# FOREST MANAGEMENT, FOREST INVENTORY AND INFORMATION SYSTEMS IN FORESTRY

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## FOREST STAND GROWTH FORECAST MODELS

The classification of stands has fulfiled into the stand density and levels yield of stands. Using the materials of enumerated forest mensuration on the 1500 sample plots and the base of forest subcompartments has made the system of prognosis the growth stands. The system includes the regressive models of growth stands on the forest site types for the main forest specieses. The relative increments in height. diameters and stand volume is estimated into the dependence of the average age and index of bonitet class. The models of relative stand increment have created in the pine stands into the stand density and levels yield. The separate models made for actualization of the forest fund. the prognosis the areas and volumes into age classes. the forest mensuration to the middle age of stands and low productivity of stands. The models of prognosis the growth stands intend to the actualization of forest fund. the forest mensuration. projection of the thinning. optimization of the forest harvesting. the monitoring system.

**Introduction.** Forestry planning and management methods and technologies have undergone considerable changes due to computer application. Recent 20 years have performed ample opportunities of new methods of forest estimation and forest management information processing. optimization of forest designing and forestry planning. creation of developing information systems of silvicultural information and forest management.

The efficiency of the taken decisions in the sphere of forestry management is determined by the accuracy and reliability of forest estimation and inventory data. Actualization and inventory of forest resources. reduction of forest survey work costs depend on the application of forest stand growth forecast models.

According to the data of forest stand inventory on 1.500 testing areas and forest sites data bank. for main forest forming species there were worked out simulating models of growth and productivity of Belarusian forest stands according to bonitet class and forest type. On the basis of these simulating models there was created a system of forest stands growth forecasting for forest inventory and actualization. forest survey. yield regulation and optimization of thinning scheduling.

**Main part.** The system of growth and productivity of forest stands in Belarus according to bonitet and forest type was developed on the basis of the site class-scale of professor Orlov. In accordance with the site-class scale there were accepted following bonitet indices.

For coniferous and hardwood broadleaved stands of seed origin bonitet index according to site-class scale (H 100) is mean height at the age of 100. for softwood broadleaved and coppice hardwood broadleaved stands it is mean height at the age of 50 (H 100).There are three levels of treatment intensity accepted in the research: 1) L – low-intensity of improvement felling (density 0.8–1.0); 2) M – medium-intensity of improvement felling (density 0.7–0.6); 3) H – high-intensity of improvement felling (density 0.4–0.5).

Within the bounds of each level of forest stands treatment intensity (L. M. H). site-class (bonitet). forest type and age there are three levels of forest productivity (low. medium. high). Medium productivity is determined as the most probable medium productivity of the growing stock (based on mass observation) within the limits of mean-square deviation value $\pm\sigma$ (random error of stock assessment). High level is above the medium level with range $+2\sigma$; low level is below the medium level. e.g. $-2\sigma$. Classification and selection of the growing stock according to composition. origin. bonitet. forest type. age. and density is conducted according to forest sites data bank.

Pine stands height. diameter and growing stock growth course within the limits of each treatment intensity level and productivity level is stated in following regression model

$$\lg y = b_0 + b_1 \lg A + b_2 \lg H100,$$

where $\lg y$ – a dependent value; $H$ – height, m; $A$ – age, years.

The parameters of regression models are introduced in Table 1.

Three regression models such as:

$$\lg y = b_0 + b_1 \lg A + b_2 \lg H100$$

describe the growth course of height. diameter and growing stock for bonitet class from Ia to Va at the age of 10–120 years. The regressions are significant

according to Fisher (F) test. explain 91-98% of dependent value with relative error 5-10%.

For plot actualization of the forestry there are models such as

$$\lg y = b_0 + b_1 \lg A + b_2 \lg^2 A + b_3 H100.$$

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Table 1

**Parameters of regression of links between pine stands inventory data on treatment intensity levels and on productivity levels (bonitet class)**

