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Harmonization of Transcontinental Allometric Models of Tree and Forest Stand Biomass on the Territory of Eurasia in the New Lighting

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ABSTRACT

For the first time in Russian literature the problem of harmonizing allometric models of forest biomass components (stem, branches, foliage, roots) on the levels of tree and forest stand by means of ensuring the principle of their additivity has been solved. Allometric models are designed using two unique volume of the databases on harvest biomass of two-needled pines (subgenus *Pinus* L. involving 86% of *Pinus sylvestris* L. data) on the levels of sample trees (2080 determinations) and forest stands (2450 determinations) growing within their natural habitats in Eurasia. The principle of additivity implies that the sum of biomass values obtained by component equations should be equal to the value of total biomass obtained by the general equation for total biomass. When using binary variable designating natural forests and plantations, additive systems of biomass component relations, as transcontinental three-step models of proportional weighting are designed. On their basis the corresponding taxation tables of the biomass component composition involving basic mass-determining inputs are suggested. In contrast to aggregating method of designing the additive model according to the principle “from particular - to general”, an alternative, disaggregating three-step method is applied when using another principle “from general - to particular”. The proposed models and corresponding biomass tables make it possible to estimate tree (kg) and stand (t/ha) biomass of *Pinus* forests on the Eurasian area as the first approximations when using traditional taxation. Because such transcontinental models and tables may have biases in local conditions for their application, in the next stage of this research more detailed, regional forest biomass models and tables through the “splitting” proposed here, common models into regional ones using the blocks of dummy variables will be developed.

INTRODUCTION

In recent years, the world forest ecology is experiencing unprecedented information boom in estimating forest biological productivity in relation to climate change, observed since 1960-1980s (Budyko 1977), but predicted at the end of the 19th century in the works of “the father of global warming” (Svante Arrhenius 1896). At the Climate Summit in Paris in 2015 December, 196 countries pledged to reduce carbon emissions and prevent rising average temperatures more than 2°C by the end of the century. The important role in this relation belongs to forest ecosystems, as sinks for atmospheric carbon.

When assessing the biological productivity and carbon-depositing functions of forests, regression allometric models of biomass of trees (Ter-Mikaelian & Korzukhin 1997, Usoltsev et al. 2017*a,b,c*) and forests (Veyisov & Kaplin 1976, Usoltsev 1985, Bi et al. 2010) are used. Allometry is considered, on the one hand, as a mathematical fractal implementations of wildlife (Mandelbrot 1983, West et al. 1997,1999, Whitfield 2001, Enquist & Niklas 2002, Gelashvili et al. 2013), and on the other hand, as an analytical approximation to any nonlinear stochastic (correlative, empirical) patterns, which expresses the relationship of certain dependent variable with one or more independent ones, which is based on the calculus of probability (Assmann 1961, Antanajtis 1976, Zeldovich & Myshkis 1965).

When designing and using allometric models, some uncertainties are detected. One of them is related to the harmonization of biomass allometric models of trees and forest stands. This harmonization, in particular, implies the observance of the principle of additivity, according to which the total of biomass components (stems, branches, foliage, roots), derived from component equations should be equal to the value of biomass, obtained according to the general equation for total biomass. The need to respect the principle of additivity in the tables of tree biomass, compiled using corresponding equations, was already shown in the earlier works devoted to the estimating tree biomass on stem diameter and tree height (Young et al. 1964). The problem has been widely discussed in world literature, and in recent years there has been an exponential increase in publications on this topic (Usoltsev 2017). Unfortunately, in Russian literature, it is completely ignored.

One of the latest developments is presented with the method of nonlinear seemingly unrelated regressions - NSUR) (Parresol 2001, Dong et al. 2016). Statistical accuracy and complication of computational algorithms, as their development have consistently increased and modern software tools were required (SAS/ETS 9.3; R-statistical package), nevertheless any evidence of increasing additive models efficiency compared with independent equations was not provided. All these additive systems of equation were implemented with aggregating method according to the principle "from particular - to general" (i.e. from component biomass equations - to the equation of total biomass).

Chinese researchers have proposed and developed an alternative method described and implemented according to the principle "from general - to particular" on examples of larches - *Larix olgensis* A. Henry (Tang et al. 2000) and *Larix gmelinii* (Rupr.) Kuzen (Dong et al. 2015). It is known as a method of three-step proportional weighting - 3SPW (Dong et al. 2015). Under the proposed structure of disaggregation, three-step proportional weighting additive model, the total biomass estimated by the initial equation is exploded on the roots and aboveground part in accordance with their shares in the total biomass presented with relevant component equations (step 1). Then, obtained aboveground biomass is indented similarly on the crowns and stems above bark (step 2), and, finally, the crown is divided in the needles and branches (step 3a), and stems above bark - on wood and bark (step 3b) (Fig. 1). Because the regression coefficients of the models for all the three steps are evaluated simultaneously, this ensures additivity of biomass components, i.e. total, intermediate and original ones (Dong et al. 2015).

For each of the fractions: the total P_t, intermediate of the 1st order P_a and intermediate of the 2nd order P_c and P_s (Fig.

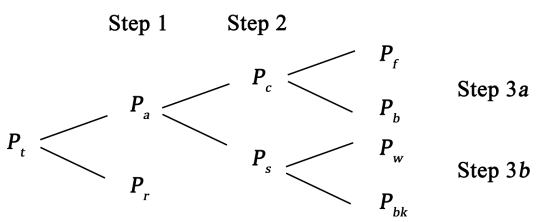

Fig. 1: The pattern of disaggregating three-step proportional weighting additive model. Designation: P_t, P_r, P_a, P_c, P_s, P_w, P_b, P_f and P_{bk} are tree biomass respectively: total, underground (roots), aboveground, crown (needles and branches), stems above bark (wood and bark), needles, branches, stem wood and bark correspondingly, kg.

1), as well as the original P_r, P_w, P_b, P_f and P_{bk} - the independent allometric models were calculated using 122 larch sample trees (Dong et al. 2015).

$$P_i = a_i D^{b_i} H^{c_i} \quad ...(1)$$

Where, P_i is biomass of *i*th component, kg; *D* - DBH, cm; *H* - tree height, m; a_i, b_i, c_i - regression coefficients of independent equations (1) for *i*th component. Algorithm for subsequent calculations with a view to obtain the additive values of biomass components is given in Table 1 in the form of three-step proportional weighting additive procedure.

Comparing the methods 3SPW and NSUR (disaggregating and aggregating, respectively) using biomass data of 122 trees, the researchers (Dong et al. 2015) concluded that although the results obtained by two methods are close to each other, the first of them gives a lower standard error of the regression coefficients when compared with the second one.

