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Evaluation of Ecological Potential of Forests

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Abstract: All indicators of the influence of forests on climate, hydrology, soil formation, sanitary and hygienic properties, recreational suitability of the territory of its growth can be reliably attributed to the ecological potential. Based on the comparative approbation of modern methods for assessing the ecological potential of forests, it is established that the landscape method is subjective as it does not give an idea of recreational fitness does not allow for mathematical processing of data but it can be used for preliminary characterization of the object. The integrated method reveals the quality of forests at the present time, allows to determine the reasons for its productivity decrease and to assess the prospects of forest use, although without specifying the objective function. According to the developed method of differentiated estimation, plantations are divided into groups: 1-standard (91-100 points) is not identified, 2-optimal (81-90) occupies 15% of the territory of the object, 3-normal (61-80) -34.5%, 4-lowered , 5-low, 6-crisis -19.9% and 7-zero -0.6%. All parameters of the ecological potential of the forest that affect the growth environment are expressed in terms of quantitative values and are divided into four groups: the sum of the values of climate-forming parameters is ΣKp; the sum of the values of water conservation and soil protection parameters is ΣBП; the sum of sanitary and hygienic values-ΣCr and the sum of the recreational parameters-ΣPk. These numerical parameters can serve as diagnostic indicators of the qualitative level of the ecological potential of forests and can be used when forest territory is included as an economic object in effective forestry relations for example, between the forest owner and the forest user (tenant).

Key words: Forest use, productivity, sustainability, evaluation, estimation, parameters

INTRODUCTION

The forest being an important component of the biosphere acts as a carrier of colossal energy which is accumulated by the main share of all the photosynthesis occurring on the Earth. In forests, at least 2/3 of the organic matter of the planet is produced annually. Russia has the largest forest areas where huge volumes of organic mass are continuously reproduced, the importance of which in the country's socio-economic development increases every year. The total area of the forest fund of the Russian Federation is 1.1 billion ha or 69% of the territory with a total stock of 81.5 billion m^3. Article 25 of the Forestry Code of Russia No. 200-FZ of 04.12.2006 (edition dated December 29, 2017) provides for the implementation of 16 types of forest use.

The use of the whole set of forest benefits is one of the main tasks of forestry production, the current trends of which are developing in two main directions. The first is to grow and use the forest as a source of raw materials, mainly wood. Zhivitsa, fruits, medicinal raw materials, hunting fauna and many other non-timber resources along with wood form a resource potential, actively used and removed from the forest but a much more important and valuable direction is another. It is associated exclusively with the lifetime properties of plantations when the resources of the forest are used at the site of its growth they can not be imported or exported. At the beginning of the 20th century this property of the forest was called a "transgressive" role ("extending influence") which is determined by its environment-forming, ecological, stabilizing function and is life-supporting for humans. Kasimov and Kasimov (2015) believe that the ecosystem

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functions of the forest ensure the quality of the environment at various levels: global, national or regional and local. Global environmental problems (greenhouse effect, air, water, soil, etc.) can not be solved without forest ecosystems.

Korets and Onuchin (2008) note that all indicators of the influence of forests on the climate, hydrological regime, soil formation processes, sanitary and hygienic properties, recreational suitability of the forest area can be reliably attributed and interpreted as the ecological potential of the forest.

Gao *et al*. (2015) draw attention to the local (narrowly territorial) dependence of the climate on anthropogenic changes in the soil and vegetation cover and its faster change compared to global warming due to increased greenhouse gas emissions.