| Treatment intensity level | Prooductivity | Dependent variable | Factorization coefficients and their value | | | | | $R^2$ | $Sy$ | $F$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $b_0$ | $b_1$ | $t_{b1}$ | $b_2$ | $t_{b2}$ | | | |
| M | high | lg $H$ | –1.2095 | 0.8229 | 36.5 | 0.7638 | 15.8 | 0.971 | 0.07 | 701.4 |
| | | lg $D$ | –1.2528 | 0.8800 | 55.6 | 0.7265 | 21.4 | 0.987 | 0.05 | 1599.9 |
| | | lg $M$ | –0.8462 | 1.0234 | 37.1 | 1.0882 | 18.4 | 0.973 | 0.08 | 750.7 |
| | medium | lg $H$ | –1.8032 | 0.9378 | 42.4 | 0.9984 | 21.1 | 0.979 | 0.07 | 980.7 |
| | | lg $D$ | –1.4623 | 0.9643 | 48.0 | 0.7266 | 16.9 | 0.982 | 0.06 | 1178.2 |
| | | lg $M$ | –1.4672 | 1.1555 | 40.6 | 1.3064 | 21.4 | 0.977 | 0.08 | 912.9 |
| | low | lg $H$ | –2.5378 | 1.0779 | 42.5 | 1.2963 | 23.8 | 0.980 | 0.08 | 1024.4 |
| | | lg $D$ | –2.1726 | 1.1002 | 45.6 | 1.0201 | 19.7 | 0.981 | 0.07 | 1094.7 |
| | | lg $M$ | –2.5237 | 1.3386 | 26.1 | 1.7670 | 16.0 | 0.950 | 0.15 | 339.9 |
| C | high | lg $H$ | –1.0132 | 0.7358 | 45.0 | 0.7079 | 19.1 | 0.975 | 0.06 | 1138.2 |
| | | lg $D$ | –0.9831 | 0.8467 | 63.3 | 0.5742 | 19.0 | 0.986 | 0.05 | 2104.6 |
| | | lg $M$ | 0.2304 | 0.7980 | 10.9 | 0.4950 | 3.0 | 0.913 | 0.07 | 262.1 |
| | medium | lg $H$ | –1.7371 | 0.8641 | 49.9 | 1.0120 | 25.9 | 0.980 | 0.06 | 1493.0 |
| | | lg $D$ | –1.6768 | 0.9763 | 35.1 | 0.8645 | 13.8 | 0.959 | 0.10 | 679.9 |
| | | lg $M$ | –1.7920 | 1.0348 | 28.2 | 1.5731 | 19.0 | 0.949 | 0.14 | 541.1 |
| | low | lg $H$ | –2.5401 | 1.0601 | 38.3 | 1.2794 | 20.4 | 0.968 | 0.10 | 886.4 |
| | | lg $D$ | –2.1900 | 1.1538 | 49.6 | 0.9612 | 18.3 | 0.978 | 0.09 | 1336.4 |
| | | lg $M$ | –2.4027 | 1.1979 | 40.8 | 1.7314 | 26.1 | 0.974 | 0.11 | 1101.3 |
| T | high | lg $H$ | –1.2413 | 0.7629 | 45.7 | 0.8326 | 20.6 | 0.975 | 0.07 | 1219.7 |
| | | lg $D$ | –1.1139 | 0.8586 | 53.7 | 0.6728 | 17.3 | 0.980 | 0.06 | 1534.8 |
| | | lg $M$ | –0.8944 | 0.8956 | 48.6 | 1.0799 | 24.2 | 0.979 | 0.07 | 1425.0 |
| | medium | lg $H$ | –1.9369 | 0.8521 | 48.5 | 1.1646 | 27.4 | 0.980 | 0.07 | 1499.6 |
| | | lg $D$ | –1.7750 | 0.9704 | 53.2 | 0.9650 | 21.9 | 0.981 | 0.07 | 1608.1 |
| | | lg $M$ | –1.7640 | 1.0157 | 49.7 | 1.4720 | 29.8 | 0.981 | 0.08 | 1622.8 |
| | low | lg $H$ | –2.4794 | 1.0042 | 40.5 | 1.3012 | 21.5 | 0.970 | 0.10 | 999.7 |
| | | lg $D$ | –2.2905 | 1.1029 | 39.5 | 1.1176 | 16.5 | 0.966 | 0.11 | 889.5 |
| | | lg $M$ | –2.4173 | 1.0987 | 35.4 | 1.7571 | 23.4 | 0.966 | 0.12 | 868.9 |