MATERIALS AND METHODS

The authors of publications on the topic of additive biomass models have used data sets of several dozen sample trees as initial materials for the given species. For a global quantitative description of biosphere functions of forest cover, the relevant databases are required, including the biological production characteristics of the world's forests, and similar databases are actively formed, in connection with which the scientific community states the arrival of the Big Data Era (http://www.gfbinitiative.org/symposium 2017). Today, some global patterns on biological productivity of forest trees and stands are designed using such "big data" compiled (Crowther et al. 2015, Poorter et al. 2015, Liang et al. 2016, Jucker et al. 2017).

The objectives of this study are, firstly, to design additive systems of equations for tree and forest stand biomass on the example of pine forests of natural and artificial origin (two-needled subgenus *Pinus* L.) growing on the territory of Eurasia and, secondly, to compare the obtained additive models with independent ones on the criteria of their adequacy. Two Trans-Eurasian databases are involved in the analysis, one of which includes harvest data on sample tree biomass (Usoltsev 2016 a, b), and the second provides information on harvest data of forest stand biomass (Usoltsev 2010, Usoltsev 2013). In both the cases, the information obtained by scientists of different countries when working on sample plots, is taken from their published sources.

The first of these databases includes 2080 definitions of sample tree biomass, of which 1520 and 560 ones were obtained respectively in natural stands and plantations. The second contains 2450 sample plots with definitions of for-

Table 1: The structure of three-step additive models sold under proportional weighting when using 122 larch trees (Dong et al. 2015). Symbols here and further as per Fig. 1 and equation (1).

Шаг 1	$P_a = \dfrac{1}{1+\dfrac{a_r D^{b_r} H^{c_r}}{a_a D^{b_a} H^{c_a}}} \times P_t$	$P_r = \dfrac{1}{1+\dfrac{a_r D^{b_r} H^{c_r}}{a_a D^{b_a} H^{c_a}}} \times P_t$
Шаг 2	$P_c = \dfrac{1}{1+\dfrac{a_s D^{b_s} H^{c_s}}{a_c D^{b_c} H^{c_c}}} \times P_a$	$P_s = \dfrac{1}{1+\dfrac{a_c D^{b_c} H^{c_c}}{a_s D^{b_s} H^{c_s}}} \times P_a$
Шаг 3*а*	$P_f = \dfrac{1}{1+\dfrac{a_b D^{b_b} H^{c_b}}{a_f D^{b_f} H^{c_f}}} \times P_c$	$P_b = \dfrac{1}{1+\dfrac{a_f D^{b_f} H^{c_f}}{a_b D^{b_b} H^{c_b}}} \times P_c$
Шаг 3*б*	$P_w = \dfrac{1}{1+\dfrac{a_{bk} D^{b_{bk}} H^{c_{bk}}}{a_w D^{b_w} H^{c_w}}} \times P_s$	$P_{bk} = \dfrac{1}{1+\dfrac{a_w D^{b_w} H^{c_w}}{a_{bk} D^{b_{bk}} H^{c_{bk}}}} \times P_s$

est stand biomass, including 1710 and 740 ones, respectively, in natural forests and plantations. Subgenus *Pinus* L. is presented mainly with Scots pine (*Pinus sylvestris* L.) (86 % of the total amount of data) and fewer species of *P. tabulaeformis* Carr., *P. massoniana* Lamb., *P. taiwanensis* Hayata, *P. yunnanensis* Franchet, *P. densiflora* S. et Z., *P. nigra* Arn., *P. pinaster* Aiton.

Harvest data of tree and forest stand biomass of different species of subgenus *Pinus* are combined respectively, in the two initial sets. A combined analysis of different species of the same genus was caused due to the fact that different but closely related species of the genus, rather than the same species, occur throughout Eurasia (e.g. *Pinus nigra* in the Balkans and *P. densiflora* in Japan), demonstrating that the habitats of woody species are associated with specific ecoregions. The latter is known as vicariation in the plant community chorology (Tolmachev 1962) whereby ecologically equivalent species replace each other in the course of long-time geographical separation once they form a separate, but continuous habitat. In order to explore the geographical distribution of woody NPP in the broadest geographical ranges, vicariation is inevitable to consider, and thus we included data from several vicariants in our database. Therefore, geographical analysis is made at the level of the genus involving some vicarious species. As a methodological approach, we have chosen the disaggregating principle, which is implemented by three-step scheme of proportional weighting (3SPW) because it: (a) allows you to dismember step-by-step the total biomass into intermediate components in accordance with their shares in the total biomass and then the resulting estimates to dismember into original components in accordance with their shares in intermediate component, (b) provides step-by-step additivity of biomass components at all the levels, (c) gives eventually biomass model for each intermediate and original component with the possibility of selecting a system of additive equations of any desired level of detailing, (d) does not require the same number of observations for all components of tree or forest stand biomass, and (e) does not require buying and use of expensive software (SAS/ETS 9.3; R-statistical package), allowing you to manage Excel tools.

It is known that when the analytical presentation of tree biomass relation to dendrometric indices takes place the heterogeneity of residual variance, and for its deleting usually one applies two ways: by linearization of equations by means of log-transformation of variables and by weighting procedure or iterative approximations. Comparing both methods on the largest standard errors, Parresol (2001) came to the conclusion that the more correct model may be obtained on the second way, but with little data sets and with insignificant internal correlation between biomass components, the first method may be preferable. In the latter case, a correction for the log-transformation is required as a function of the standard error (Baskerville 1972), and it is being successfully implemented when calculating as single (Zianis & Mencuccini 2004) and multifactorial (Carvalho & Parresol 2003) allometric models.

Since one of the objectives of our research is to provide a comparative description of independent and additive allometric biomass models, there seems to be a way to eliminate the residual variance heterogeneity in principle irrelevant, since the advantage or disadvantage of the way equally affects the correctness of both independent and additive models. Taking into account the understanding above mentioned, the calculation of compared allometric biomass models is made by means of the least squares method with linearization of dependencies by log-transformation and with the introduction of correction factor by Baskerville (1972).

RESULTS AND DISCUSSION

Independent and additive biomass equations on a tree level: At the first stage of the study, independent allometric equations are calculated in the following order (Fig. 1): firstly, for total biomass, secondly, for the aboveground part (intermediate component the 1st order) and roots (step 1), then for intermediate components of the 2nd order: crown and stem above bark (step 2), and, finally, for the original components: needles and branches (step 3*a*) and stem wood and bark separately (step 3b) according to the structure of equations, the rationale for which was given earlier (Usoltsev et al. 2017b).

$$\ln P_i = a_i + b_i(\ln D) + c_i(\ln H) + d_i(\ln D)(\ln H) + e_i X \quad ...(2)$$

After the anti-log procedure has the view;

$$P_i = a_i D^{bi} H^{ci} D^{di(\ln H)} e^{eiX} \quad ...(3)$$

Where, X is a binary variable, equal zero for natural stands and 1 for plantations. Characteristics of derived equations adjusted by involving correction factor after antilog procedure is given in Table 2.

