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Augmentative Modelling: A Template for *Populus* spp. Stand Biomass in Eurasia Region

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ABSTRACT: Today, estimating of biological productivity or carbon-depositing ability of forests is going on the global level, and its increase is one of the major factors of climate stabilization. In recent years, two trends in the harmonization of allometric models of tree biomass have been developing. The first of them is related to ensuring the additivity of the biomass component composition, and the second one – to the search for the so-called generic model applicable to a wide range of environmental conditions. However, all "generic" models give significant biases in their application in local conditions. In our modeling, we adhere to the principle of biomass additivity, split "generic" model into regional variants by introducing dummy variables, and build the model at the transcontinental level for the first time. When using the unique in terms of the volume of database on the level of stand of the genus *Populus* spp. in a number of 212 sample plots, the trans-Eurasian additive allometric models of biomass of stands for Eurasian *Populus* forests are developed, and thereby the combined problem of model additivity and generality is solved. The additive model of forest biomass of *Populus* is harmonized in two ways: it eliminated the internal contradictions of the component and the total biomass equations, and in addition, it takes into account regional differences of forest stands not only on total, aboveground and underground biomass, but also on its component structure, i.e. it reflects the regional peculiarities of the component structure of biomass.

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In recent years, the world forest ecology is experiencing unprecedented information splash in the assessment of forest biological productivity in relation to climate change observed since 1960-80-ies (Budyko 1977). The current hype surrounding the problem of breached the carbon balance of the biosphere passes into the common paradigm of sustainable development, which the first is biosphere-stabilizing function of forests, but traditional resource forest management is seen as a subordinate task (Utkin 1995). Estimating of biological productivity or carbon-depositing ability of forests is going on the global level, and its increase is one of the major factors of climate stabilization. The modern methods of modelling the biological productivity of trees and tree stands have been developed towards additivity of biomass components (Bi *et al*. 2010, Dong *et al*. 2015) and towards transition from "pseudo-generic" allometric models to really generic, involving regionalization of biomass model by introducing dummy variables (Fu *et al*. 2012), that usually fulfilled on local sets of actual biomass of trees and tree stands. We generated the database of forest stand biomass for the main forest species in Eurasia (Usoltsev 2010), that has enabled these modern methodologies to be implemented on the entirely different, higher level, namely to begin modelling additive biomass on transcontinental level. In this article, the first attempt to develop transcontinental harmonized allometric model of vicar species aspen and poplar (genus *Populus* spp.) forest stand biomass, which combine both mentioned by Jacobs and Cunia (1980) approaches, namely, ensuring the principle of additivity of biomass component composition and localizing (dismemberment) of biomass additive model on regions of Eurasia by introducing dummy variables. In other words, an attempt is made to solve the problems of combining additivity and totality of models. These models will provide the basis for the development of trans-continental regional standards for evaluation biomass of forest stands.

MATERIALS AND METHODS

Of the database mentioned the material in a number of 212 sample plots with estimations of *Populus* forest stand biomass (t/ha) is extracted. Genus *Betula* spp. is introduced by four species (correspondingly *P. tremula* L., *P. alba* L., *P. laurifolia* L., and *P.*

davidiana D.), distributed across 10 eco-regions and designated respectively with the 10 dummy variables from X_0 to X_9 (Table 1). Analysis of biomass forest stands is made on the basis of allometric additive models. According to the structure of disaggregation three-step model (Tang *et al*. 2000; Dong *et al*. 2015), biomass value, estimated by the total biomass equation, exploded into components according to the scheme presented in Figure 1. The coefficients of the regression models for all three steps are evaluated simultaneously, which ensures additivity of biomass of all the components – total, intermediate (steps 1 and 2) and initial (step 3*a*,*b*) (Dong *et al*. 2015).

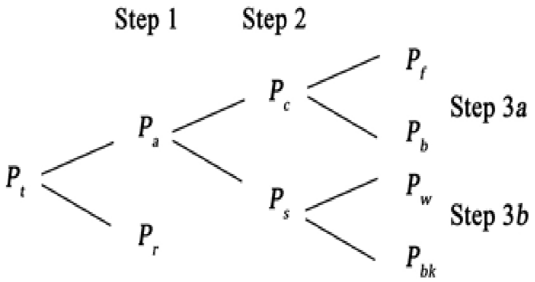

Fig. 1. The pattern of disaggregating three-step proportional weighting additive model. Designation: *Pt, Pr, Pa, Pc, Ps, Pf, Pb, Pw* and *Pbk* are stand biomass respectively: total, underground (roots), aboveground, crown (needles and branches), stems above bark (wood and bark), needles, branches, stem wood and stem bark correspondingly, t per ha.

