Development of the Control System for State Forest Inventory

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Annotation

A work presents questions of the possibility of using the system of state forest inventory for the purpose of forest plantations monitoring on of the territory of the forest park named after Foresters of Russia as some example. Stratification of forest plantations of the forest park was carried out. The number of trial plots is calculated. 25 trial plots in light coniferous ripe and over mature high-productive plantations have been laid and an assessment of their condition has been made.

1. Introduction

Urban forests of Yekaterinburg and its environs are an integral part of the city-building structure and the most important part of its ecological framework. They are included in the life support system as a fundamental environment-forming and environmental protection factor. At the same time, Yekaterinburg with a large population and developed industry is one of the largest and most dirty cities in Russia. Currently, one of the most acute problems of the city is the state of the environment.

Forest ecosystems are a powerful stabilizer of the ongoing destructive anthropogenic processes. City forests perform important environment regulative, environment formative and recreational functions. They can be used as one of the most suitable objects for accounting, estimating and forecasting the impact of human activity on the environment. By analyzing the state of forest ecosystems, it is possible to reliably monitor and predict the environmental consequences of anthropogenic influences. Environmental monitoring is the most effective way to solve such problems [4].

In our country, basic information about forests is obtained by carrying out a forest management, because of differentiated taxation. In recreational forests, the sanitary and hygienic assessment, the stage of recreational digression, and the biological resistance of forest plantations are additionally indicated. For these indicators, a general assessment of the state of forests can be made. Taking into account that the main taxation is carried out in a visual manner with a relatively low accuracy of the determination of taxation indicators, forest inventory materials cannot provide reliable information about the forests and their condition.

With the adoption of the Forest Code (Article 90), in addition to forest management, a new type of forest inventory work was introduced — the State Forest Inventory (SFI). When organizing SFI, quantitative and qualitative characteristics of forests are determined by mathematical-co-statistical method by laying circular trial plots (TP). One of the main goals of the SFI is the timely identification and prediction of the development of processes that have a negative impact on forests. As a result of the State forest inventory, more reliable data are obtained in comparison with the forest management inventory (the accuracy of the forest reserve determining the in the Middle Urals taiga region is 2%). In the field, 117 indicators are determined, taking into account, among other things, the state of the plantations. Thus, SFI activities are a full-scale forest monitoring system, while their object is the forest area of the Russian Federation.

Currently monitoring of the state of urban forests in our country has not yet been developed. The need for its organization is conditioned by the existing need to restore and improve the sustainability of forests in a more complicated ecological situation. Scientifically conditioned monitoring of the state of urban forests can be included in the general system of monitoring and the environment state control [3].

We propose to use the developed SFI activities as the main means of monitoring the state of the city forests of Yekaterinburg. The city is unique by the presence of natural forest plantations, which represent the so-called "green ring" of 15 forest parks with a total area of 12097.5 hectares of forest inventory in 2007 and urban forests with a total area of about 11274 hectares. No other city of Russia has such preserved natural forest plantations. Therefore, a scientifically based system for urban forests monitoring in Yekaterinburg can be the basis for developing a common methodological concept of these systems in large cities of Russia, including the creation of so-called "ecological skeletons".

The purpose of the work is the organization of monitoring forest plantations of the forest park named after Foresters of Russia because of the use of the State Forest Inventory (SFI).

Forest Park named after Foresters of Russia is located in the southeastern part of the city of Yekaterinburg. Its area is 882.6 hectares, of which 763 hectares are covered with forest vegetation.

2. Technique

According to the "Methodological Recommendations for the State Forest Inventory" approved by the order of Rosleskhoz of November 10, 2011, No. 472, a single scheme of stratification of forests of the Russian Federation in determining the quantitative and qualitative characteristics of forests is applied. Stratification is based on the use of high-level forest management databases by grouping forest plantations into homogeneous groups (forest strata). 49 strata were singled out in methodical recommendations, depending on the age group, bonitet group and stock groups [2].