In the second phase of the research, after substituting the regression coefficients of independent equations presented in Table 2 into the structure of the additive model, presented in Table 3, we have got the community of the original additive analytical dependencies (Table 4). After reducing common fractions, the final transcontinental additive model of component tree biomass composition in natural stands and plantations is obtained that it is designed according to three-step scheme of proportional weighting (Table 5). The model is valid in the range of harvest data of D from 0.5-0.6 to 49.0 cm and H from 1.3-1.4 to 30.0 m.

Thus, we received the additive model of tree biomass component composition for natural pine forests and plantations with eliminated internal contradiction of component equations and the total one. As additivity of biomass equations does not without fail mean improvements in the accuracy of their estimates (Cunia & Briggs 1984, Reed & Green 1985), it is necessary to clarify whether the resulting additive model has sufficient indices of adequacy and how they are compared to adequacy indices of independent equations? To this purpose, when using the original (not log-transformed) tree biomass data, the coefficients of determination R^2 and standard errors RMSE as for independent and for additive equations are calculated according to the following formula:

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{N}(Y_i - \bar{Y})^2} \qquad RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Y_i - \hat{Y}_i)^2}{N - p}} \quad ...(4)$$

Where, Y_i - observed data; $\hat{Y}_i$ - data predicted by the model; $\bar{Y}$ - mean observed biomass value for the overall (N) trees; p = 5 - variable quantity; N - total quantity of trees, involved into calculating R^2 and RMSE.

Table 2: Characteristics of independent component allometric equations (3).

Biomass component	Regression coefficients of equations				
P_t	0.1327	$D^{1.2707}$	$H^{0.3740}$	$D^{0.2638\,(\ln H)}$	$e^{-0.0188 \cdot X}$
		Step 1			
P_a	0.1220	$D^{1.7070}$	$H^{0.1664}$	$D^{0.1524\,(\ln H)}$	$e^{0.0480 \cdot X}$
P_r	0.0119	$D^{0.9448}$	$H^{1.0387}$	$D^{0.2412\,(\ln H)}$	$e^{-0.0812 \cdot X}$
		Step 2			
P_c	0.1506	$D^{2.6427}$	$H^{-1.7267}$	$D^{0.2090\,(\ln H)}$	$e^{0.2139 \cdot X}$
P_s	0.0610	$D^{1.3875}$	$H^{0.6715}$	$D^{0.1559\,(\ln H)}$	$e^{-0.0062 \cdot X}$
		Step 3*a*			
P_f	0.0710	$D^{2.6266}$	$H^{-1.5295}$	$D^{0.1046\,(\ln H)}$	$e^{0.3732 \cdot X}$
P_b	0.0506	$D^{2.7121}$	$H^{-1.5836}$	$D^{0.2184\,(\ln H)}$	$e^{0.1091 \cdot X}$
		Step 3*б*			
P_w	0.0378	$D^{1.5959}$	$H^{0.7033}$	$D^{0.1242\,(\ln H)}$	$e^{-0.0609 \cdot X}$
P_{bk}	0.0285	$D^{1.4920}$	$H^{0.1380}$	$D^{0.0775\,(\ln H)}$	$e^{0.0683 \cdot X}$

Table 3: The structure of three-step additive model, designed according to scheme of proportional weighting.

Step 1	$P_a = \dfrac{1}{1 + \dfrac{a_r D^{b_r} H^{c_r} D^{d_r (\ln H)} e^{e_r \cdot X}}{a_a D^{b_a} H^{c_a} D^{d_a (\ln H)} e^{e_a \cdot X}}} \times P_t$
	$P_r = \dfrac{1}{1 + \dfrac{a_a D^{b_a} H^{c_a} D^{d_a (\ln H)} e^{e_a \cdot X}}{a_r D^{b_r} H^{c_r} D^{d_r (\ln H)} e^{e_r \cdot X}}} \times P_t$
Step 2	$P_c = \dfrac{1}{1 + \dfrac{a_s D^{b_s} H^{c_s} D^{d_s (\ln H)} e^{e_s \cdot X}}{a_c D^{b_c} H^{c_c} D^{d_c (\ln H)} e^{e_c \cdot X}}} \times P_a$
	$P_s = \dfrac{1}{1 + \dfrac{a_c D^{b_c} H^{c_c} D^{d_c (\ln H)} e^{e_c \cdot X}}{a_s D^{b_s} H^{c_s} D^{d_s (\ln H)} e^{e_s \cdot X}}} \times P_a$
Step 3*a*	$P_f = \dfrac{1}{1 + \dfrac{a_b D^{b_b} H^{c_b} D^{d_b (\ln H)} e^{e_b \cdot X}}{a_f D^{b_f} H^{c_f} D^{d_f (\ln H)} e^{f \cdot X}}} \times P_c$
	$P_b = \dfrac{1}{1 + \dfrac{a_f D^{b_f} H^{c_f} D^{d_f (\ln H)} e^{e_f \cdot X}}{a_b D^{b_b} H^{c_b} D^{d_b (\ln H)} e^{e_b \cdot X}}} \times P_c$
Step 3*б*	$P_w = \dfrac{1}{1 + \dfrac{a_{bk} D^{b_{bk}} H^{c_{bk}} D^{d_{bk} (\ln H)} e^{e_{bk} \cdot X}}{a_w D^{b_w} H^{c_w} D^{d_w (\ln H)} e^{e_w \cdot X}}} \times P_s$
	$P_{bk} = \dfrac{1}{1 + \dfrac{a_w D^{b_w} H^{c_w} D^{d_w (\ln H)} e^{e_w \cdot X}}{a_{bk} D^{b_{bk}} H^{c_{bk}} D^{d_{bk} (\ln H)} e^{e_{bk} \cdot X}}} \times P_s$

It was noted above that the equation for the total biomass, dismembered then to component ratios by the method 3SPW, always has the better adequacy indices when compared to component equations for needles and branches biomass that have usually the lowest adequacy compared to all other biomass components. But this is legitimate only in the cases where the harvest data were measured on all biomass components. In contrary, we have to normally operate with the data where the quantity of root biomass measurements several times less when compared with aboveground components. So the original equation for total biomass in 3SPW procedure is calculated for these harvest data, that are available for both aboveground biomass and roots, and the quantity of the latter is in our case about an order of magnitude smaller data set compared to data on the aboveground biomass.

For a correct comparison of the adequacy of independent and additive equations, basic data for model calculation must be given in comparable condition, i.e. independent

Table 4: The community of the original additive analytical dependencies of biomass components upon stem DBH and height, designed according to scheme of proportional weighting.