Table 1. The encoding scheme of the regional actual biomass data sets of 212 *Populus* forest stands.

Eco-region	Species of *Populus* sp.	Block of dummy variables									Ranges of: stand age, yrs	tree number, 1000/ ha	mean diameter, cm	mean height, m	Plot quantity
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9					
West and Middle Europe	*P. tremula* L.	0	0	0	0	0	0	0	0	0	3÷57	0.64÷22.8	1.9÷30.6	2.1÷28.6	61
European part of Russia, north	*P. tremula* L.	**1**	0	0	0	0	0	0	0	0	2÷85	0.49÷92.0	2.5÷33.0	1.7÷31.0	37
European part of Russia, south	*P. tremula* L.	0	**1**	0	0	0	0	0	0	0	10÷50	0.53÷30.0	2.2÷25.2	4.9÷24.0	20
European part of Russia, south	*P. alba* L.	0	0	**1**	0	0	0	0	0	0	11÷68	0.22÷12.5	0.3÷34.7	1.5÷26.0	9
Western Siberia, taiga	*P. tremula* L.	0	0	0	**1**	0	0	0	0	0	6÷95	0.57÷30.5	2.1÷31.8	3.2÷29.6	14
Western Siberia, forest-steppe	*P. tremula* L.	0	0	0	0	**1**	0	0	0	0	10÷53	0.41÷26.3	2.3÷31.0	4.0÷22.3	26
Middle Siberia, north	*P. tremula* L.	0	0	0	0	0	**1**	0	0	0	8÷140	0.64÷22.8	2.6÷23.8	4.9÷24.5	13
Middle Siberia, south	*P. tremula* L.	0	0	0	0	0	0	**1**	0	0	21÷90	0.80÷8.50	6.2÷23.5	7.4÷24.0	11
Middle Siberia, south	*P. laurifolia* L.	0	0	0	0	0	0	0	**1**	0	10÷120	0.23÷7.87	2.9÷38.3	4.0÷25.3	12
Japanese islands	*P. davidiana* D.	0	0	0	0	0	0	0	0	**1**	11÷33	0.40÷1.24	16.0÷35.6	16.0÷23.8	9

RESULTS AND DISCUSSION

The initial allometric model is calculated;

$$\ln P_i = a_i + b_i(\ln A) + c_i(\ln A)^2 + d_i(\ln H) + e_i(\ln D) + f_i(\ln N) + \Sigma g_{ij} X_j, \quad (1)$$

where Pi – biomass of i-th component, t per ha; A – stand age, years; H – mean stand height, m; D – mean tree diameter, cm; N – tree number, 1000/ha; *a-g* – regression coefficients; i – index of biomass component: total (t), aboveground (a), roots (r), crowns (c), stems above bark (s), needles (f), branches (b), stem wood (w) and stem bark (bk); j - index (code) in the block of dummy variables coding the eco-regions, from 0 to 9 (Table 1).

Model (1) after anti-log transformation is given to the form

$$P_i = \mathrm{e}^{ai} A^{bi} A^{ci(\ln A)} H^{di} D^{ei} N^{fi} e^{\Sigma gijXj} \quad (2)$$

Characteristic of equations (1) obtained by its approximation using actual biomass data, after the introduction of correction to the logarithmic transformation after Baskerville (1972) and the subsequent anti-log transformation to (2) are given as (3). All the regression coefficients of the equations (3) with numerical variables are significant at the level of probability of 0.95 or higher, and the equations are adequate to actual data. The equations (3) are modified according to the algorithm proposed by Chinese researchers (Dong *et al*. 2015) (Fig. 2), and the final transcontinental additive model of birch biomass component composition on the level of forest stand is given as (4). The model is valid in the range of actual data of stand age, mean tree height, mean stem diameter and tree density, listed in the Table 1, and is characterized by a double harmonization: one of which provides the principle of biomass component additivity, and the second one relates to the introduction of dummy variables, localizing the model according to ecoregions of Eurasia. Characteristic of initial allometric equations for *Populus* stands (3).

