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FACTOR ANALYSIS OF DYNAMICS OF FOREST PRODUCTIVITY AS A STRATEGY TOOL OF FOREST GROWING

Forest Fund of the Republic of Belarus has undeniable national value. Basis for the formation of a rational age structure of plantations should be an analysis of the dynamics of forest productivity – one of the steps of determining the effectiveness of forest management. The article presents the factor analysis of average stock forested area, and the results indicate that the main factor influencing the productivity of species composition, is the productivity of individual species and the redistribution of specific gravity of areas with tree species according to age classes (structural changes).

Introduction. The objectives of the State development program of Forestry of the Republic of Belarus for 2011–2015 include efficiency improvement of forest resources utilization by increasing production in order to meet the needs of the domestic market better and increase the export potential of forestry as well as the use of economically and environmentally efficient technologies [1].

For Belarus, Forest Fund is an essential part of economic, social and environmental spheres. Due to the presence of valuable forest resources Belarusian economic potential of forests is quite significant. However, the existing species and age composition of forest stands is not rational and optimal, which is constraining the development of the whole forest complex of Belarus. Within the frameworks of SNTP "Forests of Belarus – productivity, sustainability, effective use" (2011–2015), group of authors have developed scientifically based guidelines to determine economic efficiency of forest management, which is based on factor analysis of changes in the average stock of forested area [2] .

Goal of research: to analyze the state of Belarus forest fund (Ministry of Forestry) and estimate the dynamics of its reproduction main indicators.

It involves the solution of following problems: to explore changes in the composition of forest fund by calculating the general indicators of structural shifts, to identify trends occurring during reproduction forest fund and formulate recommendations for responding to them.

Main part. As an indicator expressing the cost-effectiveness of forestry as an independent branch of national economy at the macro level , we have volume change of the forested area (total and average) and its economic value as a quantitative characteristic of resource and ecologically based forest abilities that will be taken into account r in the integral assessment of forest ecosystems production.

To assess the growth and dynamics of forest reserve it is necessary to use the index method of analysis.

The index method is the most common method for the analysis of socio-economic phenomena. To assess the productivity of forests and identify factors affecting it, it is advisable to use the system of indexes for constant composition, variable composition and structural changes.

The most convenient size for the analysis perio – 10 years, which corresponds to the long-term implementation of the objectives of forestry.

Information basis for analyzing is the data of state recording of forest being made by RUE "Belgosles".

According to common European and national criteria for sustainable forest management, the important parameters describing its base, are qualitative and quantitative characteristics of recourse and ecological functions of forests. The condition of these parameters is determined by species and age composition of country's forests, their productive capacity.

For a comprehensive analysis of productive capacity, age and species composition of forests it is necessary to subject the data about their age and species composition to forest clearance and study it as one unit. The main parameters studied here:

1) forest area (describes species and age composition);

2) wood volume and its ecological and economic value (characterize the process of forest reproduction).

To calculate the increase of wood stand volume and evaluate its dynamics, the evaluation of effectiveness of forest reproduction being carried (dynamics of the forested area average volume), the results of it are shown in the figure.

Analysis of changes in average volume of forest stands of prevailing species age groups showed that for a ten-year period there was an increase in average volume from 176.7 to 199.3 m^3/ha (by 12.8%). In general, an increase in the average volume of middle-aged (by 10.1%), maturing (by 10.6%), mature and over mature stands (by 13.2%) and its decrease in young stands (by 11.9%). In ad-

dition, the decrease in average volume in young stands is determined by the decrease of average volume of basic valuable species: pine (by 11.7%) and oak (by 7.2%).

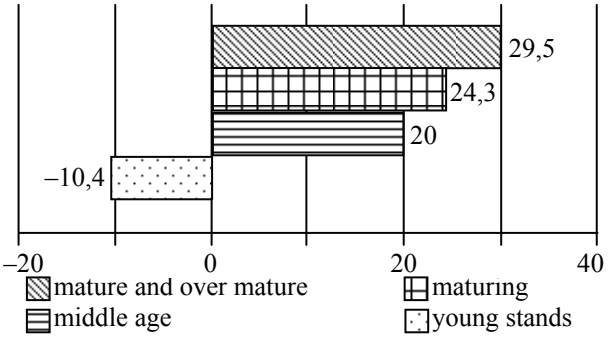

Fig. Absolute change of average volume of forested area in 2000-2010 (Ministry of Forestry of the Republic of Belarus) in view of age groups

Then, it is necessary to analyze the change in the average volume of forested area under the influence of following factors:

– structural shifts in species composition of plants;

– structural shifts in age composition of plants;

– changes in productive capacity of forests.