	$P_t = 0.1327\, D^{1.2707} H^{0.3740} D^{0.2638\,(\ln H)} e^{-0.0188 \cdot X}$
Step 1	$P_a = \dfrac{1}{1 + \dfrac{0.0119 \cdot D^{0.9448} H^{1.0387} D^{0.2412\,(\ln H)} e^{-0.0812 \cdot X}}{0.1220 \cdot D^{1.7070} H^{1.1664} D^{0.1524\,(\ln H)} e^{0.0480 \cdot X}}} \times P_t$
	$P_r = \dfrac{1}{1 + \dfrac{0.1220 \cdot D^{1.7070} H^{1.1664} D^{0.1524\,(\ln H)} e^{0.0480 \cdot X}}{0.0119 \cdot D^{0.9448} H^{1.0387} D^{0.2412\,(\ln H)} e^{-0.0812 \cdot X}}} \times P_t$
Step 2	$P_c = \dfrac{1}{1 + \dfrac{0.0610 \cdot D^{1.3875} H^{0.6715} D^{0.1559\,(\ln H)} e^{-0.0062 \cdot X}}{0.1506 \cdot D^{2.6427} H^{-1.7267} D^{0.2090\,(\ln H)} e^{0.2139 \cdot X}}} \times P_a$
	$P_s = \dfrac{1}{1 + \dfrac{0.1506 \cdot D^{2.6427} H^{-1.7267} D^{0.2090\,(\ln H)} e^{0.2139 \cdot X}}{0.0610 \cdot D^{1.3875} H^{0.6715} D^{0.1559\,(\ln H)} e^{-0.0062 \cdot X}}} \times P_a$
Step 3*a*	$P_f = \dfrac{1}{1 + \dfrac{0.0506 \cdot D^{2.7121} H^{-1.5836} D^{0.2184\,(\ln H)} e^{0.1091 \cdot X}}{0.0710 \cdot D^{2.6266} H^{-1.5295} D^{0.1046\,(\ln H)} e^{0.3732 \cdot X}}} \times P_c$
	$P_b = \dfrac{1}{1 + \dfrac{0.0710 \cdot D^{2.6266} H^{-1.5295} D^{0.1046\,(\ln H)} e^{0.3732 \cdot X}}{0.0506 \cdot D^{2.7121} H^{-1.5836} D^{0.2184\,(\ln H)} e^{0.1091 \cdot X}}} \times P_c$
Step 3*б*	$P_w = \dfrac{1}{1 + \dfrac{0.0285 \cdot D^{1.4920} H^{0.1380} D^{0.0775\,(\ln H)} e^{0.0683 \cdot X}}{0.0378 \cdot D^{1.5959} H^{0.7033} D^{0.1242\,(\ln H)} e^{-0.0609 \cdot X}}} \times P_s$
	$P_{bk} = \dfrac{1}{1 + \dfrac{0.0378 \cdot D^{1.5959} H^{0.7033} D^{0.1242\,(\ln H)} e^{-0.0609 \cdot X}}{0.0285 \cdot D^{1.4920} H^{0.1380} D^{0.0775\,(\ln H)} e^{0.0683 \cdot X}}} \times P_s$

Table 5: Final transcontinental three-step additive model of tree biomass component composition in natural stands and plantations designed according to scheme of proportional weighting.

	$P_t = 0.1327\, D^{1.2707} H^{0.3740} D^{0.2638\,(\ln H)} e^{-0.0188 \cdot X}$
Step 1	$P_a = \dfrac{1}{1 + 0.0975 D^{-0.7622} H^{-0.1277} D^{0.0888\,(\ln H)} e^{-0.1292 \cdot X}} \times P_t$
	$P_r = \dfrac{1}{1 + 10.2521 D^{0.7622} H^{0.1277} D^{-0.0888\,(\ln H)} e^{0.1292 \cdot X}} \times P_t$
Step 2	$P_c = \dfrac{1}{1 + 0.4050 D^{-1.2552} H^{2.3982} D^{-0.0531\,(\ln H)} e^{-0.2201 \cdot X}} \times P_a$
	$P_s = \dfrac{1}{1 + 2.4689 D^{1.2552} H^{-2.3982} D^{0.0531\,(\ln H)} e^{0.2201 \cdot X}} \times P_a$
Step 3*a*	$P_f = \dfrac{1}{1 + 0.7127 D^{0.0855} H^{-0.0541} D^{0.1138\,(\ln H)} e^{-0.2641 \cdot X}} \times P_c$
	$P_b = \dfrac{1}{1 + 1.4032 D^{-0.0855} H^{0.0541} D^{-0.1138\,(\ln H)} e^{0.2641 \cdot X}} \times P_c$
Step 3*б*	$P_w = \dfrac{1}{1 + 0.7540 D^{-0.1039} H^{-0.5653} D^{-0.0467\,(\ln H)} e^{0.1292 \cdot X}} \times P_s$
	$P_{bk} = \dfrac{1}{1 + 1.3263 D^{0.1039} H^{0.5653} D^{0.0467\,(\ln H)} e^{-0.1292 \cdot X}} \times P_s$

Table 6: The characteristic of “reduced” independent allometric equations (3).

Biomass component	Regression coefficients of equations				
P_t	0.1327	$D^{1.2707}$	$H^{0.3740}$	$D^{0.2638\,(\ln H)}$	$e^{-0.0188 \cdot X}$
P_a	0.1045	$D^{1.2932}$	$H^{0.3722}$	$D^{0.2608\,(\ln H)}$	$e^{0.0579 \cdot X}$
P_r	0.0119	$D^{0.9448}$	$H^{1.0387}$	$D^{0.2412\,(\ln H)}$	$e^{-0.0812 \cdot X}$
P_c	0.1244	$D^{2.1783}$	$H^{-1.1978}$	$D^{0.2357\,(\ln H)}$	$e^{0.0003 \cdot X}$
P_s	0.0968	$D^{0.6843}$	$H^{0.5040}$	$D^{0.4204\,(\ln H)}$	$e^{-0.1257 \cdot X}$
P_f	0.0892	$D^{2.0585}$	$H^{-1.1600}$	$D^{0.1725\,(\ln H)}$	$e^{-0.0177 \cdot X}$
P_b	0.1200	$D^{1.6364}$	$H^{-1.6107}$	$D^{0.5221\,(\ln H)}$	$e^{0.2308 \cdot X}$
P_w	0.0449	$D^{1.3314}$	$H^{0.5919}$	$D^{0.2445\,(\ln H)}$	$e^{0.1070 \cdot X}$
P_{bk}	0.0174	$D^{1.5095}$	$H^{0.5551}$	$D^{0.0280\,(\ln H)}$	$e^{-0.0340 \cdot X}$

Table 7: Comparison of the adequacy indices of the independent and additive equations for tree biomass in natural stands and plantations.