$$P_t=-1.4525\,A^{0.1895}\,H^{0.6266}\,D^{1.4217}\,N^{0.7278}\,e^{-0.2124\,X1}\,e^{-0.1116\,X2}\,e^{-0.1329\,X3}\,e^{0.1212\,X4}\,e^{0.1124\,X5}\,e^{-0.4512\,X6}\,e^{-0.3754\,X7}\,e^{-0.4461\,X8}\,e^{-0.1974\,X9}.\ adjR^2 = 0.941;$$

Step 1

$$P_a=-0.9172\,A^{0.0643}\,H^{0.9428}\,D^{0.9816}\,N^{0.5133}\,e^{-0.1788\,X1}\,e^{-0.0480\,X2}\,e^{-0.1404\,X3}\,e^{-0.0515\,X4}\,e^{-0.1352\,X5}\,e^{-0.3039\,X6}\,e^{-0.0687\,X7}\,e^{-0.3148\,X8}\,e^{-0.3746\,X9}.\ adjR^2 = 0.926;$$

$$P_r=-3.1790\,A^{0.0063}\,H^{0.8556}\,D^{1.4371}\,N^{0.8408}\,e^{-0.2610\,X1}\,e^{-0.0147\,X2}\,e^{0.0393\,X3}\,e^{0.4633\,X4}\,e^{0.6511\,X5}\,e^{-0.5738\,X6}\,e^{-0.5135\,X7}\,e^{-0.2593\,X8}\,e^{-0.0932\,X9}.\ adjR^2 = 0.884;$$

Step 2

$$P_c=-0.2793\,A^{-0.1122}\,H^{0.1697}\,D^{1.1417}\,N^{0.3619}\,e^{-0.2566\,X1}\,e^{-0.0515\,X2}\,e^{-0.3327\,X3}\,e^{-0.3194\,X4}\,e^{-0.0632\,X5}\,e^{-0.3539\,X6}\,e^{0.0208\,X7}\,e^{-0.5746\,X8}\,e^{-0.1100\,X9}.\ adjR^2 = 0.706;$$

$$P_s=-2.0633\,A^{0.1132}\,H^{1.1110}\,D^{1.0832}\,N^{0.6234}\,e^{-0.1603\,X1}\,e^{-0.1541\,X2}\,e^{-0.0529\,X3}\,e^{-0.0028\,X4}\,e^{-0.1563\,X5}\,e^{-0.2937\,X6}\,e^{-0.1102\,X7}\,e^{-0.2957\,X8}\,e^{-0.4256\,X9}.\ adjR^2 = 0.940;$$

Step 3a

$$P_f=-0.4315\,A^{-0.5437}\,H^{0.3299}\,D^{0.9155}\,N^{0.3727}\,e^{-0.0373\,X1}\,e^{-0.0820\,X2}\,e^{-0.5233\,X3}\,e^{-0.1438\,X4}\,e^{-0.1601\,X5}\,e^{-0.1982\,X6}\,e^{0.3844\,X7}\,e^{0.0527\,X8}\,e^{-0.5952\,X9}.\ adjR^2 = 0.625;$$

$$P_b=-1.4747\,A^{0.1242}\,H^{0.1210}\,D^{1.2555}\,N^{0.4274}\,e^{-0.3470\,X1}\,e^{-0.0604\,X2}\,e^{-0.2422\,X3}\,e^{-0.4023\,X4}\,e^{-0.0553\,X5}\,e^{-0.5191\,X6}\,e^{-0.1626\,X7}\,e^{-0.7813\,X8}\,e^{0.1811\,X9}.\ adjR^2 = 0.741;$$