The very concept of the ecological component in the productivity of the forest appeared long ago. But according to Veselkin *et al*. (2015), a special emphasis and integration assessment this type of productivity deserved in the last 100 years because of the emergence of problems, both in the sphere of socio-economic development of society and at the most varied levels of planetary processes. Active development of forest resources in the creation of sustainable prerequisites and trends in improving people's living conditions led to an equally intensive "wear out" of natural resources and gave rise to problems of eliminating negative consequences. Therefore, the preservation and maintenance of forests as a natural phenomenon, the rationality of their assessment and further use is associated not only with the limited forest resources, both in terms of area and time but also with their overall planetary ecological significance. A lot of empirical material has been accumulated in the scientific and practical sphere of forest use. This can be noted in the modern works of (Osipov and Bobkova, 2016; Golovatskaya, 2017; Kutyavin and Bobkova, 2017). However, in this bulk of the scientific literature, the issues of assessing the ecological potential of forests are still not universally recognized and are often formulated in a private way. There are also difficulties in determining the indicators of the ecological productivity of the forest. These include the effectiveness of the implementation of forest-forming, landscape-biosphere, stabilizing, oxygen-producing, water protective, water-regulating functions and the ability to neutralize technogenic, recreational and other loads, maintaining its stability, etc. Assessment of the state of forests, their influence on the environment of growth and the consequences of active use has proceeded in different directions, in interrelation with the soil (Gao *et al*., 2014; Gimbel *et al*., 2015; Katzenach and Werner, 2007) and root systems of trees (Beyer *et al*., 2013; Korets and Onuchin, 2008; Zhang *et al*., 2014) with a stand (Shi *et al*., 2013; Tomlinson *et al*., 2012) etc. In the noted works, the ratio of the subject to the object is generally marked without an assessment of the relationship of all components of the forest environment. The approach of a number of researchers is similar in determining the influence of quantitative forest indicators on the environment (Gao *et al*., 2014; Gimbel *et al*., 2015; Ryzhkov *et al*., 2014). Indeed, how can we evaluate the units to express the protective effect of forest areas? Clean air, soil, water, the amount of phytoncides, the degree of ionization of airspace or health of the population, the volume of yield increase? Most often, a qualitative characteristic of environmental productivity is used-high, medium, low, etc. In some cases, it is proposed to use the value of the average increment, increased several times for the evaluation.

In forest science, a number of methods for assessing the potential of the forest are distinguished. Simplified evaluation by Repsash and Palishkis (1981) is used in forest management when the stages of recreational digression are established in the analysis of forest biogeocenosis types (Kozhevnikov and Kozhevnikova, 2009) consider the estimation of landscapes based on landscapes where the contrasts of relief forms, mosaicism and typological spectrum of forests their aesthetic qualities, availability of water objects, lands were taken as the leading signs of the landscape; A complex (integrated) assessment of the recreational potential of forests of Rysin *et al*. (2003) is known by its attractiveness, comfort and stability; Bolshakov (2006) developed a system for the economic evaluation of recreational forests (Farber *et al*., 2014). There are developments of Serova and Kulagin (2006) on comparative evaluation of the recreational potential of the territories of individual regions. Thus, the analysis of existing methods for assessing the potential of forests and in general natural landscapes shows their diversity and the lack of a single generally, accepted methodology which necessitates the allocation of some absolute environmental indicator and the search for a more advanced method of evaluation for the scientifically sound and efficient use of forests.

The purpose of the study is to justify the parameters of a differentiated assessment of the ecological potential of forests. Research tasks: comparative testing of existing methodologies for assessing the potential of forests that have been recognized and most widely disseminated; development of methods for differentiating the ecological potential of forests.

MATERIALS AND METHODS

The object of the study is forest plantations of various natural zones of the South Urals in the territory of the Republic of Bashkortostan (RB) with an area of more than 21 thousand hectares. These are forests of the South Ural forest-steppe region, Forest-steppe area of the European part of Russia, coniferous-broad-leaved area of the European part of Russia, characterized by a complex of conditions: climate, relief, hydrology, soils and vegetation. An assessment of the potential of forests was carried out within the boundaries of forest districts on silvicultural landscapes of stands on permanent test plots of 0.5-1.0 ha by a continuous list of trees. Taxation descriptions, plans of forest plantations of forest inventory materials of different years were used. The state of the stands was assessed according to the methods generally, accepted in taxation, the ecological state of forests according to the forest condition category scale (Decree of the Government of the Russian Federation No. 414 of 29.06.2007 “On the Approval of the Rules of Sanitary Security in Forests” (as amended on 01.11.2012 No. 1128). An assessment of the potential of forests was carried out on a landscape basis (calculation of the weighted average indicator through the occupied area of each category) and 25 indicators, grouped into three main groups of indicators-attractiveness, comfort and stability. The differentiated assessment of the capacity was conducted considering weight taxational indicators in the overall capacity (estimated score was defined as the weighted average of the coefficient of correlation between the diagnostic signs).

