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SUSTAINABLE DEVELOPMENT OF BOREAL FORESTS

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This publication contains papers presented at the 7th annual Conference of the International Boreal Forest Research Association held in St.-Petersburg, Russia, in August 19-23, 1996.

These papers describe major results of boreal forest studies that have been carried out in different countries in the period between 6th and 7th Conferences.

The book will be of interest for foresters, researchers, students and post-graduate fellows of higher schools and universities, as well as for public at large concerned with problems of conservation and wise use of boreal forests.

The publication is opened by the contribution of the academician Anatoly I. Pisarenko, President of the IBFRA, other papers follow in the Russian alphabetical order. Lists of references are given mainly in the language of original presentation.

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Contents

This level implies the development of methods of growing agricultural crops, methods and technologies of forest use (clear cutting or selective gradual cutting, etc.), methods and technologies of reforestation and identification of the place and time of applying the types of forest plantations already elaborated by science and practice such as preliminary, subordinated, subsequent plantations or reconstruction of forest stands, which are both economically or ecologically inconvenient.

In order to solve the mentioned problems, forest scientists have first of all to determine:

Standards of permissible minimum forest cover by element of landscapes;

Percentage of special protected areas of natural environment: nature reserves, national parks and others;

Zones of "life-support" of cities and other settlements bearing in mind borders of a “shadow green zone" (i.e. territory outside administrative borders);

Zones of intensive forest use with adequate measures of forest reproduction;

Maximum allowable technogenic loads on a given type of landscape (percentage of territory use by industrial enterprises, transport network, settlements);

General development of landscapes, providing amenities and welfare for people.

References

1. *Dekatov N.Ye.* The Elementary measures for forest regeneration at clear-cuttings. - Leningrad: Goslestekhizdat, 1936. 112 p.

2. *Kalinichenko N.P.*, Pisarenko A.I., Smirnov N.A. Forest reforestation on cuts. Moscow: Lesnaya Promyshlennost, 1973. 326 p.

3. *Kravchinski D.M.* About types of forest stands and their economic importance. St. Petersburg, 1909. 9 p.

4. *Larcher W.* Ecology of plants. - Moscow: Mir, 1978. 382 p.

5. *Melekhov I.S.* Final cuts. - Moscow - Leningrad: Goslesbumizdat, 1962. 330 p.

6. *E. Odum.* Bases of ecology. Ìoscow: Mir, 1975. 740 p.

7. *Pobedinski A.V.* Forest reforestation on concentrated cut areas. - Moscow: Goslesbumizdat, 1955. 92 p.

8. *Pobedinski A.V.* Final cuts. Moscow: Lesnaya Promyshlennost, 1964. 209 p.

9. *Pobedinski A.V.* Harvesting and reforestation in taiga forests of the USSR. Moscow: Lesnaya Promyshlennost, 1973. 200 p.

10. *Pobedinski A.V.* Influence of forest management measures upon water protective role of the forest. Moscow: TsBNTI of the USSR Gosleskhoz, 1975, 48 p.

11. *Uspenski Ye. N.* Specifity of survival of young spruce growth on clearcut areas in the subzone of mixed conifer/broadleaved forests //Silviculture, forest cultures and soil science. Leningrad: Publ. house of Leningrad State University, **2**, 1973. p. 39-46.

12. *Chistyakov A.R.*, Leukhina T.A., Uspenski Ye.I. Physiological condition of spruce young growth of different survival categories //Lesnoi Zhurnal, 1968, No 1, p.10-12.

13. *Chmyr A.F.* Study of suppression degree of spruce under the canopy of decidous young growth //Condition of regeneraion and methods of young growth forming on concentrated cuts of the North-West of the USSR European part. Archangelsk, 1971. p. 327-329.

14. *Chmyr A.F.* Biological bases of spruce forests' reforestation in the southern taiga. Leningrad: Publ. house of Leningrad State University, 1977. p.1-160.

15. *Yakovlev G.V.* Peculiarity of subsequent forest regeneration in the subzone of southern taiga //Regeneration and forming of forests on cutovers. Moscow: Moscow Forestry Institute, 1975. p. 120-131.

SIMULATION OF STAND DYNAMICS WITH ACCOUNT OF FORESTRY IMPACTS

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According to Instruction of forest organization in the Forest Fund of Russia [10] one of the necessary items of forest and inventory works is the forecasting of Forest Fund dynamics and forest exploitation. It is pointed out that the indexes of Forest Fund forecasting dynamics must characterise the effectiveness of the projected forestry works and their impact on forest improvement and wise use of Forest Fund lands. Hence, when forecasting, it is necessary to take into account the consequences of these actions. One should mention that the forecast of Forest Fund dynamics must be made for a long period, up to a cutting cycle. It is impossible to do without models adequately describing the forest stands dynamics under the influence of endogenic and exogenic, including anthropogenic, factors, and special programming means, realising these models.

Now there are a great quantity of stand dynamics models. Good surveys of such models are represented in review by F.Beresovskaya et al., [2], A.Chetverikov [5], G.Rosenberg [17].