Step 3b

$$P_w=-2.6758\,A^{0.2233}\,H^{1.3109}\,D^{0.8992}\,N^{0.6475}\,e^{-0.2941\,X1}\,e^{-0.1883\,X2}\,e^{-0.2036\,X3}\,e^{-0.2261\,X4}\,e^{-0.1707\,X5}\,e^{-0.2746\,X6}\,e^{-0.1082\,X7}\,e^{-0.3844\,X8}\,e^{-0.2004\,X9}.\ adjR^2 = 0.944;$$

$$P_{bk}=-3.0307\,A^{0.1745}\,H^{0.7320}\,D^{1.0653}\,N^{0.6320}\,e^{-0.2812\,X1}\,e^{-0.1739\,X2}\,e^{0.2057\,X3}\,e^{-0.3775\,X4}\,e^{-0.2488\,X5}\,e^{-0.4703\,X6}\,e^{-0.3576\,X7}\,e^{0.0061\,X8}\,e^{-0.1908\,X9}.\ adjR^2 = 0.900;$$

Three-step additive model of biomass component composition for *Populus* forest stands, built by proportional weighing (4)

$$Pt= -1.4525\,A^{0.1895}H^{0.6266}D^{1.4217}N^{0.7278}e^{-0.2124X1}e^{-0.1116X2}e^{-0.1329X3}e^{0.1212X4}e^{0.1124X5}e^{-0.4512X6}e^{-0.3754X7}e^{-0.4461X8}e^{-0.1974X9}$$

Step 1

$$Pa=\frac{1}{1+1.9579\,A^{-0.2259}H^{0.2603}D^{0.0487}N^{0.1502}e^{-0.0548X1}e^{0.1301X2}e^{0.2150X3}e^{0.4389X4}e^{0.6956X5}e^{-0.1410X6}e^{-0.1835X7}e^{0.2234X8}e^{0.1348X9}}\times Pt$$

$$Pr=\frac{1}{1+0.5108\,A^{0.2259}H^{-0.2603}D^{-0.0487}N^{-0.1502}e^{0.0548X1}e^{-0.1301X2}e^{-0.2150X3}e^{-0.4389X4}e^{-0.6956X5}e^{0.1410X6}e^{0.1835X7}e^{-0.2234X8}e^{-0.1348X9}}\times Pt$$

Step 2

$$Pc=\frac{1}{1+4.1422\,A^{0.4776}H^{1.8496}D^{-1.1537}N^{-0.0127}e^{-0.0949X1}e^{0.0159X2}e^{0.5068X3}e^{-0.2762X4}e^{-0.3984X5}e^{-0.1354X6}e^{0.5175X7}e^{0.2470X8}e^{0.0020X9}}\times Pa$$

$$Ps=\frac{1}{1+0.2414\,A^{-0.4776}H^{-1.8496}D^{1.1537}N^{0.0127}e^{0.0949X1}e^{-0.0159X2}e^{-0.5068X3}e^{0.2762X4}e^{0.3984X5}e^{0.1354X6}e^{-0.5175X7}e^{-0.2470X8}e^{-0.0020X9}}\times Pa$$

Step 3*a*

$$Pf=\frac{1}{1+1.4133\,A^{0.2735}H^{-0.2065}D^{0.4817}N^{-0.0284}e^{0.0261X1}e^{0.3359X2}e^{0.6524X3}e^{0.3247X4}e^{0.5145X5}e^{0.0485X6}e^{-0.3598X7}e^{-0.3400X8}e^{0.5685X9}}\times Pc$$

$$Pb=\frac{1}{1+0.7076\,A^{-0.2735}H^{0.2065}D^{-0.4817}N^{0.0284}e^{-0.0261X1}e^{-0.3359X2}e^{-0.6524X3}e^{-0.3247X4}e^{-0.5145X5}e^{-0.0485X6}e^{0.3598X7}e^{0.3400X8}e^{-0.5685X9}}\times Pc$$

Step 3*b*

$$Pw=\frac{1}{1+1.1326\,A^{-0,0487}H^{-0,5789}D^{0,1660}N^{-0,0155}e^{0,0129X1}e^{0,0145X2}e^{0,4093X3}e^{-0,1513X4}e^{-0,0781X5}e^{-0,1957X6}e^{-0,2493X7}e^{0,3904X8}e^{0,0096X9}}\times Ps$$

$$Pbk=\frac{1}{1+0,8829\,A^{0,0487}H^{0,5789}D^{-0,1660}N^{0,0155}e^{-0,0129X1}e^{-0,0145X2}e^{-0,4093X3}e^{0,1513X4}e^{0,0781X5}e^{0,1957X6}e^{0,2493X7}e^{-0,3904X8}e^{-0,0096X9}}\times Ps$$

