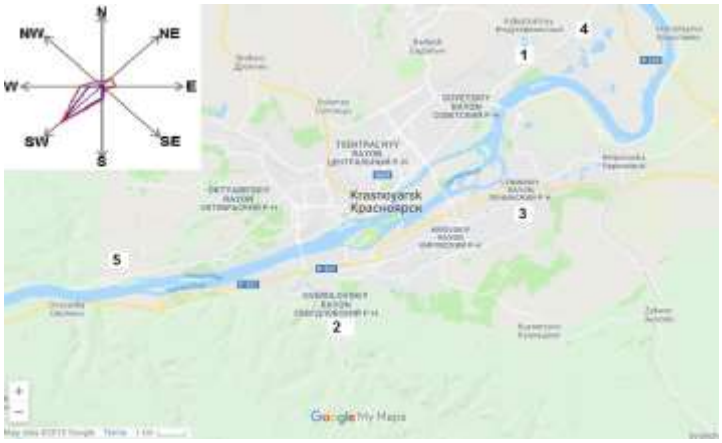
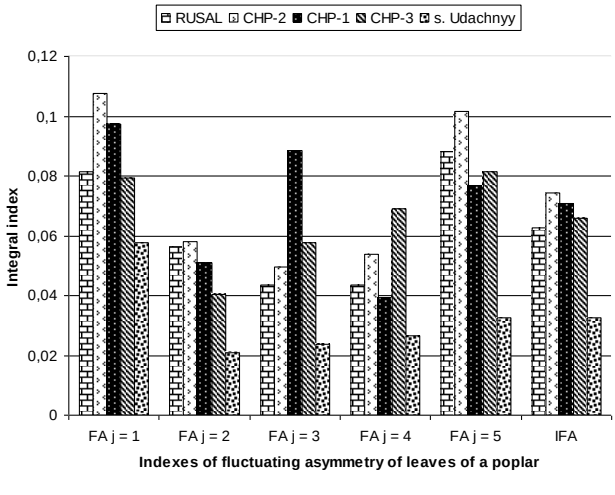


Figure 1. Map-scheme of sites for the selection of plant samples in the city of Krasnoyarsk: 1 - the area of the Krasnoyarsk Aluminium Plant (RUSAL); 2 - the area of the Krasnoyarsk CHP-2; 3 - Krasnoyarsk CHP-1 area; 4 - Krasnoyarsk CHP-3 district; 5 - control area (Udachny village).