At fig. 1 are presented a fragment of forest block with two species of different habitus and different indexes of crown light energy absorption (fig. 1, a) and the basic means of tree crown representation along with the Sun position at the corresponding models (fig. 1, b ... 1, e).

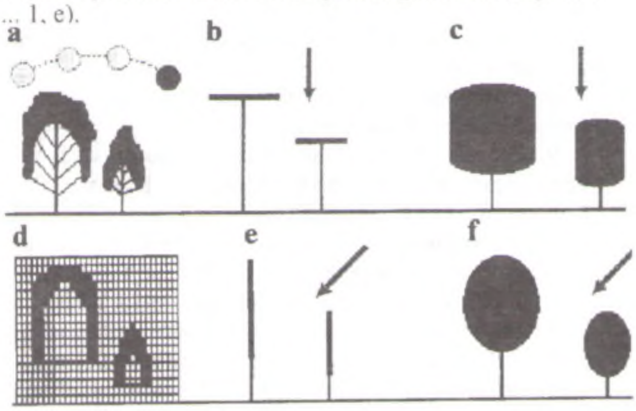


Fig. 1. Crown presentation in the model

In the well-known gap models (models of gaps, canopy breaks) two ways of crown representation are used. The first one being horizontal screens, distributed at tree height [3] (fig. 1, b). Solar radiation is absorbed by crowns discretely, in proportion to the species absorption coefficient.

In the second one the crowns are presented as bodies of rotation (cylinders, cones, ellipsoids) with uniform absorption within the whole crown volume [13] (fig. 1, c). Such crown representation is closer to the real one. Light is absorbed gradually when going deeper into the stand canopy. In both cases the increment of certain tree is determined by the light energy reaching its top.

In gap models the light source is situated vertically above. The main assumption is that the competition within the gap is much bigger than with neighbour gaps. Therefore every gap is considered independent of its neighbours. Statistical processing of the gap simulation results is spread to the whole stand.

In some works on stand dynamics simulation the crowns are presented as vertical screens [11]. Here the stand is presented as a tree line in the north-south direction (fig. 1, e). The light source is on the south side, thus the trees, standing closer to it, are shading their northern neighbours. The growth is determined by the ratio of non-shaded and shaded parts of the crown.

In another work [18] the growth processes are going similarly to the previous case, but crowns are presented as bodies of rotation (ellipsoids of rotation). The allotment of trees remains linear (fig. 1, f).

In all the above-mentioned models one of the basic factors, determining the tree growth rate, is the available photosynthetic active radiation. One should mention, that according to meteorological data [16] for Moscow latitude the solar radiation intensity from the southern sector of the sky is 20%, and from the upper one only 8% from the total one. Consequently, to obtain more accurate calculations of light availability it is necessary to take into account the radiation coming from all directions of the firmament.

In order to fulfil this goal a model was elaborated, where the crown (fig. 1, d) is presented by a set of rectangular parallelepipeds - cells [15]. From the viewpoint of calculating light the cell is semi-transparent. It allows to imitate the movement of the Sun along the firmament from East to West changing its angle and the intensity both of direct and scattered radiation. In the suggested model a similar approach is used. This model belongs to the hierarchical system of uneven-aged multispecies stand dynamics models FORUS (**FO**rest of **RUS**sia) [7].

Here is a concise description of the model. The sizes of forest ranges under simulation make up to tens of thousand hectares; the step of simulation is 10 years. The simulation predicts the change of stand inventory characteristics (height, diameter, age, stock, etc. - to several tens of characteristics) in storeys, the change of species and age structure of each stratum - primary registration unit of forest planning and inventory works. The most important feature of the described model is the account of stratum position in space and their mutual influence.

As initial information for the mathematical model are used the perstratum data bank and cartographic bank of plans and cartographic materials of the forest planning and inventory works, which for particular leskhoses exist in the form of information systems (DBMS or GIS). As a result of the model work a similar information is obtained.

To take into account bioecological processes in real forest communities, a large number of reference data bases is used within the simulation. Below are listed the main ones.

A. Bioecological characteristics of tree species development. The information compiling these data bases was assembled as a result of literature analysis and long-term natural researches [9, 19]. Also the accumulated experience of mixed uneven-aged stand's simulation is taken into account [6]. For the model work reference bases are created for species main bioecological parameters separately for each stage of tree ontogenesis of each species. These reference bases were compiled proceeding from the concept of ontogenesis discrete description [8]. The application of this concept for the simulation of complicated stands gives more authentic results (fig. 2) than with fixed biological parameters for the whole ontogenesis duration.

B. Crown biometrics characteristics. The crown form is approximated by a combination of elementary bodies of rotation: cone and cylinder. The model peculiarity is that it takes into account the internal crown space (shadow cone), in which there are no photosynthetic elements [14]. The comparison of stand development with different density has shown, that growth in height depends on light availability at the active growth zone and not at the top of a tree. The active growth zone is a part of the tree crown, where is concentrated the large share of its green biomass. In the reference base this zone is given by the position of the shadow cone in the tree crown.