Adequacy indices	Biomass components *								
	P_t	P_a	P_r	P_s	P_w	P_{bk}	P_c	P_b	P_f
	Independent equations								
R^2	0.986	0.745	0.982	0.891	0.821	0.723	0.859	0.654	0.719
RMSE	17.79	77.36	3.23	43.55	50.20	3.60	10.94	13.71	3.29
	Additive equations								
R^2	0.986	0.929	0.977	0.909	0.931	0.873	0.881	0.879	0.785
RMSE	17.79	40.78	3.66	39.86	31.27	2.44	10.06	8.11	2.88

*Designations see Fig. 1. Bold components, for which R^2 values of the additive models higher than independent ones but RMSE indices are respectively below.

equations for all biomass components should be calculated on the same data on that the additive equations for total biomass is calculated. The characteristic of “reduced” independent allometric equations is given in Table 6.

The adequacy indices of R^2 and *RMSE* obtained as independent “reduced” equations (Table 6) and additive ones (Table 5), are calculated on the same number of observations on which component equations (see Table 2) were calculated, proportional weighting of which according to three-step procedure gives, as a result, additive equations shown in Table 5. The results of the comparison (Table 7) suggest that the additive equations are not only internally consistent, but also have higher adequacy indices compared with independent (not harmonized) equations. The only exception seems to be in the root biomass equation (Table 7).

By tabulating the additive tree biomass model for natural pine forests and plantations according to given values *D* and *H* the desired tables of biomass component composition intended to estimating the biomass of pine forests growing on the territory of Eurasia are obtained (Tables 8 and 9).

Comparative analysis of Tables 8 and 9 shows that encoding natural pine and plantation trees by means of the binary variable in additive equations takes into account their difference on biomass component structure. For example, trees in natural pine exceed the trees of the same size in plantations on the total biomass, biomass of roots, stem above bark and stem wood at 2, 13, 3 and 4% respectively. On the contrary, the plantations exceed the natural stands on aboveground biomass, biomass of crown, needles, branches and stem bark at 1, 21, 42, 9, and 9% respectively. The biggest difference of natural pine forests and crops, there has been a mass of needles (42%), owing to the recent growth with less density. The biggest difference between natural and plantation trees is observed in needles biomass (42%), because the latter grow at lower density. Plantations and natural trees also differ on the proportion of pine needles in the aboveground biomass, which is in the first case 7.7, and in the second one 5.5%.

Independent and additive biomass equations on a forest level: At the first stage of this study, verifying of the presence or absence of differences in the biomass structure of natural pine forests and plantations, provided equality of their taxation (mass-determining) indices is undertaken. To this purpose, component models of forest stand level, the structure of which received justification previously (Usoltsev 1988), are designed using the materials of above mentioned database. They include the basic mass-determining indices of forest stands;

$$\ln P_i = a_i + b_i(\ln A) + c_i(\ln A)^2 + d_i(\ln H) + e_i(\ln D) + f_i(\ln N) + g_i X \qquad \text{...(5)}$$

Where, P_i - biomass of *i*th component, t per ha; *A* - stand age, yrs; *H* - mean stand height, m; *D* - mean stand DBH, cm; *N* - tree number, thousand trees per ha; *X* - binary variable: for plantations $X = 1$, for natural forests $X = 0$.

Regression analysis of biomass structure according to equation (5) showed that six of the nine biomass components have the actual Student’s criterion value for regression coefficient g_i of the binary variable *X*, more than the standard one, i.e. for most biomass components the difference between equations (5) for natural forests and plantations are statistically significant (Table 10).

Therefore, the binary variable *X* is stored in the structure of equation (5), and in the second stage, the calculations for natural pine forests and plantations are fulfilled separately according to equation (5), and after the anti-log procedure the following equation is obtained.

$$P_i = a_i A^{bi} A^{ci(\ln A)} H^{di} D^{ei} N^{fi} e^{giX} \qquad \text{...(6)}$$

Independent (traditional) allometric equations (5) are calculated in the same sequence as equation (3) for tree biomass (Fig. 1), according to their accepted structure. The model is valid on the ranges of mass-determining indices: $A = 7 \div 310$ yrs; $D = 0.5 \div 54.0$ cm, $H = 1.3 \div 38.0$ m and $N =$

Table 8: Additive component composition of tree biomass (kg of absolutely dry matter) for the evaluation of natural forest biomass in Eurasia.

H, m	Biomass components	Diameter at breast height, cm						
		6	10	14	18	22	26	30
6	Total biomass	5.45	13.00	23.03	-	-	-	-
	Roots	0.74	1.35	1.99	-	-	-	-
	Aboveground	4.71	11.65	21.04	-	-	-	-
	Crown	1.29	5.00	11.41	-	-	-	-
	Needles	0.62	2.21	4.78	-	-	-	-
	Branches	0.67	2.79	6.64	-	-	-	-
	Stem above bark	3.42	6.65	9.63	-	-	-	-
	Stem wood	2.86	5.65	8.25	-	-	-	-
	Stem bark	0.56	1.00	1.38	-	-	-	-
14	Total biomass	11.18	29.86	57.03	92.48	136.04	-	-
	Roots	3.06	6.68	11.08	16.13	21.72	-	-
	Aboveground	8.12	23.18	45.95	76.35	114.32	-	-
	Crown	0.41	2.29	6.84	15.19	28.28	-	-
	Needles	0.18	0.91	2.52	5.27	9.31	-	-
	Branches	0.23	1.37	4.32	9.93	18.97	-	-
	Stem above bark	7.70	20.90	39.11	61.16	86.04	-	-
	Stem wood	6.92	18.99	35.78	56.22	79.38	-	-
	Stem bark	0.78	1.91	3.33	4.94	6.67	-	-
22	Total biomass	-	-	92.52	154.58	232.90	327.61	438.84
	Roots	-	-	26.33	40.23	56.33	74.45	94.46
	Aboveground	-	-	66.19	114.35	176.57	253.16	344.38
	Crown	-	-	3.92	9.45	18.88	33.35	53.99
	Needles	-	-	1.35	3.01	5.67	9.51	14.72
	Branches	-	-	2.58	6.43	13.21	23.84	39.27
	Stem above bark	-	-	62.27	104.90	157.69	219.81	290.39
	Stem wood	-	-	58.29	98.59	148.63	207.67	274.89
	Stem bark	-	-	3.97	6.31	9.06	12.14	15.51

0.100 ÷ 94.0 thousand trees per ha. After involving into equations (6) the correction factor by Baskerville (1972), their characteristics are given in Table 11.

At the third stage of the study, the system of additive biomass equations for natural pine forests and plantations are obtained (Table 12) by means of the algorithm, similar to what was used at the tree level (Fig. 1 and Table 1). After the reduction of fractions in Table 12, the final structure of three-step additive model of forest biomass component composition is obtained, that is designed on the principle of proportional weighting (Table 13).