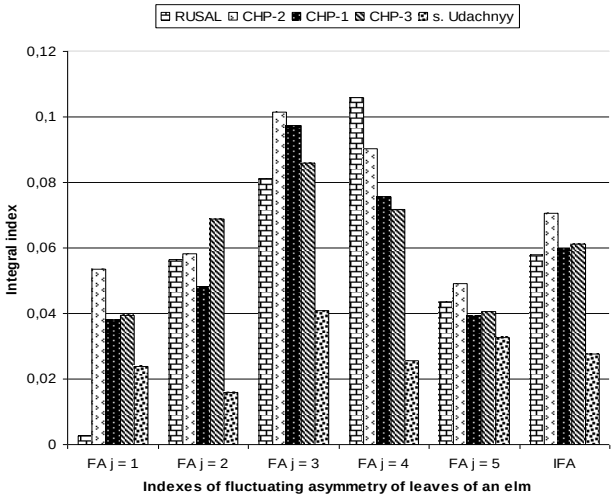
4. Discussion of results

In most works, to assess the quality of the habitat by size, IFA uses a five-point scale, which was developed by Zakharov and Streltsov for the European part of Russia (Kaluga region) [9, 10]. In accordance with the scale [10], all the studied samples, except for the control one (0.0277–0.0392), were characterized by the level of fluctuating asymmetry exceeding the conditional norm for the background state of the environment (0.040). The following rows were built for the industrial zones of Krasnoyarsk according to the integral FA index: Krasnoyarsk Aluminum Plant area - 0.0577 (bird cherry) < 0.0579 (elm) 0.0583 (apple) 0.0625 (poplar); CHP-2 - 0.0585 (bird cherry) < 0.0593 (apple) 0.0705 (elm) 0.0744 (poplar); CHP-1 - 0.0561 (bird cherry) < 0.0565 (apple) 0.0596 (elm) 0.0707 (poplar); CHP-3 - 0.0501 (apple) < 0.0502 (bird cherry) 0.0613 (elm) 0.0658 (poplar). The obtained integral indices of FA correspond to the critical state of the environment (5 points). In the area of CHP-3 according to data on apple and bird cherry, the quality of the environment corresponds to 4 points or a significant deviation from the norm. This is probably due to the fact that CHP-3 has the lowest environmental impact compared to other Krasnoyarsk CHPs.

However, as a result of this study, we are inclined to agree with the opinion of M. V. Kozlov [3] that this method is not desirable to use for assessing the quality of the environment. It is possible that it works well in the study of IFA of leaf plates of birch hanging.

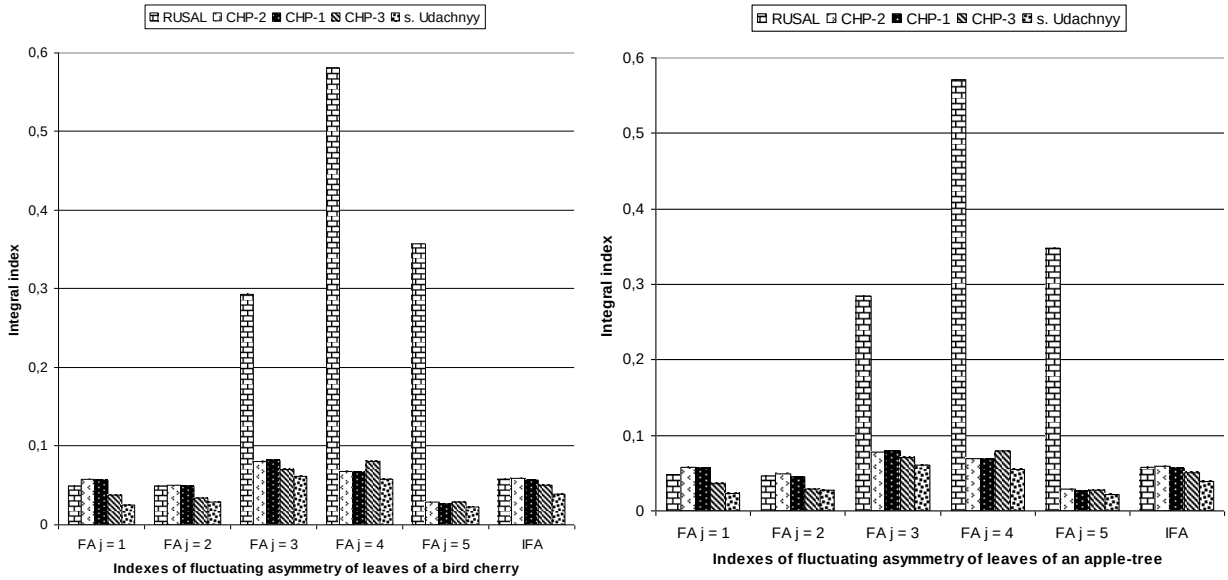


Populus balsamifera



Ulmus pumila

Figure 2. Indicators and integral indices of fluctuating asymmetry: (FAj = 1 ... 5) - indicators of fluctuating asymmetry of the corresponding bilateral signs; (IFA) - integral index of fluctuating asymmetry.



Prunus padus *Malus baccata*

Figure 3. Indicators and integral indices of fluctuating asymmetry: (FAj = 1 ... 5) are the indicators of the fluctuating asymmetry of the corresponding bilateral signs; (IFA) - integral index of fluctuating asymmetry.

But in our case, there is a different reaction of woody plants to the degree of anthropogenic pollution. Thus, table 1 presents the gradation of the most sensitive indicators of fluctuating asymmetry for the objects considered.