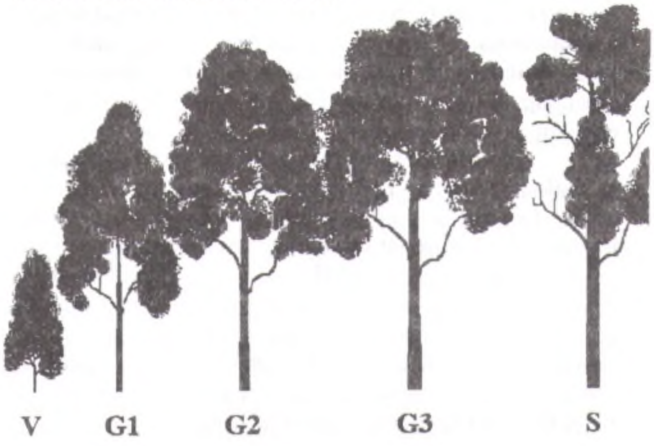


Fig. 2. Tree species ontogenesis
Ontogenic stage: V - virginile, G1 - young reproductive, G2 - mature reproductive, G3 - old reproductive, S - senile

C. Demand for light (shade tolerance) [1, 20].

D. Crown transmittance of light [1].

E. Distance of seeds spread [21].

F. Sprouting ability [19, 21].

G. Yield tables (YT) [12], more preferable are local yield tables or obtained on the bases of inventory descriptions [4].

To calculate the growth rates' data about solar radiation at a given latitude of district were used. The differentiation of light flow is proceeded by azimuth, by height of the Sun above horizon, by quantitative relation between direct and scattered radiation. Also were used data about average long-term quantity of sunny (cloudy) days in the region during the vegetative period; about condition of clouds and dust in the day time; about general air pollution, weakening the natural light factors.

The simulation model of multispecies uneven-aged stand dynamics consists of several target blocks (fig. 3). The first stage of initial data transformation - the construction of plane uniform net - is carried out by means of the used GIS (fig. 4). The square dimension is determined by the geographical latitude of the district and by the height of the top stand story. So, for example, for Moscow latitude and stand height 25 m its area makes about 270 m^2. As a result the complicated configuration of each stratum in plan is approximated by set of elements, having properties of the stratum, to whom they belong. Further the element is divided on vertical by cells 2.5 m tall. The cell (from the point of view of simulation) is indivisible minimum unit of the three-dimension space. Such representation of the simulated space permits to take into account both self shadowing, and shadowing from adjacent elements during the solar day movement.

Block "Light" begins each step of simulation, where the transparence of each cell in view of the species parameters is determined and the light availability is calculated (fig. 5). The integral value of the photo-synthetic active radiation (PAR) in the space cell is calculated with account of self-shadowing and light penetrating characteristics of the adjacent cells (fig. 6). The calculating algorithm of light availability is described thoroughly in S.Chumachenko's work [6].

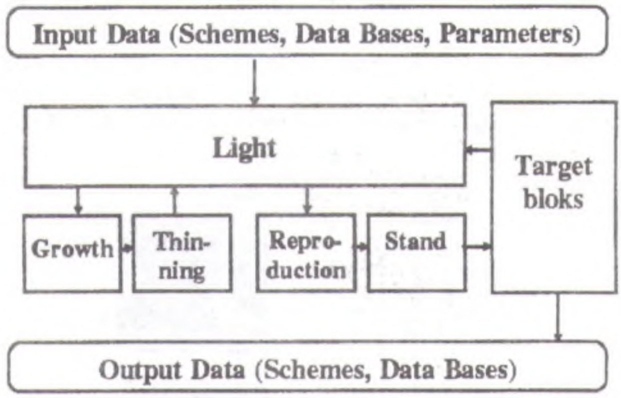


Fig. 3. Model scheme

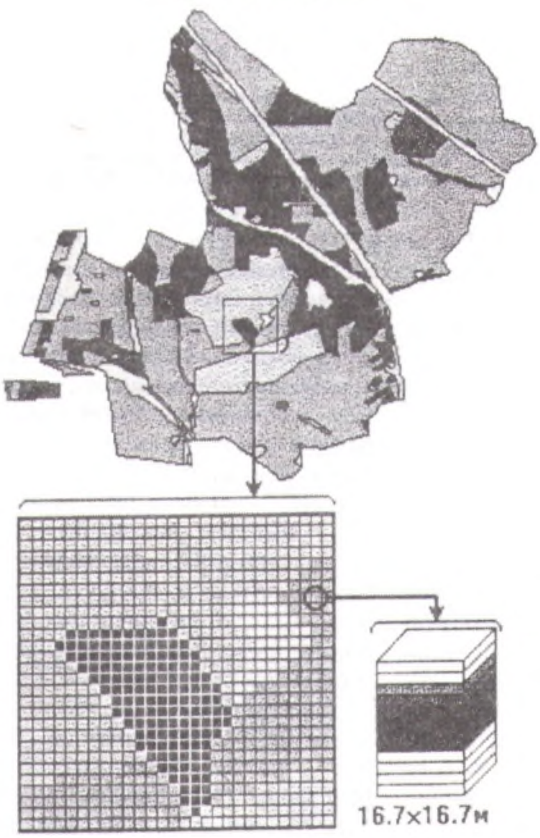
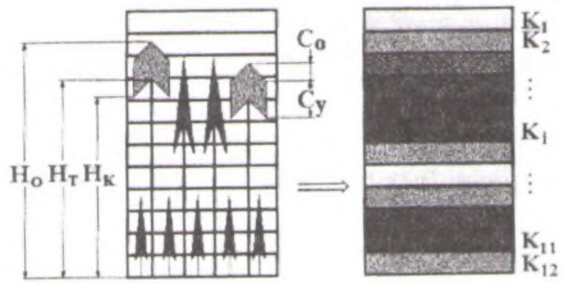