RESULTS AND DISCUSSION

When assessing forests on a landscape basis (Kasimov and Kasimov, 2015) it is established that forest areas of a very high category constitute an insignificant share-11.5%, dominated by medium quality landscapes-47.3% (Table 1). Landscape assessment provides cognitive perception of forests, it is characterized by subjectivity, blurred edges between categories, lack of a clear idea of recreational capacity it is possible that very high-quality areas have low capacity (person/ha). However, landscape assessment can serve as a basis for constructing detailed scoring scales with quantitative indicators and provide a transition to a complex characteristic of the object, although, it does not allow for mathematical processing of data.

With a complex (integrated) assessment of the potential of forests, plantations are divided into four Classes of Recreational Value (CRV) in three main groups of parameters attractiveness, comfort and resistance to impacts which are composed of a combination of one or another (out of 25 defined for each homogeneous forest area) forestry and landscape indicators that take into account the complex of biological, humanitarian and socio-economic needs of the forest user. This assessment reveals the quality of the forest at the present time and allows us to assess the prospects for its use, to identify the reasons for its decline. For the objects studied, the forests of the Krasnokamsk District forestry showed the lowest coefficient of attractiveness, the highest one Belebeyevsky and Arkhangelsky, the forests of Chishminsky forestry were the most comfortable. However, the integral evaluation by the Coefficient of Recreational Value (CRV), calculated by the indicators of attractiveness, comfort and stability did not give such differentiation, leveling of the estimated data occurred, uncertainty in the objective function appeared (Table 2). In the generalized sense, it is clear but there is no detail on the indicators what should be the economic impact.

The achievement of a simultaneous highest level of all indicators of attractiveness, comfort and stability is hardly achievable, since, it is difficult to form an “ideal” plantation in nature with simultaneous maximum expression of all parameters. Specific plantation is characterized by features inherent of it only which raise it

Table 1: Landscape assessment of forests

			Rating category							
			Very high		High		Medium		Low	
Forest area	Precinct forest districts	Area (ha)	Hectares	Percentage	Hectares	Percentage	Hectares	Percentage	Hectares	Percentage
South Ural	Arkhangelskoye	3182	146	4.6	1756	55.2	1257	39.5	23	0.7
forest-steppe region	Kiginskoye	1602	302	18.9	852	53.2	332	20.7	116	7.2
Forest-steppe area	Belebeyevskoe	4341	730	16.8	2967	68.3	630	14.5	14	0.3
of the European part of Russia	Chishminskoe	11781	1300	11.0	2296	19.5	7830	66.5	355	3.0
Coniferous-broad-leaved area of the European part of Russia	Krasnokamskoe	997	54	5.4	560	56.2	305	30.6	78	7.8
Total (ha, %)	21903/100	2532	11.5	8431.0	38.5	10354.0	47.3	586.0	2.7	

Table 2: Integrated assessment of forests

		Coefficient			
Forest area	Precinct forest districts	Attractiveness	Comfort	Sustainability	Coefficient of recreational value (CRV)
South Ural forest-steppe region	Arkhangelskoye	0.78	0.73	0.72	2.0
	Kiginskoye	0.77	0.72	0.74	2.0
Forest-steppe area of the European part of Russia	Belebeyevskoe	0.75	0.69	0.75	2.0
	Chishminskoe	0.71	0.78	0.73	2.0
Coniferous-broad-leaved area of the European part of Russia	Krasnokamskoe	0.52	0.66	0.71	3.0
Average		0.74	0.71	0.74	22.2

Table 3: Options for combining indicators of integrated assessment of forests by the objective function

Variants	Target function	Subordinated indicators	
1	Attractiveness	Comfort	Sustainability
2	Attractiveness	Sustainability	Comfort
3	Comfort	Attractiveness	Sustainability
4	Comfort	Sustainability	Attractiveness
5	Sustainability	Comfort	Attractiveness
6	Sustainability	Attractiveness	Comfort

to the upper step of value while other parameters fall into a subordinate position. For example, from a combination of three groups of indicators (attractiveness, comfort, stability), six variants are obtained (Table 3). The question of which indicator is of paramount importance in the formation of a forest with a high ecological potential remains open. Despite this, an integrated assessment of the plantation makes it possible to develop measures to increase the ecological value of the plantation by the lowest levels of their characteristics. The essence of the method of differentiated forest assessment is that the diagnostic features under specific conditions can not be equivalent in the formation of the ecological potential of the forest with a differentiated approach, the total score is defined as the weighted average (Sultanova and Nafikova, 2011):

$$\text{Б}_{\circ} = \frac{\text{б}_1 r_1 + \text{б}_2 r_2 +, \ldots, + \text{б}_n r_n}{r_1 + r_2 +, \ldots, + r_n}$$