As it can be seen from the presented data, a complete match is achieved only for the bird cherry and berry apple. Poplar balsamic and elm squat have different response indicators of fluctuating asymmetry of leaf plates on the state of the environment.

According to the study [11], under the influence of the road load, there is a violation of the stability of the Balsam poplar under conditions of the city of Krasnoyarsk, the authors point out the applicability of the method of evaluating FA for environmental pollution by vehicle emissions, although we believe that it is difficult to isolate the effect of both stationary and mobile sources of pollution. Thus, we once again point out the inexpediency of using the rating scale, developed primarily on the basis of studying the morphometric parameters of birch.

Table 1. Gradation of the studied areas by the most sensitive indicators of fluctuating asymmetry.

Leaf plates of objects	Possible ranking of urbanized areas in order of decreasing pollution (from left to right)				
Balsam poplar	CHP-2	RUSAL	CHP -3	CHP -1	Udachny vil.
Elm squat	CHP -2	CHP -1	CHP -3	RUSAL	Udachny vil.
Bird cherry	RUSAL	CHP -1	CHP -2	CHP -3	Udachny vil.
Apple tree berry	RUSAL	CHP -1	CHP -2	CHP -3	Udachny vil.

5. Conclusion

Based on the above, the following conclusions can be made:

- it is undesirable to use woody plants to assess the quality of the environment without conducting a significant amount of research, both in terms of temporal and spatial factors;
- since the apple berry and cherry trees belong to the same family (*Rosaceae*), it led to their identical response to the degree of anthropogenic impact;

- it is not recommended to compare indicator species belonging to different families by IFA.

References

[1] Slepov A N, Lagunov A N, Korotchenko I S, Boyarinova S P and Pervyshina G G 2019 Assessment of the possibility of using Sorbus aucuparia for the recultivation of disturbed lands near the Borodinsky open-pit mine *Coal* **4** 101-5

[2] Korotchenko I S 2015 The influence of the heat and power complex of the city of Krasnoyarsk on the value of fluctuating asymmetry of a leaf plate of poplar balsamic *Bulletin of the Krasnoyarsk State Agrarian University* **8** 15-20

[3] Kozlov M V 2017 Study of plant fluctuating asymmetry in Russia: mythology and methodology *Ecology* **1** 3-12

[4] Sandnera T M, Zverev V and Kozlov M 2019 Can the use of landmarks improve the suitability of fluctuating asymmetry in plant leaves as an indicator of stress? *Ecological Indicators* **97** 457-65

[5] Zorina A A and Korosov A V 2007 Characteristics of the fluctuating asymmetry of a leaf of two types of birch trees in Karelia *Proceedings of the Karelian Research Center of the Russian Academy of Sciences* **11** 28-36

[6] Zykov I E, Fedorova L V and Baranov S G 2015 Evaluation of the bioindicative value of the level of variability of parameters of small-leaved linden plates (Tilia cordata Mill.) in the conditions of the city of Orekhovo-Zuyevo and Orekhovo-Zuyevo district *Bulletin of Moscow State Regional University* **1** 15-21

[7] Mikhailuta S V, Lezheninc A A, Pitt A and Taseiko O V 2017 Urban wind fields: Phenomena in transformation *Urban Climate* **19** 122-40 doi: https://doi.org/10.1016/j.uclim.2016.12.005

[8] Bukharina I L, Zhuravleva A N and Bolysheva O G 2012 *Urban plantings: the environmental aspect* (Izhevsk: Udmurt University Publishing House)

[9] Zakharov V M, Baranov A S, Borisov V I *et al.* 2000 *Environmental Health: Evaluation Technique* (Moscow: Center for Environmental Policy of Russia)

[10] 2003 Guidelines for the implementation of environmental quality assessment on the state of living beings: disposal of Rosecology of October 16, 2003 **460**

[11] Popelnitskaia I M, Semenova A R, Bukharova Y B, Popelnitskii Y V and Popov A O 2018 The impact of vehicle emissions on sustainability of balsam poplar (*Populus balsamifera*) in the urban environment of Krasnoyarsk *International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management; Sofia* **18** pp 973-80