Fig. 4. Spatial data preparation

Using data about species growth, that are in the stand structure, the **block "Growth"** calculates for each element the current increment of the species by diameter and height, taking into account the element position and its light maintenance. It is accepted in the model, that the main factor, affecting the tree growth under forest canopy, is the light availability, for other considerable factors (such as available moisture and soil fertility) are rather stable integrated (average for 10 year) characteristics of the element and are taken into account when species biological quality is determined for each stratum. The methods of defining biological site classes for stands, typical in various growing conditions, are still developed insufficiently. In the present realisation of the model the table of greatest possible site classes for the prevailing species is built by an expert in interactive mode on the basis of initial inventory data and relief characteristics by taking into account available moisture and soil active nutrients, with the use of the following main assumptions.



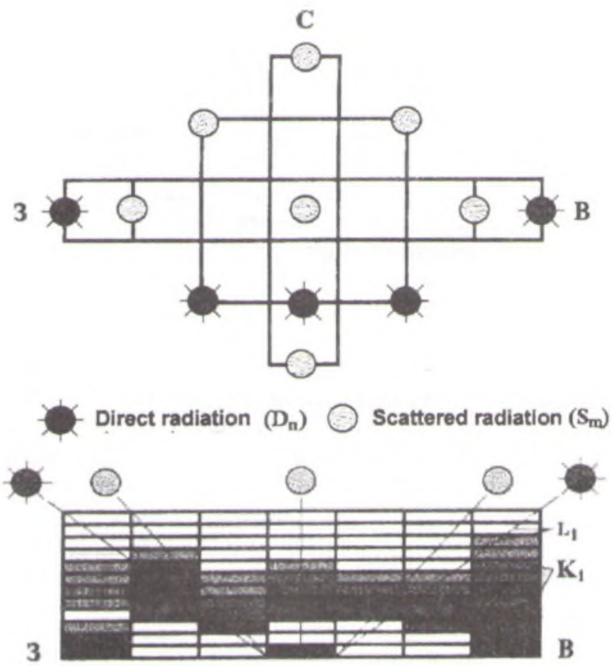
$$K_i = \sum_j P_j V_{ij} / V_c$$

Fig. 5. Calculation of light transmittance K_i
Conditional designations: H_o - tree height, H_T - height of the shade cone begining, H_K - crown fastening height, C_y - cylinder part of the crown, C_o - cone part of the crown, P_j - crown transmittance of j species, V_{ij} - volume, ocupied by j species in i cell, V_c - cell volume

The **block "Thinning"** includes two main options of behaviour of the model: endogenic thinning, as a consequence of intra- and interspecific competitive relations and thinning as a result of exogenous factors. The endogenic thinning is simulated by three consecutive operations. Firstly, the model searches and excludes from the element those species which do not reach the habitus being typical for a given species at a given age (for the lowest of site classes available). Similarly the model excludes the species, that have reached the utmost age, according to yield table data for these ones. Secondly, because of light being the main limiting factor in the model, for each species in the given stratum element it is calculated a factor of increment loss during one step. The factor in the model is defined as a ratio of the real increment to that from yield tables. The dying off criterion is the calculated factor being reduced below the given level (in the present realisation of the model - 10%). Thirdly, for the maintenance of tree number below critical values (according to biological parameters), the block "Thinning" executes the recalculation of their number within an element. In each story the zone of best competition for space - a cell with maximum crown plan, and accessible area for crown growth - is determined. The redistribution of area in story is executed at the expense of intercrown clearance and begins with shade-tolerant species. In such way, they supersede more intolerant ones, changing the proportion of areas engaged to each species.

Thinning as a result of exogenic factors includes anthropogenic, technogenic and other external effects on the simulated species. The conditions of additional thinning can be connected at any step, and they are selective ones. In the last version of the model they are taken out of the model into the block "Target blocks and statistics". After simulation of thinning, each cell light availability is recalculated with simultaneous data changing as to crown height for some species in the element.

In the **block "Reproduction"** the quantitative valuation of young growth appearing in each element is made. The intensity of germ occurrence depends on the degree of the element remoteness from generative trees of the given species and the light conditions of their development. The opportunity of coppice young growth in the element is also simulated. In view of various speeds of growth and ontogenesis duration, different yield tables for coppice and seedling stands the calculations for them are carried out separately.



$$C = \sum_n D_n \prod_i K_i^{L} + \sum_m S_m \prod_i K_i^{L}$$

Fig. 6. Solar radiation

After processing of each step of the model, the element contains characteristics for species and age structure of the stand and its biometrics parameters: species, stem quantity, age and age condition, average height of tree and average crown height, average stem diameter, crown canopy and crown form, achieved (calculated) site class. Besides these are calculated stock and stand density. These data are basic for the work of various applied blocks, external to the main model. By means of the rules given in the model the block **"Target blocks and statistics"** carries out samples, performs statistical processing, executes the assembly of elements into inventory strata and prepares the information for representation to DBMS and GIS.