For the correct comparison of the adequacy of the independent and additive equations, the harvest stand data needed for calculating independent biomass equations are modified by the analogy with trees data and are reduced to a comparable condition, and independent equations are calculated on the same data set that was used when calculating additive equations for total biomass. Characteristics of reduced equations are given in Table 14.

The adequacy indices of R^2 and *RMSE* obtained for, both independent "reduced" equations (Table 14) and additive ones (Table 13), are calculated on the same number of observations on that component equations (Table 11), proportional weighting of which according to three-step procedure gives, as a result, additive equations given in Table 13. The results of the comparison (Table 15) suggest that for five components of eight ones the additive equations not only internally consistent, but mainly have higher adequacy indices compared with independent (not harmonized) equations. The only exceptions seem to be for the aboveground, root and stems above bark biomass equation (Table 15) to which underestimation is not more than 0.5-1.4%.

At the fourth stage of the study, the system of additive multifactorial models listed in the Tables 12 and 13 has to be translated into tabular (mensuration standard) form that is necessary for practical purposes. This table, when the number of its entries equals to the number of independent variables will be too cumbersome and inconvenient in practice. This system of multifactorial models works on the principle of "What will be, if ...?" and to represent it in a tabular form, you must involve the values of mass-determining indices *A*, *H*, *D* and *N* into the equations obtained. This is possible, for example, by combining the additive model with age-related trends of mass-determining indices mentioned above (Usoltsev 2001).

Table 9: Additive component composition of tree biomass (kg of absolutely dry matter) for the evaluation of plantation biomass in Eurasia.

H, m	Biomass components	Diameter at breast height, cm						
		6	10	14	18	22	26	30
6	Total biomass	5.35	12.76	22.60	-	-	-	-
	Roots	0.65	1.18	1.73	-	-	-	-
	Aboveground	4.70	11.58	20.87	-	-	-	-
	Crown	1.50	5.60	12.44	-	-	-	-
	Needles	0.82	2.85	6.02	-	-	-	-
	Branches	0.68	2.76	6.42	-	-	-	-
	Stem above bark	3.20	5.98	8.42	-	-	-	-
	Stem wood	2.62	4.97	7.08	-	-	-	-
	Stem bark	0.58	1.00	1.34	-	-	-	-
14	Total biomass	10.97	29.30	55.97	90.75	133.50	-	-
	Roots	2.73	5.92	9.79	14.21	19.10	-	-
	Aboveground	8.24	23.38	46.18	76.54	114.40	-	-
	Crown	0.52	2.80	8.26	18.09	33.24	-	-
	Needles	0.27	1.30	3.57	7.39	12.96	-	-
	Branches	0.25	1.50	4.69	10.70	20.28	-	-
	Stem above bark	7.72	20.58	37.92	58.45	81.16	-	-
	Stem wood	6.84	18.47	34.29	53.14	74.08	-	-
	Stem bark	0.88	2.11	3.63	5.31	7.08	-	-
22	Total biomass	-	-	90.79	151.70	228.55	321.50	430.65
	Roots	-	-	23.51	35.83	50.05	66.02	83.64
	Aboveground	-	-	67.28	115.87	178.50	255.47	347.01
	Crown	-	-	4.90	11.69	23.17	40.63	65.28
	Needles	-	-	1.98	4.43	8.31	13.89	21.41
	Branches	-	-	2.91	7.26	14.87	26.74	43.87
	Stem above bark	-	-	62.38	104.18	155.33	214.84	281.74
	Stem wood	-	-	57.89	97.10	145.26	201.44	264.74
	Stem bark	-	-	4.49	7.08	10.07	13.40	17.00

Table 10: Comparison of actual and standard Student's criterion values for regression coefficient g_i of the binary variable X .

Biomass component*	P_t	P_a	P_r	P_c	P_s	P_f	P_b	P_w	P_{bk}
Actual Student's criterion value	0.58	2.62	0.29	0.89	3.51	5.11	4.00	7.12	2.80
Standard Student's criterion value on the level of probability $P_{0,95}$	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96

*Designations: P_t, P_a, P_r, P_c, P_s, P_f, P_b, P_w and P_{bk} -forest biomass correspondingly: total, underground (roots), aboveground, crown (needles and branches), stem above bark, needles, branches, stem wood and stem bark, t per ha. Bold biomass components, for which differences of natural forests and plantations are statistically significant, i.e. $t_{act} > t_{stand}$.

It is known that the productivity of any forest stand is defined in terms of its age and height in the form of so-called site index scale. Therefore, we adopted as a base dependency $H = f(A)$, on which dependencies $D = f(A, H)$ superimpose consistently and then $N = f(A, H, D)$ on recursive principle. Calculation results of calculating mentioned recursive system of equations are presented in Table 15. All regression coefficients are significant at the level of probability $P_{0.95}$, and the equations are adequate to origin data.

By tabulating the recursive system of equations provided in Table 16 on the selected forest age values and predicted values of *H*, *D* and *N*, the desired table of age dynamics of mass-determining indices and additive biomass component composition of natural pine forests and plantations in Eurasia is obtained (Table 17). If on the tree level biomass indices of natural pine and plantation were compared, supposing the equality of their dendrometric indices, then at the forest level the difference between forest biomass structure depends not so much upon the morphology of their compiling trees, as upon morphology of forest stands as a whole. So, if the needle biomass of trees of equal dimensions differs in plantations and natural stands, as it

Table 11: Characteristics of independent allometric equations (6).

Biomass component	Regression coefficients of equation (6)						
P_t	0.4275	$A^{-0.2682}$	$A^{0.0421(\ln A)}$	$H^{1.0240}$	$D^{1.1326}$	$N^{0.7202}$	$e^{-0.0104 \cdot X}$
			Step 1				
P_a	0.5650	$A^{-0.1803}$	$A^{0.0276(\ln A)}$	$H^{1.0137}$	$D^{0.9412}$	$N^{0.6010}$	$e^{0.0319 \cdot X}$
P_r	0.0226	$A^{0.7036}$	$A^{-0.0674(\ln A)}$	$H^{0.6186}$	$D^{1.2091}$	$N^{0.6833}$	$e^{0.0084 \cdot X}$
			Step 2				
P_c	1.7310	$A^{-0.5687}$	$A^{0.0424(\ln A)}$	$H^{0.1322}$	$D^{1.2336}$	$N^{0.4657}$	$e^{-0.0143 \cdot X}$
P_s	0.0836	$A^{0.3540}$	$A^{-0.0282(\ln A)}$	$H^{0.2499}$	$D^{0.8805}$	$N^{0.6589}$	$e^{0.0430 \cdot X}$
			Step 3*a*				
P_f	1.2798	$A^{-0.5382}$	$A^{0.0307(\ln A)}$	$H^{0.0711}$	$D^{1.0062}$	$N^{0.4654}$	$e^{0.0814 \cdot X}$
P_b	0.4843	$A^{-0.3350}$	$A^{0.0146(\ln A)}$	$H^{0.1179}$	$D^{1.4003}$	$N^{0.4562}$	$e^{-0.0765 \cdot X}$
			Step 3б				
P_w	0.0270	$A^{0.5689}$	$A^{-0.0537(\ln A)}$	$H^{1.2273}$	$D^{1.0914}$	$N^{0.7375}$	$e^{0.1024 \cdot X}$
P_{bk}	0.0237	$A^{0.2248}$	$A^{-0.0010(\ln A)}$	$H^{0.4297}$	$D^{1.2735}$	$N^{0.7890}$	$e^{0.0686 \cdot X}$

