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Features of forest dynamics in developed regions

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Abstract. The current state of forests is characterized by massive destruction of forest biota, which leads to significant changes in the environment, biotic factors of environment formation and forest growing conditions. Anthropogenic transformation of forest growing conditions contributes to a corresponding change in forest-forming processes and the replacement of primary forests with secondary vegetation. Secondary forests form the basis of almost all economically important forests in the developed regions in general and in the study region in particular. Characteristic features of secondary forests are associated with the assessment of the restoration-age processes taking place in them. Sustainable existence of secondary forests as a reforestation failure is accompanied by sustainable recovery processes. Incompleteness has been established and the exogenous nature of sustainable-restorative successions associated with anthropogenic mass destruction of the biological environment and the corresponding transformation of forest growing conditions has been substantiated. In the developed regions, forest typology is based on characteristic features of the recovery-age dynamics, primarily of secondary forests. Determination of the forest genesis, with an effective assessment of the dynamics of natural environment, is dictated by modern forest features, and developmental needs of forest science and practical forestry.

1. Introduction

By determining the forest type, foresters evaluate the features of the forest formation process, state of forest growing conditions and habitat conditions of forest communities. Forest type is not equivalent to the type of forest community (forest stand), type of habitat conditions (THC) and type of forest growing conditions (TFGC); to a greater extent it corresponds to the type of forest biogeosystem. Forest biogeosystem combines all restorative-age states, primary and various secondary stages of development of one initial-primary type of forest biogeocenosis, provided that stability of regenerating forests is preserved [1]. The study of the dynamics of forest biogeocenoses, including their biotic and abiotic components, forms the basis of the modern forest typology [2, 3].

Forest successions are observed in all forests, both primary and disturbed (secondary). With the destruction of environmental conditions (forest growing conditions, habitats), it becomes likely that



forest stability is not restored to its original state; therefore, forest communities degrade, forming forest derivatives, irreversible and sustainable secondary forests. The problem of assessing trends in forest dynamics, including identifying processes of reforestation or forest degradation, is quite relevant. The use of forest typology methods allows describing the current state of forests, their dynamics and genesis. Determination of the main trends in the dynamics of forests growing in developed regions is the goal of our research. Research tasks included a survey of oak forests and forests derived from them growing in the conditions of the Republic of Tatarstan.

2. Methods and Materials

Taking an active part in the forest management of the forest fund of a number of regions of Russia, the authors got a clear idea of the state and dynamics of forests. The research was carried out based on the results of a survey of oak forests and forests derived from them, which are widespread in the belt of "coniferous-broad-leaved forests with oak" occupying the northern part of the Republic of Tatarstan [4]. The oak forests of the region are damaged by fellings and severe frosts of the late 1970s. Many oak forests have been replaced by birch, aspen and lime forests, which we attribute to the recovery-age (secondary) stages of development of primary oak forests.

Most of modern forests have been cleared in the course of economic land development; for example, forest cover within Tatarstan decreased from 54% (in 1800) to about 17.5% (by 2021) [5]. The destruction of such an important environmental factor as forest biota influenced forest restoration processes. Reforestation processes and recovery-age changes can be seen in all forests, both secondary and semi-primary. The results of reforestation are determined by the state of the most important environmental factors, from relatively successful restoration [6, 7] to very problematic in developed regions with destroyed forest biota [8].

When assessing forests, materials of the Forest Plan of the Republic of Tatarstan, forestry regulations of forestry units, results of a route-reconnaissance forest survey, as well as the inventory characteristics of forest stands obtained on sample plots, were used. Based on the methods of V N Sukachev, route-reconnaissance and semi-stationary forest surveys were carried out [2, 3]. Forest type was determined taking into account the advancements of "biogeocenotic", "dynamic", "geographic-genetic", and other areas of forest typology [2, 3, 6, 7].

3. Results and Discussion

Forest biota is the largest part of terrestrial biota, the state of which determines formation of the environmental conditions of the biosphere. Forest changes serve as an indicator of natural forest growing conditions. Typological affiliation of modern "anthropogenic forests" should be established taking into account restoration processes taking place in them, productivity and sustainability of forests.

Under conditions of mass deforestation and destruction of forest biota, the contribution of this biota to environmental formation processes also changes. To assess prevailing conditions, it is necessary to record and use the difference between THC and TFGC. Widespread destruction of forest biological environment leads to the transformation of forest growing conditions, entire forest formation process and forest growth effect. Anthropogenically determined forest growth effect is observed after massive deforestation, in the conditions of "global deforestation". With the destruction of forest biota, overgrowth processes are provoked, requiring the manifestation of a pioneering strategy of plant life and changing social behavior of plants [1, 8].

Even an obvious forest degradation can be represented as its "transition" to a qualitatively different state. The early stages of reforestation processes are associated with formation of early succession, initial, pioneer, and derivative plant communities. Secondary forests usually contain all forest-forming species, late succession "primary forest species" and early succession pioneer species. Changes in species composition are associated with the change of age generations of forest forming species and replacement of dominants in the succession series of forest restoration or degradation [1, 6]. Forest

successions were described by V I Vasilevich [9], series by V N Sukachev [2, 3], stages by B P Kolesnikov [7], and I S Melekhov [10].