The submitted imitation model is an open one, i.e. it permits to add various target blocks. Such blocks (e.g. stimulating final felling of various configurations, cleaning cutting, etc.) can be attached at any step of the model work. The model permits to simulate the effect of various catastrophic factors (fire, blowdown, etc.) and forest management influence (final felling, tending, forest regeneration measures, etc.).

To testify the adequacy of the model the growth of mixed spruce-birch stand was simulated with the following initial parameters (birch/spruce): average height - 14.1/7.5 m; average diameter - 10/7 cm; tree number - 2000/2368 stems. At fig. 7 are shown the spruce height growth in mixed spruce-birch stand according to yield table of mixed stands (light bands) and according to the model (dark ones). The mean relative error is 3.4%, the maximum one 5%, that allows to say that the model gives adequate results for mixed stands.

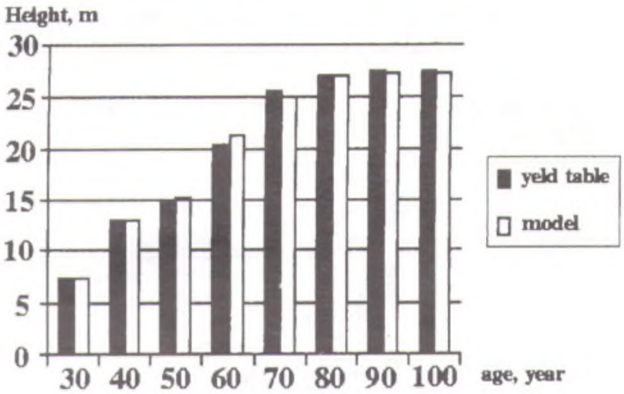


Fig. 7. Model verification

Returning to gap-models as the most used in forestry practice of foreign countries, let us remind, that in these models every gap is considered independently from its neighbours. This assumption is possible, when a uniform forest site is simulated or global (regional) processes are investigated such as global warming, mass pest and disease damage etc. However, when simulating real forest communities which are spatial distributed set of non-uniform strata, or forecasting the impact of forestry works such as gap felling, stripped-coupe gradual felling and other fellings, this assumption is incompetent. Let us show it on a sample.

Let us have a uniform forest site (inventory stratum) covered with oak coppice 40 years of age and 16.6 metres average height. A forecast of oak cultures, planted on sites after gap felling of various areas and widths, is to be obtained. Then we shall compare the results of the proposed model (imitating the solar day motion) and those of the gap-models (the light resource is above). The difficulty of the analysis is complicated by the fact that in these models there are different functions for the growth and destruction of trees. To avoid methodical errors the proposed model was used, the calculations were made both for the Sun being above and with its day motion.

If we use the gap-model, all the above-mentioned ways of cutting give the same result: the oak cultures are growing accordingly with the set biological site class (in the given case I). By 60 years of age the oak cultures have the average height 22.1 m, and the surrounding oak coppice has the average height - 26 m. However, in spite of the significant superiority by height of the surrounding stand, the oak cultures are growing without inhibition, because the light source is situated above and the surrounding shading is not taken into account.

Essentially different are the results obtained if the solar day motion is considered, when the intensity of its brightness during various day hours is given, and the direct and scattered radiation and the surrounding stand are taken into consideration. Thus, for example, for the gap felling of one element area (270 m^2) by the age of 60 years the oak is only 15 m height, i. e. the error of the gap-model is 7.1 m or 48% (table 1).

Table 1. Variants of 60 years old oak height calculation

GAP felling			
Size	1 x 1 element	3 x 3 elements	5 x 5 elements
GAP-models, m	22.1	22.1	22.1
Our model, m	15	17.1	19.9
Discrepancy	7.1 (48%)	5 (29%)	2.2 (11%)
Stripped-coupe felling			
Width	1 element	3 elements	5 elements
GAP-models, m	22.1	22.1	22.1
Our model, m	16.2	19.6	20.3
Discrepancy	5.9 (36%)	2.5 (13%)	1.8 (9%)

A set of simulation experiments were carried out with various areas of gap felling (from 270 up to 2500 m^2) and stripped-coupe felling of unlimited length and various width (from 16 up to 80 m) and directions (N-S, W-E). The error is diminishing with growing the felling area (table 1). Here the average error is considered, because the light conditions of oak growth are different in various parts of the gap felling at the expense of forest side shading, surrounding the cultures, and their self-shading (fig. 8). At the central and northern parts of the cutover the oak trees are the highest, the lowest - at the south-western and south-eastern parts.

The difference between the maximum and minimum heights (22.1 and 16 m respectively) makes up 6.1 m under the gap felling area 50x50 m.