At the next stage of the study the comparison of the adequacy of additive model (4) and independent equations (3) is fulfiled. For their correct comparing the sample plots with incomplete biomass component structure are deleted from the initial harvest data, i.e. only those records are left in which the data are available on both aboveground and underground biomass. The equations (2) are approximated according to such "methodized" data, and their final forms are given as (5). The characteristics of "methodized" independent allometric equations for *Populus* stands (5).

$$P_t = -1.4525\,A^{0.1895}\,H^{0.6266}\,D^{1.4217}\,N^{0.7278}\,e^{-0.2124\,X1}\,e^{-0.1116\,X2}\,e^{-0.1329\,X3}\,e^{0.1212\,X4}\,e^{0.1124\,X5}\,e^{-0.4512\,X6}\,e^{-0.3754\,X7}\,e^{-0.4461\,X8}\,e^{-0.1974\,X9}.\ adjR^2 = 0.941$$

Step 1

$$P_a = -1.6237\,A^{0.2322}\,H^{0.5953}\,D^{1.3884}\,N^{0.6906}\,e^{-0.2062\,X1}\,e^{-0.1448\,X2}\,e^{-0.1757\,X3}\,e^{0.0244\,X4}\,e^{-0.0445\,X5}\,e^{-0.4328\,X6}\,e^{-0.3301\,X7}\,e^{-0.4827\,X8}\,e^{-0.2281\,X9}.\ adjR^2 = 0.936$$

$$P_r = -3.1790\,A^{0.0063}\,H^{0.8556}\,D^{1.4371}\,N^{0.8408}\,e^{-0.2610\,X1}\,e^{-0.0147\,X2}\,e^{0.0393\,X3}\,e^{0.4633\,X4}\,e^{0.6511\,X5}\,e^{-0.5738\,X6}\,e^{-0.5135\,X7}\,e^{-0.2593\,X8}\,e^{-0.0932\,X9}.\ adjR^2 = 0.884$$

Step 2

$$P_c = -0.6632\, A^{-0.1791}\, H^{-0.8127}\, D^{2.3410}\, N^{0.7293}\, e^{-0.1356\, X1}\, e^{-0.1705\, X2}\, e^{-0.5251\, X3}\, e^{0.2522\, X4}\, e^{0.3068\, X5}\, e^{-0.3045\, X6}\, e^{-0.7258\, X7}\, e^{-0.6854\, X8}\, e^{-0.2512\, X9}\,.\ adjR^2 = 0.769$$

$$P_s = -2.7471\, A^{0.2985}\, H^{1.0369}\, D^{1.1873}\, N^{0.7166}\, e^{-0.2305\, X1}\, e^{-0.1547\, X2}\, e^{-0.0183\, X3}\, e^{-0.0240\, X4}\, e^{-0.0916\, X5}\, e^{-0.4398\, X6}\, e^{-0.2084\, X7}\, e^{-0.4384\, X8}\, e^{-0.2493\, X9}\,.\ adjR^2 = 0.942$$

Step 3a

$$P_f = -1.0533\, A^{-0.3594}\, H^{-0.6045}\, D^{1.9471}\, N^{0.7628}\, e^{-0.1921\, X1}\, e^{-0.4363\, X2}\, e^{-1.0141\, X3}\, e^{-0.0199\, X4}\, e^{-0.1355\, X5}\, e^{-0.4413\, X6}\, e^{-0.4714\, X7}\, e^{-0.4350\, X8}\, e^{-0.6588\, X9}\,.\ adjR^2 = 0.585$$

$$P_b = -1.4887\, A^{-0.0859}\, H^{-0.8110}\, D^{2.4288}\, N^{0.7343}\, e^{-0.1660\, X1}\, e^{-0.1004\, X2}\, e^{-0.3616\, X3}\, e^{0.3048\, X4}\, e^{0.3790\, X5}\, e^{-0.3928\, X6}\, e^{-0.8312\, X7}\, e^{-0.7750\, X8}\, e^{-0.0903\, X9}\,.\ adjR^2 = 0.795$$