Where:

- $\text{Б}_{\circ}$ = The total score
- $\text{б}_1, \text{б}_2, \text{б}_n$ = Points of separate stand indicators
- r_1, r_2, r_n = The correlation coefficients between the diagnostic parameters (33 indicators)

The score for each indicator is calculated by the equation:

$$\text{б} = \frac{\Pi_{\text{ф}} * 100}{\Pi_{\text{M}}}$$

Where:

- б = The score
- $\Pi_{\text{ф}}$ = The actual value of the indicator of the assessed stand
- Π_{M} = The value of the same indicator taken as the reference (the maximum (optimal) value is taken as the standard)

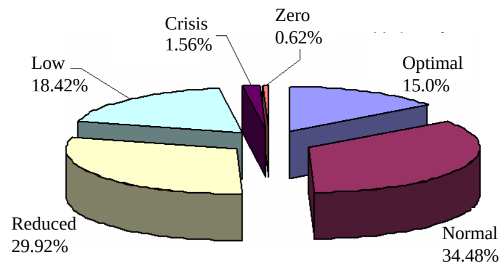

Fig. 1: Distribution of total forest area by value groups (%)

A differentiated forest assessment is a quantitative expression of the suitability of a forest for a particular type of forest use in points. Depending on the value of the scoring points, a classification of forests according to, the ecological potential is made where all plantations are divided into 7 groups (highest, optimal, normal, low, reduced, crisis and zero). The highest (reference) group is represented by plantations with maximum scores (91-100), optimal (81-90) forests that support a dynamic balanced balance of landscapes, normal (61-80) forests that meet the modern regulatory needs of society, etc. Based on the results of a differentiated assessment of the environmental potential of the facilities, both the overall pictures of well-being and the disadvantages of individual forest areas are established. There is a wide range of variations in forest value groups. The ratio of plantings of optimal, normal, reduced and low values is shown in Fig. 1. Despite the fact that individual plantations have the maximum values of estimated points, reference forests have not been identified, optimal plant groups are 15% and low and crisis -19.98% which indicates the need to develop specific forest management measures to improve the condition of plantations.

Correlation links show that not all parameters are equal and equivalent in forming the ecological productivity of forests. Some of them are leading, more valuable, others are less valuable. Coefficients of correlation (r) between the indicator of the forest cover of the territory and climate-forming factors turned out to be equal to 0.54, water protection and soil protection -0.82, sanitary-hygienic -0.70, recreational -0.51. A significant influence of the forest cover of the territories on the average temperature and relative humidity of air was found, especially in July. With the decrease of the forest cover, the number of days in the year increases when the wind speed exceeds 10-15 m/sec.

Perhaps in the future there will be such parameters of ecological potential or ecological productivity of the forest which will have greater significance. Today the determining parameters of the ecological productivity of the forest are water conservation and soil protection, sanitary and hygienic. Sanitary and hygienic parameters are characterized by the release of Oxygen (O_2), the deposition of Carbon (C), ionization of the air, air saturation with phytoncides, dust filtration and accumulation of trace elements, a reduction in wind speed as well as a damper function (noise reduction), etc. Restoration of consumed oxygen is only part of the problem solved by forests. To maintain a stable composition of the atmosphere, it is necessary not only to replenish it with oxygen but also to neutralize harmful industrial emissions, the amount of which is proportional to the volume of production. Studies have established that throughout the ontogenesis of trees the intensity of CO_2 absorption does not remain constant. From an ecological point of view, young plants and middle-aged plantations have the highest efficiency of absorption from the atmosphere of greenhouse gases, i.e., actively growing forests. The accumulation of mature and overmature stands leads to a decrease in the level of performance of their environment-forming functions. The ability of carbon deposition by separate wood species is also different. If we take as 100% a hectare of plantings from spruce (*Picea abies*) by its ability to absorb annually from 4.6-6.5 tons of the main greenhouse gas Carbon dioxide (CO_2) and to allocate from 3.5-5.0 tons of Oxygen, then Larix sibirica is valued at 120, *Pinus sylvestris* (L.) at 160, *Tilia cordata* (Mill) at 250, Quercus robur (L.) oak-at 450, Balsamic poplar (*Populus balsamifera* L.) at 700%.