Table 2

**Models growth stands forecast**

| Dependent variable | Regression coefficients | | | | $R^2$ | Standard error | Fisher's F-criterion |
|---|---|---|---|---|---|---|---|
| | $b_0$ | $b_1$ | $b_2$ | $b_3$ | | | |
| Pine | | | | | | | |
| lg $P_H$ | 1.9067 | –0.4152 | –0.2512 | –0.1955 | 0.954 | 0.11 | 1751.8 |
| lg $P_D$ | 1.7597 | –0.4002 | –0.2156 | –0.1275 | 0.960 | 0.09 | 2028.8 |
| lg $P_M$ | 2.3102 | –0.2026 | –0.9096 | –0.0415 | 0.939 | 0.12 | 1283.7 |
| lg $P_H$ | 1.6925 | 0.7982 | –0.8417 | –0.2774 | 0.995 | 0.06 | 1672.5 |
| lg $P_D$ | 0.7256 | 1.0598 | –0.7992 | 0.0524 | 0.987 | 0.08 | 651.9 |
| lg $P_M$ | 6.7039 | –3.5580 | 1.0193 | –1.9168 | 0.996 | 0.06 | 2101.4 |
| Oak | | | | | | | |
| lg $P_H$ | –2.2046 | 4.8823 | –1.8595 | –0.3718 | 0.992 | 0.06 | 747.1 |
| lg $P_D$ | 5.7947 | –3.7044 | 1.7497 | –2.3069 | 0.987 | 0.09 | 377.8 |
| lg $P_M$ | 1.2781 | 0.2790 | –5.7413 | 0.0440 | 0.996 | 0.28 | 991.4 |

Continuation of table 2

| Dependent variable | Regression coefficients | | | | $R^2$ | Standard error | Fisher's F-criterion |
|---|---|---|---|---|---|---|---|
| | $b_0$ | $b_1$ | $b_2$ | $b_3$ | | | |
| Birch | | | | | | | |
| lg $P_H$ | 1.5464 | 0.0642 | –0.5268 | –0.0680 | 0.995 | 0.04 | 1795.1 |
| lg $P_D$ | 1.9560 | –0.6680 | –0.2096 | 0.0015 | 0.997 | 0.02 | 3249.6 |
| lg $P_M$ | 5.2210 | –3.3010 | 1.7828 | –2.8075 | 0.939 | 0.14 | 129.2 |
| | | | | | | | |
| lg $P_H$ | 1.9362 | –0.6106 | –0.3298 | 0.00001 | 0.987 | 0.07 | 760.1 |
| lg $P_D$ | 0.9604 | 0.3663 | –0.5029 | 0.00002 | 0.969 | 0.08 | 311.9 |
| lg $P_M$ | 3.8935 | –0.1279 | 0.3324 | –0.7372 | 0.990 | 0.07 | 896.2 |
| Black alder | | | | | | | |
| lg $P_H$ | 1.1756 | 0.5971 | –0.8790 | 0.0835 | 0.989 | 0.08 | 637.8 |
| lg $P_D$ | 2.6166 | –1.1927 | –0.1244 | –0.1308 | 0.978 | 0.10 | 342.4 |
| lg $P_M$ | 3.6904 | –2.2480 | 0.3819 | –0.5988 | 0.980 | 0.09 | 328.4 |
| Speckled alder | | | | | | | |
| lg $P_H$ | 1.2674 | 0.6426 | –1.0427 | 0.0568 | 0.983 | 0.11 | 221.0 |
| lg $P_D$ | 2.6591 | –0.5049 | –1.0506 | –0.9943 | 0.994 | 0.07 | 626.9 |
| lg $P_M$ | 4.6447 | –3.0418 | 1.1250 | –2.0124 | 0.985 | 0.11 | 258.3 |

For plot actualization of the forestry there are models such as

$$\lg y = b_0 + b_1 \lg A + b_2 \lg^2 A + b_3 H100.$$

Regression coefficients are significant at 5% level. reliable according to F-test with relative error 5–10% (Table 2).

The models (Table 2) for spruce. birch. oak. black alder and grey alder were worked out according to the data in the local tables of growth course of forest stands in Belarus.

The regression models of current changes of the growing stock are of the form

$$\lg P_M = b_0 + b_1 \lg A + b_2 \lg M.$$

On the basis of the stands increment forecast on the basis of the growing stock. there are the tables of the stock increment percent according to the average age and growing stock for the main forest forming species of Belarus.

**Conclusion.** Regression models. presented for the main forest forming species of Belarus. allow on the basis of stand's average age and bonitet to estimate increment percent according to height. diameter and growing stock. On the basis of current increment of stand inventory percent it's possible to obtain stock increment forecast for the defined period.

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