Factor model for analysis of structural changes impact on species composition of forests in age groups has the form

$$\overline{X} = \frac{\sum_{i=1}^{n} f_i x_i}{\sum_{i=1}^{n} f_i}, \qquad (1)$$

where $\overline{X}$ – the average volume of forested area (m3/ha); n – number of major forest forming species ; f_i and x_i – respectively specific gravity of predominant species (proportion in the plants area of certain age groups, %) and average volume (m^3/ha).

Total change in the effective index is estimated by the formula

$$I_{\overline{x}} = \left(\frac{\sum_{i=1}^{n} f_{1i} x_{1i}}{\sum_{i=1}^{n} f_{1i}} : \frac{\sum_{i=1}^{n} f_{0i} x_{0i}}{\sum_{i=1}^{n} f_{0i}} \right) \cdot 100\% = \frac{\sum_{i=1}^{n} f_{1i} x_{1i}}{\sum_{i=1}^{n} f_{0i} x_{0i}} \cdot 100\%, \qquad (2)$$

where $I_{\overline{x}}$ – relative change in average volume of forested area - index of variable composition (%).

Influence of productivity of individual species on variation of effective index (index of constant composition – $I_{\overline{x}}^{x}$, %) is determined by the formula

$$I_{\overline{x}}^{x} = \left(\frac{\sum_{i=1}^{n} f_{1i} x_{1i}}{\sum_{i=1}^{n} f_{1i} x_{0i}} \right) \cdot 100\%. \qquad (3)$$

Influence of structural changes (changes in the distribution of species composition by age groups) during the reporting period is defined as the index of structural change ($I_{\overline{x}}^{f}$,%):

$$I_{\overline{x}}^{f} = \left(\frac{\sum_{i=1}^{n} f_{1i} x_{0i}}{\sum_{i=1}^{n} f_{0i} x_{0i}} \right) \cdot 100\%. \qquad (4)$$

Advantage and peculiarity of the above index method is the possibility of extending the individual changes in individual elements, determining the role of individual factors in the change in effective index and the convenience of practical use. The obvious advantage of using the index method is that it allows you to make a "decomposition" into factors not only of an absolute change of studied complex phenomenon, but also a relative one, which is especially important in the study of dynamic factor models.

To analyze the impact of structural changes in age composition of forests on the change in the average volume of forested area one can also use the above mentioned formulae. Construction of factor model, as well as evaluation of changes in efficiency indicator comes by analogy with the analysis of structural changes in species composition of stands, the only difference is in the method of determining of specific gravity of age group of the forested area (f_i).

Results of analysis of average volume forested area dynamics, depending on the structural changes in species composition of stands (age groups) and changes in the productive capacity of plants are presented in the table.

Analysis of the impact of structural changes in the species composition showed that in all age groups the average volume has increased by 22.6 m^3/ha, with the basic factor affecting the average volume increase of forested area is a rise in productivity of individual species (average volume per hectare). Owing to this influence the average volume of forested area has increased by 14%. Structural shifts in the distribution of species in specific gravities of species dropped average volume by 1.87 m^3/ha or 1.1%. With a favorable increase of average volume of stands, analysis of structural shifts impact in species composition and productivity of forest species in view of age groups revealed the following trends:

– reduction of the average volume of forested area in young stands: in valuable conifers (by 16.06 m^3/ha or 21.2%) and hardwood stands (by 0.26 m^3/ha or 7.3%). In conifer young stands decreasing factor being structural shifts (decrease in the proportion of coniferous species in total area of young trees) due to structural rearrangements average volume has decreased by 11 m^3/ha (14.5%). In hardwood stands average volume reduces under the influence of productive capacity (by 0.31 m^3/ha or 8.6%). In deciduous young stands he average volume of forest area increases by 5.93 m^3/ha (72.1%);

– in middle-aged stands for the analyzed period the increase in the average volume of forest area takes place in stands of all species, where both estimated factors in almost all cases has a positive impact on this change;

– in maturing woods, as well as ripe and overripe undesirable structural shifts occur in species composition: in coniferous (in spruce maturing stands the average volume has decreased by 2.3% or 6.7 m^3/ha) in hardwood stands (in maturing – decreases by 0.98 m^3/ha or 19.8%, in mature and over mature – by 1.39 m^3/ha or 19.7%).

There is a growth of the productive capacity of softwood stands in all age groups, softwood and hardwood – in middle aged, maturing, mature and over mature stands.

Then, it is necessary to consider the impact of structural shifts in the age composition of forests on average volume of forested area (by species).

In general, the average volume of forested area during this period has increased under the positive effects and structural changes in the age composition by 7.1 m^3/ha (4.0%), and productivity of species by 15.49 m^3/ha (8.4%).

But in young stands there is a fall in average volume by 30.8% (the main factor – unfavorable structural shifts).