When stratification is carried out, the variation of reserves within strata is reduced (in the mathematical-statistical sense), and homogeneous types of groups covered and not covered by forest vegetation of lands (a typical type of sample by qualitative characteristic) are distinguished by qualitative characteristics. With this approach, the greatest effect is achieved from stratification of forests with the achievement of the planned accuracy of accounting for land areas and timber reserves with an optimal selective population (the number of trial plots).

On the territory forest park named after Foresters of Russia. We identified 18 strata in forest areas covered by forest vegetation. As a result, the data presented in Table 1 were obtained. Their analysis shows that the territory of the forest park named after Foresters of Russia are significantly dominated by 10 strata (light coniferous ripe and over-productive high yielding) — 77%. This indicates a low stability of forests. The carrying out of monitoring and assessment of the state of plantations will be of particular importance here.

The number of trial plots for each stratum is determined by the formula:

$$N = \frac{S^2 * t^2}{(x * g)^2},$$

where, S is the variance of wood reserves; t^2 — the value of the Student's test; X — mean value of wood stock m^2 / ha; g — target accuracy (in units of units) 1%, 5% and 10% [1].

The calculation of the number of trial plots is given in Table 1. The data show that with the increase in the accuracy index, the number of trial plots decreases, so when the basic accuracy (g = 1%) is taken, their number is 13179 pieces, with g = 5% — 527 pieces, g = 5% — 132 pcs. It should be noted that according to the formula above-mentioned the number of TP does not depend on the area of the object. For assessing the state of the forest park in the forest park named after Foresters of Russia, we consider it sufficient to lay 132 trial plots at 10% accuracy of determining the reserves. For the study of all urban forests, it is necessary to include their entire area.

To determine the locations of the trial plot laying, a digital basis was created because of differentiated data of forest inventory materials. The created digital base is used to locate the centers of trial plots, by a method combining a systematic and random sampling. Trial areas were located in the corresponding forest strata in a random manner while simultaneously striving for an equal number of their location throughout the work site. For this, a systematic sampling over a virtual network with a random spread is used. Placing the required number of trial plots is done with the determination of the coordinates of their centers.

In our work, when creating a digital basis, we used the software Quantum GIS and MapInfo Pro. On the territory of the forest park on a digital basis, only 132 PPs were placed in the WGS-84 coordinate system, and in each stratum, their number corresponds to the calculated index in Table 1. In the 10 strata, 28 trial plots were placed. Thus, a bio indication ecological monitoring network was established on the territory of the forest park named after. Foresters of Russia, shown in Figure 1.

It should be noted that the established bio indication-monitoring network in case of random placement does not take into account the intensity of anthropogenic impact. It is obvious that road transport, recreational loads, industrial emissions and others will affect the forest plantations depending on their location with different degrees of influence. To solve this problem, it may be expedient to double stratify these factors. In our work, we did not set out to carry out such an analysis.

Table 1: Stratification of forest plantations and calculation of trial plots in the territory of the forest park named after Foresters of Russia

Number of strata	Name of stratum	number of allotments in stratum	total weight of strata		Specific weight of strata	area, ha	area, ha			deviation	variability,%	dispersion	No. of trial plots		
			area, ha	%			minimum value	maximum value	average value				1 %	5 %	10 %
2	young litters of natural origin	5	3	0.4	0.09	231	50	110	77	26	34	680	375	15	4
3	artificial litter	8	6.8	0.9	0.14	992	10	330	146	93	64	8686	2137	85	21
4	light middle-aged medium-productive and high-productive	43	47.7	6.3	0.73	15895	110	540	333	111	33	12230	3100	124	31
7	light coniferous ripening high- productive	4	8.7	1.1	0.07	3710	260	480	426	96	22	9158	132	5	1
10	light coniferous ripe and over mature high- productive	129	593.2	77.7	2.20	228305	250	590	385	70	18	4861	2771	111	28
11	light coniferous ripe and over-productive medium-productive	6	5.8	0.8	0.10	1298	110	420	224	103	46	10710	840	34	8
26	soft-leaved middling medium-productive	3	2	0.3	0.05	577	150	370	289	124	43	15433	364	15	4
29	soft-leaved ripe and over-productive medium-productive	22	13.6	1.8	0.37	3725	150	460	274	84	31	6999	1343	54	13
31	small-leaved middle-aged medium-productive and high-productive	4	3.4	0.4	0.07	469	30	180	138	68	49	4600	633	25	6
37	small-leaf ruminant ripe and over-mature high-performance	18	47	6.2	0.31	12370	160	380	290	75	26	5612	788	32	8
38	small-leaved ripe and over-productive medium-productive	13	26.4	3.5	0.22	4140	70	210	157	42	27	1758	608	24	6
41	hard-leafed medium-aged and mating medium-productive	3	3.1	0.4	0.05	231	60	90	75	18	25	233	83	3	1
43	solid hard maturing, ripe and over mature high-performance total	2	2.3	0.3	0.03	243	100	110	106	7	7	50	6	0	0
	Subtotal	260	763	100.0	4.43	272186			2918				13179	527	132