Table 12: The community of the original additive equations for biomass components of natural forests and plantations designed on the principle of proportional weighting.

$$P_t = 0.4275A^{-0.2682}A^{0.0421(\ln A)}H^{1.0240}D^{1.1326}N^{0.7202}e^{-0.0104 \cdot X}$$

Step 1

$$P_a = \frac{1}{1 + \dfrac{0.0226A^{0.7036}A^{-0.0674(\ln A)}H^{0.6186}D^{1.2091}N^{0.6833}e^{0.0084 \cdot X}}{0.5650A^{-0.1803}A^{0.0276(\ln A)}H^{1.0137}D^{0.9412}N^{0.6010}e^{0.0319 \cdot X}}} \times P_t$$

$$P_r = \frac{1}{1 + \dfrac{0.5650A^{-0.1803}A^{0.0276(\ln A)}H^{1.0137}D^{0.9412}N^{0.6010}e^{0.0319 \cdot X}}{0.0226A^{0.7036}A^{-0.0674(\ln A)}H^{0.6186}D^{1.2091}N^{0.6833}e^{0.0084 \cdot X}}} \times P_t$$

Step 2

$$P_c = \frac{1}{1 + \dfrac{0.0836A^{0.3540}A^{-0.0282(\ln A)}H^{0.2499}D^{0.8805}N^{0.6589}e^{0.0430 \cdot X}}{1.7310A^{-0.5687}A^{0.0424(\ln A)}H^{0.1322}D^{1.2336}N^{0.4657}e^{-0.0143 \cdot X}}} \times P_a$$

$$P_s = \frac{1}{1 + \dfrac{1.7310A^{-0.5687}A^{0.0424(\ln A)}H^{0.1322}D^{1.2336}N^{0.4657}e^{-0.0143 \cdot X}}{0.0836A^{0.3540}A^{-0.0282(\ln A)}H^{0.2499}D^{0.8805}N^{0.6589}e^{0.0430 \cdot X}}} \times P_a$$

Step 3*a*

$$P_f = \frac{1}{1 + \dfrac{0.4843A^{-0.3350}A^{0.0146(\ln A)}H^{0.1179}D^{1.4003}N^{0.4562}e^{-0.0765 \cdot X}}{1.2798A^{-0.5382}A^{0.0307(\ln A)}H^{0.0711}D^{1.0062}N^{0.4654}e^{0.0814 \cdot X}}} \times P_c$$

$$P_b = \frac{1}{1 + \dfrac{1.2798A^{-0.5382}A^{0.0307(\ln A)}H^{0.0711}D^{1.0062}N^{0.4654}e^{0.0814 \cdot X}}{0.4843A^{-0.3350}A^{0.0146(\ln A)}H^{0.1179}D^{1.4003}N^{0.4562}e^{-0.0765 \cdot X}}} \times P_c$$

Step 3б

$$P_w = \frac{1}{1 + \dfrac{0.0237A^{0.2248}A^{-0.0010(\ln A)}H^{0.4297}D^{1.2735}N^{0.7890}e^{0.0686 \cdot X}}{0.0270A^{0.5689}A^{-0.0537(\ln A)}H^{1.2273}D^{1.0914}N^{0.7375}e^{0.1024 \cdot X}}} \times P_s$$

$$P_{bk} = \frac{1}{1 + \dfrac{0.0270A^{0.5689}A^{-0.0537(\ln A)}H^{1.2273}D^{1.0914}N^{0.7375}e^{0.1024 \cdot X}}{0.0237A^{0.2248}A^{-0.0010(\ln A)}H^{0.4297}D^{1.2735}N^{0.7890}e^{0.0686 \cdot X}}} \times P_s$$

was noted, at 42%, then their difference per unit area is reduced to 11% (Table 17).

CONCLUSIONS

Thus, when using harvest biomass databases of unique volume for trees and stands of two-needled pines, additive

Table 13: Final three-step additive model for biomass components of natural forests and plantations designed on the principle of proportional weighting.

$$P_t = 0.4275A^{-0.2682}A^{0.0421(\ln A)}H^{1.0240}D^{1.1326}N^{0.7202}e^{-0.0104 \cdot X}$$

Step 1

$$P_a = \frac{1}{1 + 0.0400A^{0.8839}A^{-0.0950(\ln A)}H^{-0.3951}D^{0.2679}N^{0.0823}e^{-0.0235 \cdot X}} \times P_t$$

$$P_r = \frac{1}{1 + 25.0000A^{-0.8839}A^{0.0950(\ln A)}H^{0.3951}D^{-0.2679}N^{-0.0823}e^{0.0235 \cdot X}} \times P_t$$

Step 2

$$P_c = \frac{1}{1 + 0.0483A^{0.9227}A^{-0.0706(\ln A)}H^{0.1177}D^{-0.3531}N^{0.1932}e^{0.0573 \cdot X}} \times P_a$$

$$P_s = \frac{1}{1 + 20.7057A^{-0.9227}A^{0.0706(\ln A)}H^{-0.1177}D^{0.3531}N^{-0.1932}e^{-0.0573 \cdot X}} \times P_a$$

Step 3*a*

$$P_f = \frac{1}{1 + 0.3784A^{0.2032}A^{-0.0161(\ln A)}H^{0.0468}D^{0.3941}N^{-0.0092}e^{-0.1579 \cdot X}} \times P_c$$

$$P_b = \frac{1}{1 + 2.6426A^{-0.2032}A^{0.0161(\ln A)}H^{-0.0468}D^{-0.3941}N^{0.0092}e^{0.1579 \cdot X}} \times P_c$$

Step 3б

$$P_w = \frac{1}{1 + 0.8778A^{-0.3441}A^{0.0527(\ln A)}H^{-0.7976}D^{0.1821}N^{0.0515}e^{-0.0338 \cdot X}} \times P_s$$

$$P_{bk} = \frac{1}{1 + 1.1392A^{0.3441}A^{-0.0527(\ln A)}H^{0.7976}D^{-0.1821}N^{-0.0515}e^{0.0338 \cdot X}} \times P_s$$

systems of biomass component ratios are designed. On the basis of this system, the relevant tables for the evaluation of biomass of trees and stands on their main determining indices are compiled for the first time all over Eurasia. In contrast to "aggregating" method of constructing an additive model according to the principle "from particular to general", an alternative "disaggregating" three-step method is designed on the principle "from general to particular". The proposed models and the corresponding tables provide the ability to define at the first approximation, the biomass of trees (kg) and stands (t/ha) of two-needled pines of Eurasia using the

Table 14:. Characteristics of reduced allometric equations (6).