Examples of successful (typical) post-fire reforestation are given in the works of T.A. Komarova [6]. In complex forests, the nature of forest succession becomes more complicated. Chances of fate can lead to overgrowing of felled or burnt areas with such different species as *Betula costata* Trautv., *Tilia cordata* Mill. and *Populus tremula* L. Regeneration of birch (with a life expectancy of up to 200 years), lime (more than 200 years) or aspen (about 70 years) have fundamental differences [6]. Successions without a change in the main species, for example, the formation of “conditionally secondary” spruce forests of the same age, the replacement of high-stemmed oak forests with low-stemmed ones, or the change of generations of primary species in long-term secondary forests, are often far from the original state, reflecting stabilization of productivity.

Long-term existence of secondary forests often lead to a loss of stability, that is, to impossibility of restoration to its original primary state. Resilient unstable forests which lost stability are often called resiliently derived or irreversibly derived. Under conditions of constant exogenous impact on forest successions, for example, in the floodplains of rivers, there are destabilized-resistant forests formed by pioneer-serial species. Typological assessment of secondary forests requires typical succession series of reforestation [6]. The construction of such series, under conditions of massive destruction of biota and unclear succession of forest communities, is associated with certain difficulties, because succession series of different types of forest intertwine, forming networks according to V I Vasilevich [9].

In practical forest typological work, it is customary to assess forest type according to the degree of participation of plant species in the composition of forest communities. Forest type is defined according to the dominant species: predominant, edificatory, coedificatory and indicator - differential. The use of the dominant biogeocenotic approach in forest typology is justified in primary forests for the purposes of short-term planning. Methods of geographic-genetic and dynamic typology are usually applied in primary and short-term secondary forests, for the purposes of long-term planning of forestry activities. The use of generally accepted forest typological approaches in secondary forests is associated with the development of succession series showing the order of changes in dominants and the role of edificatory species in the course of regenerative-age development of forests. The use of ecological scales with differential species presupposes the use of indicator species for assessing the conditions of natural environment, including forest-forming species with a negligible share of participation in the composition of forest communities. Determination of the degree of secondary development, restoration, and level of forest degradation is the main task of forest typology in developed regions.

To understand the trends in the dynamics of forests of Tatarstan, let us consider individual indicators of the forest fund composition presented in table 1.

Table 1. Composition of the forest fund of the Republic of Tatarstan from 2003 to 2018.

Management type (management section)	Year of survey	Forested area		Growing stock	
		Thousand hectares	%	Million m ³	%
Coniferous	2003	258.1	23.0	40.48	25.3
	2013	278.7	24.1	49.65	26.1
	2018	280.6	23.7	57.60	27.1
Hardwood	2003	209.7	18.7	21.43	13.4
	2013	192.5	16.7	23.18	12.2
	2018	194.6	16.5	26.10	12.3
Soft-leaved	2003	646.4	57.6	98.05	61.2
	2013	677.3	58.7	117.34	61.6
	2018	706.3	59.8	128.60	60.6

Total	2003	1123.8	100	160.15	100
	2013	1156.0	100	190.27	100
	2018	1181.5	100	212.30	100

As shown in table 1, area forested area increased by 57.7 thousand hectares (5.1%) from 2003 to 2018, and during this period the growing stock increased by 52.15 million m³, or 32.6%, which indicates general increase in the forest age. The share of participation of forestry "management sections" in the forest fund is generally stable, we can only note an increase in growing stocks of coniferous forests and an increase in the area of deciduous forests. A large (up to 60%) participation of soft-leaved species indicates a wide distribution of secondary forests on the territory of the forest fund of Tatarstan.

Table 2 shows the distribution of forests in Tatarstan by species composition. As shown in table 2, oak forests occupy less than 14% of the forested area of the region. Areas of birch forests (17.8%), aspen forests (20.2%), and lime forests (19.1%) are represented in approximately equal proportions. Lime forests stand out in terms of the growing stock, 212.6 m³ per hectare.

Table 2. Species composition of the forests of the Republic of Tatarstan in 2018.

Forest-forming species	Forested area		Growing stock	
	Thousand hectares	%	Million m ³	%
Tall oak	102.8	8.7	14.7	6.9
Short oak	61.0	5.2	8.6	4.1
Birch	210.4	17.8	35.3	16.6
Aspen	238.8	20.2	41.6	19.6
Lime	225.3	19.1	47.9	22.6
Pine	202.2	17.1	47.9	22.6
Spruce	72.5	6.1	8.4	3.9
Other species	68.5	5.8	7.9	3.7
Total	1181.5	100	212.3	100

A significant share of lime forests in the composition of the forests of Tatarstan (table 1) suggests a wide distribution of secondary forests which have replaced oak forests. Despite the presence of the so-called "primary lime forests", most of the lime forests replaced oak forests, representing late successive stages of the regenerative development of oak forest communities. Most of birch and aspen forests also replaced oak forests and coniferous-deciduous forests [1, 8].