Fig. 1. Bio indication network of ecological monitoring on the territory of the forest park named after Foresters of Russia.

To assess the application of the system (SFI) for monitoring forest plantations, we conducted field studies with the insertion of PP in the most predominant stratum. The test area was laid at a point with predetermined coordinates of the center of the trial plot. To do this, the TP network was loaded into the navigator. We used the GARMIN OREGON 650T navigator. Work began with the binding and fixation of the armored peg center of the TP.

The test area, with a total area of 500 m², is a concentric circular platform of a constant radius of 12.62 m. within the limits of which measurements and mapping of trees were carried out. The scheme of the trial plot is shown in Figure 2.

For field data collection, we used the Field-Map program-measuring complex (PMC Field-Map), which allows to measure and map trees in real time. The PMC Field-Map used consists of a field table computer with installed software, a laser rangefinder with Bluetooth, a circular reflector, an electronic measuring plug.

The position of the tree on the trial plot is mapped using a laser distance number with the capabilities of an electronic goniometer, an electronic compass, and a reflector placed on the surface of the trunk. Field-Map automatically checks whether the tree is inside or outside the trial plot, so you do not need to mark the area boundary on the terrain.

In the process of measuring by the laser rangefinder, PMC Field-Map automatically numbers the trees and assigns them to the sides of the world in automatic mode. In attributive data of the program, in addition to taxation indicators, information was included on the evaluation of the state of trees. The use of modern information technologies, with the ability to determine accurate data on the location of trees and their condition is important in monitoring forest plantations.

In the course of the work, we laid 25 trial plots in 10 strata of light coniferous ripe and over mature high-productive plantations.

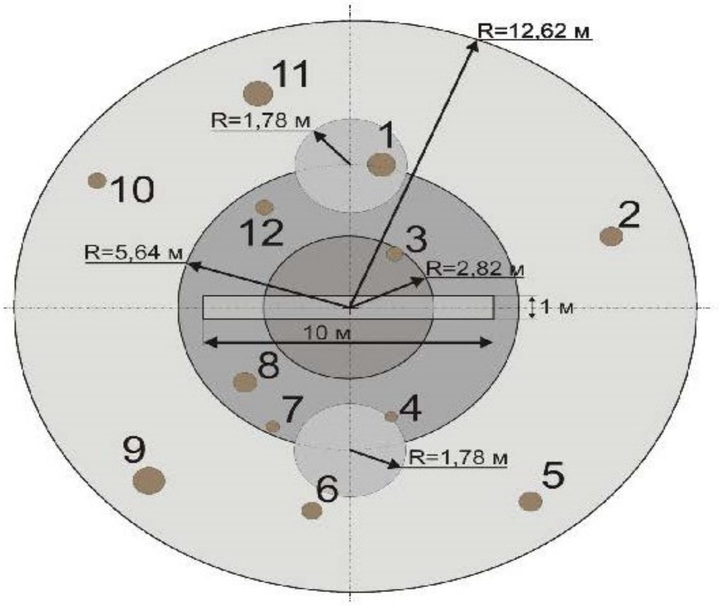

Fig.2. Scheme of the trial plot

In the basis of assessing the state of trees, we followed the methodology of European monitoring of forests [5, 6], according to which the conditions of the surveyed plants were determined on the basis of the use of the bio indication method, in which morphological changes in trees were taken into account. The most important bio indication signs of tree damage are de-foliation (loss of needles and foliage) and dechromation (discolouration) of tree crowns. Deflation and dechromation of tree crowns were estimated as a percentage with an accuracy of 5-10%. Based on these indices, the integral classes of tree damage are given in Table 2.