Biomass component	Regression coefficients of equation (6)						
P_t	0.4275	$A^{-0.2682}$	$A^{0.0421(\ln A)}$	$H^{1.0240}$	$D^{1.1326}$	$N^{0.7202}$	$e^{-0.0104 \cdot X}$
P_a	0.9015	$A^{-0.6349}$	$A^{0.0830(\ln A)}$	$H^{1.1409}$	$D^{0.9772}$	$N^{0.6579}$	$e^{-0.0208 \cdot X}$
P_r	0.0264	$A^{0.6810}$	$A^{-0.0661(\ln A)}$	$H^{0.6367}$	$D^{1.1663}$	$N^{0.6674}$	$e^{0.0090 \cdot X}$
P_c	2.9627	$A^{-1.1286}$	$A^{0.1151(\ln A)}$	$H^{0.4065}$	$D^{1.1389}$	$N^{0.5358}$	$e^{-0.1010 \cdot X}$
P_s	0.1818	$A^{-0.1357}$	$A^{0.0246(\ln A)}$	$H^{1.3261}$	$D^{0.9251}$	$N^{0.6771}$	$e^{0.0241 \cdot X}$
P_f	1.4932	$A^{-1.0345}$	$A^{0.0922(\ln A)}$	$H^{0.2870}$	$D^{1.0876}$	$N^{0.5724}$	$e^{0.0279 \cdot X}$
P_b	0.8116	$A^{-1.0264}$	$A^{0.1081(\ln A)}$	$H^{0.3308}$	$D^{1.4267}$	$N^{0.5906}$	$e^{-0.1776 \cdot X}$
P_w	0.0640	$A^{0.3049}$	$A^{-0.0180(\ln A)}$	$H^{1.4644}$	$D^{0.7326}$	$N^{0.6477}$	$e^{0.1044 \cdot X}$
P_{bk}	0.0143	$A^{0.5812}$	$A^{-0.0503(\ln A)}$	$H^{0.6777}$	$D^{1.0470}$	$N^{0.7485}$	$e^{0.1027 \cdot X}$

Table 15: Comparison of the adequacy indices of the independent and additive equations for forest biomass in natural stands and plantations.

Adequacy indices	Biomass components*								
	Pt	Pa	Pr	Ps	Pw	Pbk	Pc	Pb	Pf
	Independent equations								
R^2	0.893	0.862	0.715	0.880	0.881	0.405	0.483	0.503	0.300
RMSE	28.29	24.70	7.91	21.01	19.43	3.79	5,69	4.60	1.93
	Additive equations								
R^2	0.893	0.859	0.701	0.877	0.882	0.503	0.502	0.517	0.322
RMSE	28.29	24.97	8.11	21.34	19.30	3.46	5.59	4.53	1.90

* Designations see Fig. 1. Bold components, for which R^2 values of the additive models higher than independent ones but RMSE indices are respectively below.

Table 16: Characteristics of recursive system of mass-determining indices in the form of their age trends.

Dependent variables	Regression coefficients and independent variables					R^2	SE
	a_0	$a_1(\ln A)$	$a_3(\ln H)$	$a_4(\ln D)$	a_5X		
H	-14.8682	7.6100	-	-	0.3578	0.590	4.57
$\ln D$	-0.2068	0.1250	0.9183	-	0.0217	0.900	0.21
$\ln N$	4.3477	-0.1972	1.2172	-2.3533	0.0729	0.891	0.35

data of forest inventory and the rate of carbon sequestration, when repeating measurement of forests and their communities. Because such pancontinental models and tables may have biases in local conditions for their application (Usoltsev et al. 2017*a, b, c*), in the next stage of this research more detailed, regional forest biomass models and tables through the "splitting" proposed here, common models into regional ones using the blocks of dummy variables will be developed.

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Table 17: Additive component composition of forest biomass (t per ha, absolutely dry matter) for the evaluation of natural forest and plantation biomass in Eurasia.

A, yrs	*H*, m	*D*, cm	*N*, trees per ha	Biomass, t per ha* P_t	P_a	P_c	P_f	P_b	P_r	P_s	P_w	P_{bk}
Natural forests of two-needled pines												
10	2.7	2.7	16 139	17.6	14.6	7.3	4.0	3.3	3.0	7.3	5.5	1.8
20	7.9	7.9	4 086	66.8	55.3	15.4	6.2	9.2	11.5	40.0	34.6	5.3
40	13.2	13.8	1 796	117.9	96.7	17.9	5.9	12.0	21.2	78.9	71.0	7.8
60	16.3	17.6	1 207	148.2	121.4	18.6	5.6	13.1	26.8	102.8	93.6	9.2
80	18.5	20.5	930	170.3	139.8	19.2	5.4	13.8	30.6	120.6	110.2	10.3
100	20.2	22.8	767	188.1	154.7	19.7	5.3	14.4	33.4	135.0	123.7	11.3
120	21.6	24.8	659	203.0	167.5	20.2	5.3	14.9	35.5	147.3	135.2	12.1
140	22.7	26.6	581	216.1	178.9	20.7	5.2	15.5	37.2	158.2	145.3	12.9
Plantations of two-needled pines												
10	3.0	3.1	14 638	21.6	18.0	8.4	4.8	3.6	3.5	9.6	7.4	2.2
20	8.3	8.4	4 005	73.2	60.9	15.9	6.9	9.0	12.3	44.9	39.2	5.7
40	13.6	14.4	1 790	126.1	103.8	18.1	6.5	11.6	22.2	85.7	77.6	8.1
60	16.6	18.3	1 208	157.4	129.4	18.8	6.2	12.6	28.0	110.7	101.1	9.5
80	18.8	21.3	934	180.2	148.4	19.3	6.0	13.3	31.8	129.1	118.,5	10.6
100	20.5	23.7	771	198.5	163.9	19.7	5.9	13.8	34.6	144.2	132.6	11.6
120	21.9	25.8	663	214.0	177.2	20.2	5.8	14.4	36.8	157.0	144.6	12.5
140	23.1	27.6	585	227.5	189.0	20.7	5.8	14.9	38.5	168.3	155.1	13.3

*Designations see the text.

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