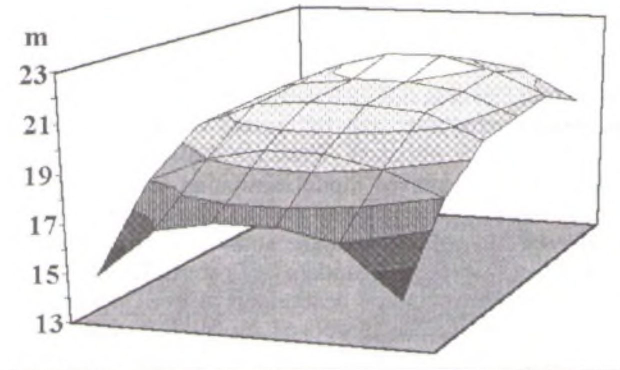


Fig.8. Height of 60 years old oak in 5 x 5 elements gap in 100 years old oak forest.

As a sample object for checking the model work was chosen the forest range of Korobovsky forest district (fig. 9). The territory is located on Moscow-Oka plane (in the South of Moscow Region) within the limits of spruce-broadleaved forest zone. Cover loam soils on a carbonate moraine are acting as soil forming rocks. The sample object area makes about 600 hectares. The forests typical for the middle part of European Russia are growing there. The central part of the forest range (30% of its area) is covered by broadleaved forests with prevalence of lime and oak of 70...100 years old, to have appeared as a result of repeated felling. At the periphery of the forest range, there are birch forests of 60...80 years old (50% of the area), arisen at arable land.

At this sample a stand dynamics was simulated under two kinds of external forestry effects: 1) final felling only, when the stand reaches its maturity age; 2) combined cleaning cutting and final felling. As a result of the model work per-stratum data bases are obtained of the sample forest range for 8 steps of simulation (80 years) according to the two options of external effects (fig. 10, 11).

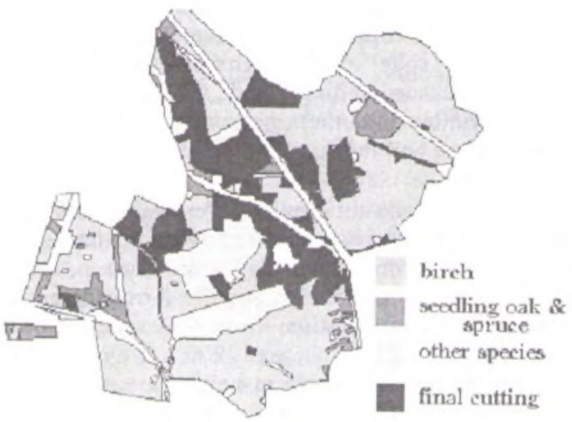


Fig. 9. Modern condition of the forest range (1-th step)

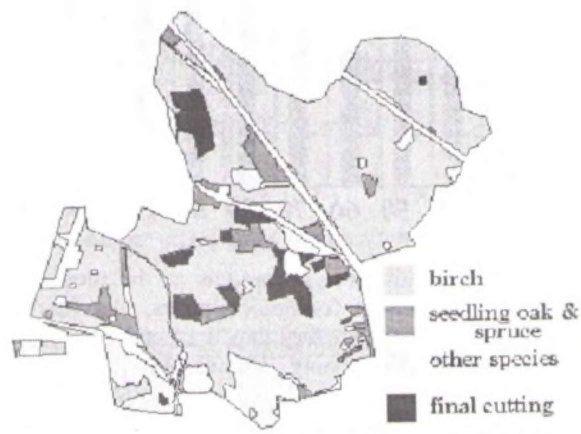


Fig. 10. Forest range simulation results, final felling only. 8-th step (80 years)

Under area change of gap felling the error is changing alongside an S-curve, i.e. at the beginning it diminishes slowly to 30% at the area of 800 m^2, then quickly up to 15% (area 1500 m^2), and then again more slowly up to 10% (area 2500 m^2).

When simulating stripped-coupe felling the error value depends to a larger extent on the cutting width than on its orientation. Thus, under 16 m width the error is up to 6 m at West-East cutting orientation and 5.2 m at North-South one. Under 32 m width it is 2.5 m, and under 48 m - 1.8 m.

From the aforesaid it follows, that the field of classical gap-models use is restricted by the problems of stand dynamics forecast under global environment changes. A spatial stand structure account is necessary when predicting a concrete stands dynamics under forestry works (in first turn the cleaning cutting and non-clear final felling).

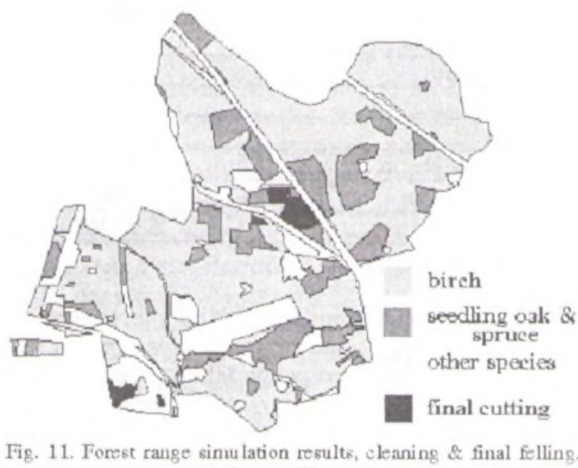


Fig. 11. Forest range simulation results, cleaning & final felling. 8-th step (80 years)

In the first case of simulation (simulation of clear final felling), the dynamics of standing crop changes is closely connected with the dynamics of birch stands timber volume (fig. 12, a). The observed sharp fall of birch stock that happens at the third step is connected with the clear felling of the birch stands that reach their maturity age. The stock fluctuations of another pioneer species - aspen - are significant. A sharp increase of aspen participation at the 5...7th steps of simulation is due to the mass clear cutting after the third step. The share of valuable species - spruce and seedling oak at such regime of management remains at a very low level (fig. 10, 12, A).