Table 2: Integral class of damage to trees
Degree of defoliation, % Degree of needle color change, %

Degree of defoliation, %	Degree of needle color change, %			
	< 10	11-25	26-60	> 60
< 10	0	0	1	2
11-25	0	1	2	2
26-60	1	2	3	3
61-99	3	3	3	3
100	4	4	4	4

2. Results and its analysis

To assess the vital state of the tree stands, the state index (I, scores) is used, which is a weighted average damage class of tree stand components:

$$I = \sum_{i=0}^{4} \mathrm{i}\, w_{\mathrm{i}} / \mathrm{W},$$

where i — numbers of classes of damage of trees, points; wi — number of trees of the i-th class of damage in the given plantation; W is the total number of trees.

By the value of the index of the state, the stands are classified as follows: healthy 0-0.5; weakened by 0.6-1.5; damaged by 1.6-2.5; dying off 2.6-3.5; deadly > 3.6 points.In addition, the category of the state of each tree was determined.

Data on defoliation, dechromation and index of coniferous stands assessment for all trial plots

Table 3: Data on t of defoliation, dechromation and index of coniferous stands assessment in the forest park named after Foresters of Russia.

Number of trees examined, pcs.	Number of dead trees, pcs. /%	Mean values		
		defoliation, %	dechromation, %	state index, score
392	18/5	37	22	1.76

According to the European method, light coniferous ripe and over mature pine stands are damaged (I = 1.76). The maximum values of defoliation and dechromatization are 100%; this is due to the presence of dead trees, the smallest — 5%. The total number of examined trees was 392 pieces, of which about 5% are deadwood.

For the purpose of spatial analysis of forest plantation monitoring, indicators of the state of pine plantations were separately determined for each trial plot. The results are shown in Figure 3. The histogram data showed an uneven distribution of the TP by the state index. Its minimum value is marked by 6 TP and is 0.61; the maximum value on sample 24 is 2.92. The coefficient of variation for these indicators is about 40%, which indicates a heterogeneous population with a wide range of values. Perhaps such dispersion is associated with the location of trial plots, depending on the degree of impact of anthropogenic factors. In this paper, we did not conduct such studies, TP were located randomly through the forest park in 10 strata.