In developed regions, almost all modern forests of economic importance are classified as secondary. Determination of the degree of secondary development and further prospects of restoration processes in such forests is essential for forest science and practical forestry. To assess the degree of secondary development, we laid a number of sample plots. The inventory descriptions of stands on the sample plots are given in table 3. All sample plots were established in oak forests, and those described in table 3 we attribute to different stages of oak forest regeneration.

Table 3. Inventory description of secondary stands on sample plots.

Sample plot	Species composition ^b	A, years	H, m	D, cm	Forest type ^c / TFGC	Relative basal area	Growing stock, m ³ /ha
Primary and conditionally primary							
4-2015	5O5L +B,M	130	24.0	52.9	Doc / D2	0.810	264.68
2-2015	6O3L1A +M	80	22.7	27.3	Doc / D2	0.755	256.29
3-2014 ^a	7O3B +L,M	50	16.7	17.3	Doc / D2	0.774	182.55
Short-term secondary							
1-2015	3O6L1M	60	20.1	22.4	Doc / D2	0.647	179.48
Long-term secondary							
1-2019	5B4L1O +A	80	25.1	32.4	Boc / C2	0.585	212.40
1-2020	6L2B1O +M	70	21.7	29.2	Ltp / C2	0.620	248.00

Sustainable secondary						
2-2020	7L2B1A +M	80	22.2	31.4	Ltp / C2	0.701
3-2020	6L3B1A +M	60	19.1	21.9	Ltp / C2	0.610

^aOak forest plantations (conditionally primary forest on sample plot 3-2014).

^bO: oak; L: lime; B: birch; M: maple; A: aspen.

^cDoc: Oak forest with sage; Ltp: lime forest with herbaceous species; Boc: birch forest.

At the early stages of reforestation successions in the studied forests, the participation of forest-forming species with different types of life strategies is possible; the participation of birch, aspen, and lime is noticeable. Further on, the formation of conditionally primary and primary forests is noted with a clear predominance of oak, the main forest-forming species. We classify reforestation successions with successful regeneration of the main forest-forming plant as typical [1, 6]. A significant part of modern forests are characterized by incomplete successions with a slowed-down regeneration of the main forest-forming species (oak, spruce, etc.) and primary forests. Incomplete successions are noted in long-term and stable secondary forests. Incomplete successions are characterized by the absence of natural regeneration of the main forest-forming species and stabilization of serial, stable secondary forests. In oak forest growing conditions, stable secondary forests are lime forests with maple and other species in the absence or diminished participation of oak (sample plots 2, 3-2020, table 3). Irreversible secondary forests are probably present in modern forests, but their assessment requires proper justification.

The variety of modern forests in terms of the prospects for their restoration (sustainability) can be characterized in accordance with the proposed scheme (table 4).

To build table 4 we used information available in the extensive forest typological literature [2, 3, 6, 7]. A statement about the loss of sustainability by sustainable secondary forests will be quite relevant and with elements of scientific novelty. In these forests, their secondary nature or inability to recover to their original, primary state becomes stable. Due to the loss of stability, restorative successions occurring in stable secondary forests acquire an incomplete and exogenous character. We associate the latter circumstance with massive destruction of biological environment, biotic factors of environmental formation, and anthropogenic transformation of forest conditions [1, 8]. Clarification of the concepts of forest productivity and regeneration-age changes will make it possible to identify the typological structure of modern forests, taking into account their dynamics.

Table 4. Schematic subdivision of forests according to their sustainability – renewability.

Dynamic state	Features of forest succession	Types of forest successions	Participation of the main forest forming species	Stability of communities
Primary (virgin) forest	Age range	Standard	Dominates the community	Stability (recoverability) remains
Conditionally primary forest	Recovery-age		Dominates the community	
Short term secondary forest	Short recovery		Community edificator	
Long term secondary forest	Long-term recovery	Incomplete	Community edificator	Lost partly
Sustainable secondary forest	Sustainable recovery		The share of participation is negligible or absent	
Irreversible secondary forest	Irreversible-restorative	Irreversible	Various options for participation are possible	Lost completely

In order to further assess forest typological affiliation of secondary and degraded forests in modern forestry conditions, it is practically convenient and quite effective to use patterns of social behaviour

of plants in forest communities [11]. Phytosociology can be used to indicate forest types and trends in their dynamics by manifestations of silvicultural properties, peculiarities of social behaviour of plants at different stages of reforestation successions [1, 6, 8, 11]. The need for such work is dictated by both theoretical and practical tasks of forestry.

4. Conclusion

Determination of the degree of secondary forest development is one of the foundations of modern forestry in developed regions. By comparing forest typological approaches generally accepted in modern geobotany, dynamic states of secondary forests were characterized, the stability and incomplete nature of reforestation successions in sustainable secondary forests were established. The use of forestry properties to assess trends in forest dynamics is dictated by the modern features of forests in developed regions and by the needs of forestry development.

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