Analysis of changes in average volume, analyzed according to age groups in each species group and in individual species makes possible to note:

– for conifer stands there are unfavorable phenomena in young stands - decrease in average volume by 33.0%, by means of unfavorable age shifts by 27.4%, in the middle-aged, maturing, mature and overripe positive impact on the average stock have both factors.

Moreover, for mature and over mature stands both factors are favorable in terms of increase of average volume. However, for mature and over mature stands dominant factor is favorable structural shifts and for middle-aged and maturing stands dominant factor is increasing productivity;

– in hardwood stands negative impact of two factors occurring in young stands (average volume has fallen by 6.0 m^3/ha or 26.4% compared to the base year), in maturing stands volume decreased by 4.29 m^3/ha due to negative structural shifts, in other age groups average volume has increased, mainly in the result of increasing productivity of stands;

– in deciduous forests there is a decrease in the average volume of maturing stands by 2.84 m^3/ha (structural shifts have reduced the average volume by 11%).

The next step after factor analysis of forest productivity is the study of identified trends of dynamics of structure of Belarus forested area affect the change in ecological and economic value of forest capital.

Relative change in average volume of forest stands, %

Species	According to age groups												Total amount		
	young stands			middle age stands			maturing			mature and over mature					
	$I_{\bar{x}}$	$I_{\bar{x}}^{f}$	$I_{\bar{x}}^{x}$	$I_{\bar{x}}$	$I_{\bar{x}}^{f}$	$I_{\bar{x}}^{x}$	$I_{\bar{x}}$	$I_{\bar{x}}^{f}$	$I_{\bar{x}}^{x}$	$I_{\bar{x}}$	$I_{\bar{x}}^{f}$	$I_{\bar{x}}^{x}$	$I_{\bar{x}}$	$I_{\bar{x}}^{f}$	$I_{\bar{x}}^{x}$
Influence of structural shifts in species composition															
Coniferous	78.8	85.5	92.2	107.1	94.0	113.9	112.9	100.0	113.0	115.9	99.2	116.9	108.4	92.4	117.3
Deciduous	92.7	101.4	91.4	122.8	107.8	114.0	80.2	79.7	100.7	90.3	82.6	109.3	111.4	98.9	112.6
Broad-leafed species	172.1	148.6	115.8	117.2	111.2	105.4	107.0	101.6	105.4	113.6	103.3	110.0	125.0	116.9	106.9
All species	88.1	92.1	95.7	110.1	98.7	111.6	110.6	100.0	110.6	113.2	100.1	113.1	112.8	98.9	114.0
Influence of structural shifts in age composition															
Coniferous	67.0	72.6	92.2	123.4	108.3	113.9	125.2	110.9	113.0	164.7	141.0	116.9	117.3	105.3	111.5
Deciduous	73.6	80.4	91.4	132.1	115.9	114.0	83.1	82.5	100.7	119.9	109.6	109.3	112.6	103.7	108.6
Broad-leafed species	115.5	99.7	115.8	106.6	101.2	105.4	93.8	89.0	105.4	127.5	116.0	110.0	106.9	100.1	106.8
All species	69.2	78.5	88.1	117.2	106.4	110.1	113.2	102.4	110.6	148.6	131.3	113.2	112.8	104.0	108.4

Analysis of changes in forest capital in monetary terms showed that during the study period its value has increased by 36.36% for the middle-aged stands, by 33.87% for maturing stands, by 72.39% for mature and over mature stands and has decreased by 21.79% for young stands. The cost of the most valuable species increases almost 2 times slower than softwood species (only by 2.7% per year). If analyze the annual change in the amount of forestry capital according toage groups, we can see that the leaders in annual growth of forest capital volume are mature and over mature forests of coniferous and broadleaved species (6.05% and 5.84% per year, respectively), then come young stands of softwood species (4.80% per year). As a negative trend there can be noted a decrease in the value of forest capital of softwood young stands by 3.08% per year.

Conclusion. Balanced species composition of forests in Belarus is the major factor for meeting the requirements of the national economy in timber and acts as a guarantor of environmental conservation value. Formation of rational age structure of stands must be guided by the factorial analysis of forest productivity index, the results indicate that the main factor influencing the increase in the average volume of the forested area is an increase in the productivity of individual species (average volume per hectare).

Owing to the influence of this factor average volume of forested area has increased by 14%. Structural shifts in the distribution of species in specific gravities of the forested area (by age groups) lowered the average volume by 1.1%.

Model and the results of the above analysis by means of index method in the natural values are the basis for the analysis of ecological and economic value of wood volume, its high rate and sustainable growth characterize the resource potential of multipurpose forest utilization. Thus, preservation and maintenance of constant and high forest productivity, optimization of both species and age structure of Belarusian forest fund will contribute into realization of the principles of sustainable forest management in practical activity of any forestry.

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