The second way of simulation differs, because in the scenario the simulation of cleaning cutting is added (fig. 12, B). The main difference of this variant from the previous one is the smooth increase of valuable species share (spruce and seedling oak) in stand structure beginning from the third step. It should be noted, that when executing cleaning cutting the birch and aspen stocks are on lower level, than in the first case. Besides that, the regular execution of cleaning cutting permits to ensure the constant volume of cut wood of not less than 50 thousand cubic m for each step of the simulation (fig. 11, 12, B).

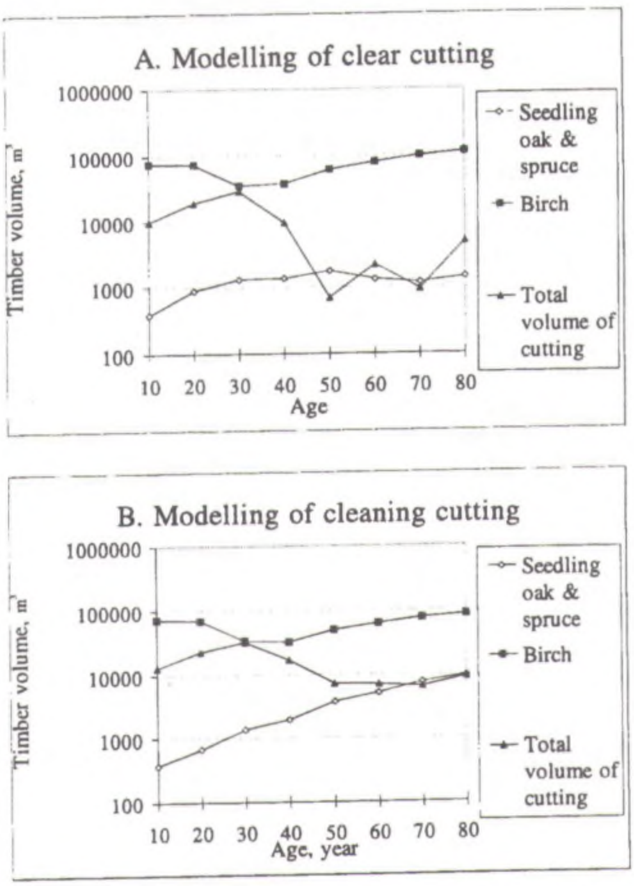


Fig. 12. Change of timber stocks on steps of modeling at the different scripts of forestry impacts

The submitted results of model work have shown the adequate reflection of stand growth and development under different scenarios of forestry effects. The model reacts correctly on change of the scenario of forestry effects. When executing a total cycle of forestry work (cleaning cutting and final felling), it will take place an increase of valuable species share. The possibility to add target blocks permits considerably to expand the opportunities of the model. So, changing at any step the biological site classes plan, it is possible to simulate the influence of environment pollution, swamping, soil infringement, drainage reclamation influence, etc.

References

1. *Alekseyev, V.A.* Forest light regime. Moscow: Nauka, 1975. 228 p. (in Russian)

2. *Berezovskaya F.S.*, Karev G.P., Shvidenko A.Z. Stand dynamics simulation; ecologo-physiological approach. Moscow: VNIITslesresource, 1991. 83 p (in Russian)

3. *Botkin D.B., Janak J.F., Wallis J.R.* Some ecological consequences of a computer model of forest growth // Journal of Ecol., 1972. V. 60. N 5. P. 849...873.

4. *Bredikhin, M.A.* Dynamics model of forest growth // Mathematical modelling in biogeocoenology. Petrozavodsk: Karelian Branch of the Academy of Sciences of the USSR, 1985. P. 36...37. (in Russian)

5. *Chetverikov A.N.* Stand thinning simulation. Part 1. Preprint. Petrozavodsk, 1988. 26 p. (in Russian)

6. *Chumachenko S.I.* Basis model of dynamics of multispecies uneven-aged forest coenosis // Transactions of Moscow Forestry Institute. 1993. N 248. P. 147...180. (in Russian)

7. *Chumachenko S.I.* Hierarchical simulation system for forest objects FORUS // Transactions of conference "Forest ecosystem conservation". Moscow: MFI, 1994. V. 4. P. 26. (in Russian)

8. *Coenopopulation* of plants (essays on population biology). Moscow: Nauka, 1988. 183 p. (in Russian)

9. *East* European broadleaved forests. Ed. by O.V.Smirnova. Moscow: Nauka, 1994. 363 p. (in Russian)

10. *Instruction* of forest organization in the Forest Fund of Russia. Part 2. Moscow: VNIITslesresurs, 1995. 112 p. (in Russian)

11. *Korzukhin M.D.*, Ter-Mikhaelyan M.T. Model of multispecies phytocoenosis under competition for light // Investigations of mathematical population ecology. Vladivostok, 1983. 100...115 pp. (in Russian)

12. *Kozlowski V.B., Pawlov V.M.* Yield tables of main forest species. Moscow: Lesnaya promyshlennost', 1967. 540 p. (in Russian)

13. *Leemans R., Prentice F.* FORSKA a general forest succession model. Uppsala, 1989. 60 p.