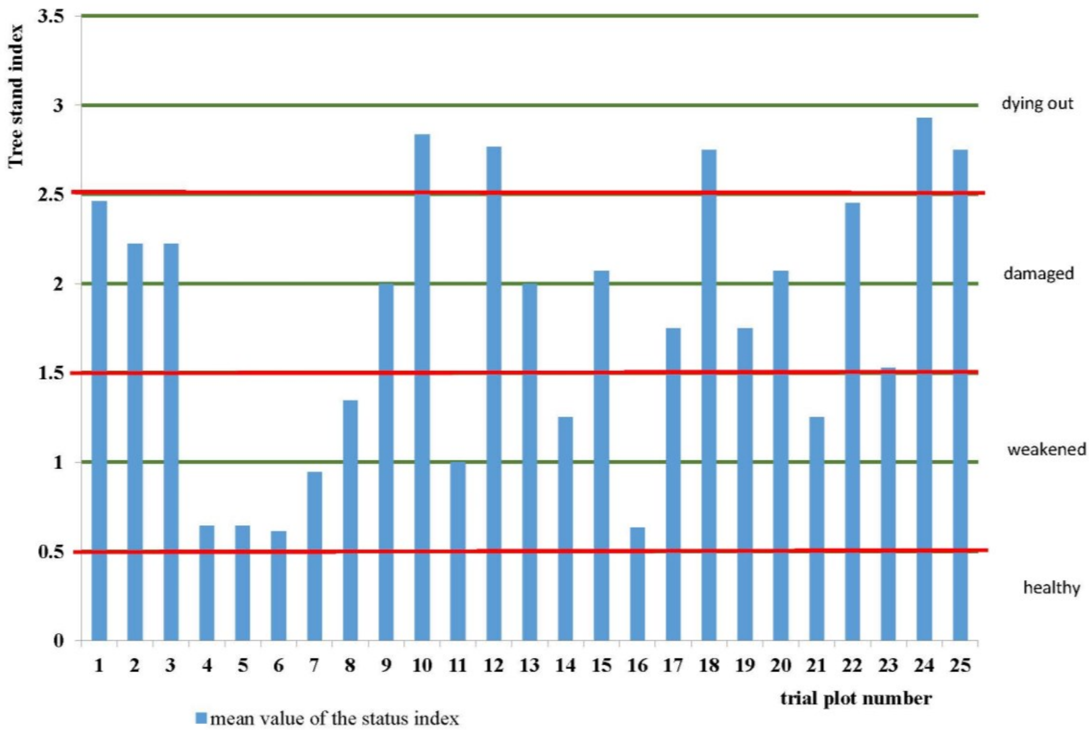

Fig.3. Distribution of trial plots by state index

Generalized data on the distribution of PP by the state index are shown in Fig. 4. In the laid 10 stratum in the light coniferous ripe and over mature high-productive plantations, PP with a state index from 1.6 to 2.5 (damaged) predominate. The weakened stands are represented by 9 TP; the proportion of dying off is 20% (5 TP). In general, given that the TPs were laid in pine outposts with an average age of about 180 years, this distribution indicates a relatively good state of the plantations.

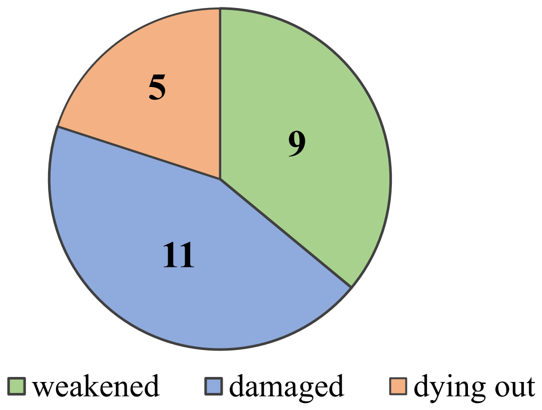

Fig.4. Distribution of TP according to their state

The main parameters of the bio indication network for terrestrial monitoring of forests of a certain area is the total number of model trees that are located on the PP. In monitoring, first of all, it is necessary to justify the number of surveyed trees required for reliable conclusions about the state of forests [1]. To this end, we used the Chebyshev equation:

$$N = s^2 / a^2 P,$$

where, s^2 is the variance of the distribution of trees by damage classes, and is the admissible error in determining the average damage class and P is the probability of deviation of the true mean value of the damage to trees from the calculated one. To calculate this formula, you need to specify the values of the values in its right-hand side. The admissible error in determining the average damage class (a) should be put equal to 0.1, and the error probability P = 0.05 [1].

In our case, when examining 392 trees, the variance is 1.5. Substituting the values into equality, the required number of trees to evaluate the state is 300 pieces. Thus, the methodological recommendations for conducting the state forest inventory of Russia with the stratification carried out on the territory of the forest park named after Foresters of Russia were used as a basis for demonstrating the possibility of using them to create a monitoring of the city's forests in Ekaterinburg.

3. Conclusions

Stratification of forests on the territory of the forest park named after Foresters of Russia showed a significant predominance of light coniferous ripe and over mature high-productive plantations. In conditions of high anthropogenic factors, monitoring of forests is of particular importance here.

The use of (SFI) activities to monitor urban forests has given:

1. The random placement of trial plots in space does not take into account the anthropogenic impact. It is necessary to improve the algorithm for determining the places of TP insertion.
2. A field survey showed a damaged state of plantations in 10 countries.
3. The state of plantations in trial plots is not uniform.
4. A sufficient number of examined trees.

The State Forest Inventory has a well-developed methodology based on modern information technologies. Its use and improvement with the aim of creating monitoring of urban forests can have broad practical application

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