Forest area of the Republic of Bashkortostan is 5,186.5 thous. ha with phytomass of 597.1 million tons. Carbon stocks in these plantations are 91.9 million tons and are in a permanently bound state. Each year, carbon absorption by forests is more than 4.3 million tons. *Pinus sylvestris* (L.) is the leader in the total amount of carbon deposition (27.4%) which is facilitated by an increase in the area of young growth due to intensive planting of forest cultures. Of the hardwoods, a considerable volume is made by linden (18.3%), birch (17.3%) and aspen (15.9%).

Specific indicators of the stock of plantations, phytomass and carbon deposition by objects differ significantly which is due to differences in the soil and climatic conditions of the zones where forests of various composition and productivity (m^3/ha) grow.

As a result, all the parameters of the ecological productivity of the forest, affecting the state of the environment and characterized by specific physical quantities are divided into 4 groups. The most difficult point in assessing the ecological productivity of forests is that many of the results of the ecological impact of forests improving the environment, working conditions, recreation and health improvement of the population are difficult to assess. If the initial effect of the ecological productivity of the forest is to stabilize, to maintain the dynamic balance of the landscape then the final the socio-economic effect in raising the standard of living of the population. The social effect is accompanied by savings in the costs of social insurance and treatment, the elimination of product losses during the days of illness and the decline in labor productivity. In general, the ecological productivity of a forest can be determined by the equation:

$$П_э = ΣКр+ΣВп+ΣСГ+ΣРk$$

Where:

- $П_э$ = Ecological productivity of forests
- ΣKp = The sum of the values of the climate-forming parameters
- ΣBn = The sum of the values of water conservation and soil protection parameters
- ΣCr = The sum of the values of sanitary and hygienic parameters
- ΣPk = The sum of values of recreational parameters

It is these parameters that can be adopted as the basic diagnostic features for determining the ecological potential of forests.

In view of the fact that the forest performs multifaceted functions, its economic evaluation should include the effect of long-term economic use in conjunction with the ecological value of the stand. Currently, for Belebey Administrative Region of the Republic of Bashkortostan average share index of the cadastral value of forest land, constituting 20,500 rub./ha (RB Government Decree of 11.24.2015 #500 “On approval of the results of the state cadastral valuation of Bashkortostan Republic of forest” as of 01.01.2015) and the index of the standard price of recreational land is 30,500 rub./ha (RB Government Decree of 28.08.2017 #395 “On the normative price of land in the Republic of Bashkortostan for 2017”) are given without taking into account the level of ecological potential of forests. In market conditions with different forms of ownership of the forest (for example, in the transfer of forests for rent) assessing its potential is a necessary condition for effective forestry production.

CONCLUSION

When assessing the objects of research on a landscape basis, a wide range of fluctuations has been obtained for forest value groups in forestry (with very high, high, medium and low dignities). The ratio between the estimated forest areas is 11.5:38.5:47.3:2.7. The complex (integrated) assessment gave a much smaller range of change in landscape categories. The differentiated estimation allows most objectively to classify forests according to the value of their ecological potential and to develop measures for regulating the regime of use. So, on the basis of a differentiated assessment on one of the sites, 1.9% of the territory should be excluded from active recreational use by 3.5% it is required to limit the use; preservation of the existing status of forest use is possible on an area of 17%. At the same time it is recommended to develop new recreational tanks for 21% of the area.

IMPLEMENTATIONS

The formation of a system of market relations involves the development and implementation in economic practice of new approaches to the economic and environmental assessment of the natural resources involved in social production. In this regard, the importance of environmental assessment of forests becomes particularly relevant when they are included as an economic object in the production relationship between the forest owner and the forest user (tenant). Environmental assessment data can serve as a basis for compiling a forest inventory for differentiating rent for forest use depending on the value of forests.

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