14. *Nosova L.M., Frantsuzov A.V.*, Chumatchenko S.I. Modelling of stand biomass structure of forest ecosystem // Problems of monitoring and modelling

forest ecosystem dynamics. Moscow: Ecos-Inform, 1995. P. 244...251. (in Russian)

15. *Popadyuk R.V., Chumachenko S.I.* Imitation bioecological model of the development of multispecies uneven-aged stand // Biological sciences, 1991. N 8 (332). P. 67...78. (in Russian)

16. *Radiation* characteristics of atmosphere and earth surface. Leningrad: Gidrometeoizdat, 1969. 564 p. (in Russian)

17. *Rosenberg G.S.* Models in phytosociology. Moscow: Nauka, 1984. 240 p. (in Russian)

18. *Sankovsky A.G., Tatarinov F.A.* Simulation of woody species population dynamics // Mathematical modelling of plant population and phytocoenosis. Moscow: Nauka, 1990. P. 86...89. (in Russian)

19. *Smirnova O.V., Chistyakova A.A., Popadyuk R.V. et al.*, Population organization of vegetation cover of forest territories. Pushchino: Biol. Research Sci. Center of the USSR Acad. of Sci., 1990. 92 p. (in Russian)

20. *Tsel'niker Yu.L.* Physiological bases of shade tolerance of woody plants. Moscow: Nauka, 1978. 212 p. (in Russian)

21. *Udra I.F.* Plant population space-time structure simulation on the basis of woody plants dissemination peculiarities // Mathematical modelling of plant population and phytocoenosis. Moscow: Nauka, 1990. P. 104...105. (in Russian)

GENERALIZED ESTIMATION OF INCREMENT AND MORTALITY IN RUSSIAN FORESTS

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Introduction

The forest account system to have been established in Russia is featured, along with many advantages recognized by foresters all over the world, by some drawbacks, of which it is necessary to mention three fundamental ones. First, there exists no national inventory system (similar to the ones applied, for instance, in Scandinavian countries), and data derived from the State Forest Account (SFA) represent only a generalization of forest account materials of different accuracy that were obtained at different periods of time. The accepted system of SFA updating is extremely imperfect and, practically, does not change the state of things. The second drawback is bound up with absolute prevalence of ocular estimations by performing forest inventory & planning work: the values of corresponding systematic errors cannot be determined within individual stands. At last, the third drawback relates to inadequate consideration for ecological factors within the framework of national forest account: some parameters being of value for comprehensive ecological and economic forest estimation (basic wood increment, biomass structure, types of age-class composition, etc.) are not directly assessed within each individual stand.

Basic wood increment is one of few (if not unique) integral quantitative parameters to describe current state and productivity of forests. SFA deals with a mean volume growth, but that index relates to the entire life of a stand (or stands) and can't describe actual (relating to a current forest account) productivity. The planned reform of forest account system in Russia (Strakhov et al., 1994) intends to establish a system of national forest inventory which would involve a proper estimation of basic wood increment. However, even if such a system could be promptly developed and adopted, its implementation all over Russia would take many decades. Meanwhile, the need for obtaining basic wood increment parameters is obvious for the benefit of present and future forest management, and because of those values being regarded as the most important indicators for describing, at least, two criteria of sustainable development of Russian forests: productivity and influence of forests upon global ecological cycles.

The present work attempts, for the first time, to give an aggregated estimation of basic wood increment parameters for Russian forests at large, as well as for the forests of Russian Federation's members. The relevant official figures have been never appeared, and neither we know of any scientific work of this kind.

The following two parameters to describe a basic wood increment are of the greatest interest: annual net increment and annual gross increment. Assuming both total volume TV (i.e. a stem wood volume produced by a stand over a period from its birth up to age A) and growing stock change GS (i.e. a total volume of all alive stems in a stand of age A) to be dependent on time, we can determine annual net increment (or total increment) dTV and annual gross increment dGS as follows: $dTV = TV'(A)$ and $dGS = GS'(A)$.

The ecological meaning of above parameters is obvious: dTV represents a stem wood constituent of net primary production in forest ecosystems (NPP), and dGS is a similar constituent of net production (NEP). Both dTV and dGS being considered for complete (normal) stands, a difference $DM = dTV - dGS$ yields a natural mortality as a function of time A. Natural mortality is a result of competition between woody plants, as well as of natural death of mature and overmature individuals. In case of modal stands, a value dM has a complex structure which can be presented approximately as a sum composed of terms of different nature, for exam-