Step 3b

$$P_w = -2.6758\, A^{0.2233}\, H^{1.3109}\, D^{0.8992}\, N^{0.6475}\, e^{-0.2941\, X1}\, e^{-0.1883\, X2}\, e^{-0.2036\, X3}\, e^{-0.2261\, X4}\, e^{-0.1707\, X5}\, e^{-0.2746\, X6}\, e^{-0.1082\, X7}\, e^{-0.3844\, X8}\, e^{-0.2004\, X9}\ adjR^2 = 0.944$$

$$P_{bk} = -3.0307\, A^{0.1745}\, H^{0.7320}\, D^{1.0653}\, N^{0.6320}\, e^{-0.2812\, X1}\, e^{-0.1739\, X2}\, e^{0.2057\, X3}\, e^{-0.3775\, X4}\, e^{-0.2488\, X5}\, e^{-0.4703\, X6}\, e^{-0.3576\, X7}\, e^{0.0061\, X8}\, e^{-0.1908\, X9}\,.\ adjR^2 = 0.990$$

Step 1

$$P_a = \frac{1}{1 + \frac{a_r D^{b_r} H^{c_r}}{a_a D^{b_a} H^{c_a}}} \times P_t \qquad P_r = \frac{1}{1 + \frac{a_r D^{b_r} H^{c_r}}{a_a D^{b_a} H^{c_a}}} \times P_t$$

Step 2

$$P_c = \frac{1}{1 + \frac{a_s D^{b_s} H^{c_s}}{a_c D^{b_c} H^{c_c}}} \times P_a \qquad P_s = \frac{1}{1 + \frac{a_c D^{b_c} H^{c_c}}{a_s D^{b_s} H^{c_s}}} \times P_a$$

Step 3*a*

$$P_f = \frac{1}{1 + \frac{a_b D^{b_b} H^{c_b}}{a_f D^{b_f} H^{c_f}}} \times P_c \qquad P_b = \frac{1}{1 + \frac{a_f D^{b_f} H^{c_f}}{a_b D^{b_b} H^{c_b}}} \times P_c$$

Step 3*b*

$$P_w = \frac{1}{1 + \frac{a_{bk} D^{b_{bk}} H^{c_{bk}}}{a_w D^{b_w} H^{c_w}}} \times P_s \qquad P_{bk} = \frac{1}{1 + \frac{a_w D^{b_w} H^{c_w}}{a_{bk} D^{b_{bk}} H^{c_{bk}}}} \times P_s$$

Fig. 2. The structure of three-step additive model built by proportional weighting (Dong *et al.*, 2015). Symbols here and further see equation (1).

As the "methodized" additive model, and "methodized" independent equations, are tabulated according to actual mass-forming indices of the modified data and the obtained values are compared with harvest biomass data using the formula:

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{N} (Y_i - \bar{Y})^2} \qquad 6$$

Where Y_i is observed value; $\hat{Y}_i$ is predicted value; $\bar{Y}$ is the mean of N observed values for the same component.

The results of comparison of the adequacy of two modeling methods are summarized in the Table 2 and they indicate that the adequacy of the two systems of equations for aboveground biomass, underground one and stem biomass are similar and the indices of additive equations for mass of crown, needles and branches are slightly worse. This corresponds to the view (Cunia and Briggs 1984; Reed and Green 1985), that the correction of internal inconsistency of biomass equations by ensuring their additivity does not necessarily means improvements in the accuracy of biomass estimating.

Table 2. The comparison of adequacy indices of independent and additive equations for *Populus* stand biomass calculated with their regionalization by introducing dummy variables.

Index	Biomass components								
	Pt	*Pa*	*Pc*	*Pf*	*Pb*	*Pr*	*Ps*	*Pw*	*Pbk*
Independent equations									
R^2	0.832	0.829	0.775	0.507	0.797	0.576	0.788	0.792	0.908
Additive equations									
R^2	0.832	0.829	0.774	0.500	0.795	0.575	0.798	0.563	0.840

The ratio of actual values and derived ones by tabulating independent and additive stand biomass models (Figure 3) shows the degree of correlativeness of the actual and calculated values and, in many cases, the absence of visible differences in the structure of residual variances obtained on two named models. More or less the value of R^2 of one or the other model is determined by the random position of actual values of maximum stand biomass in confidence range and uneven dispersion, namely accidental because of their small number and the greatest contribution to the residual variance (Figure 3).

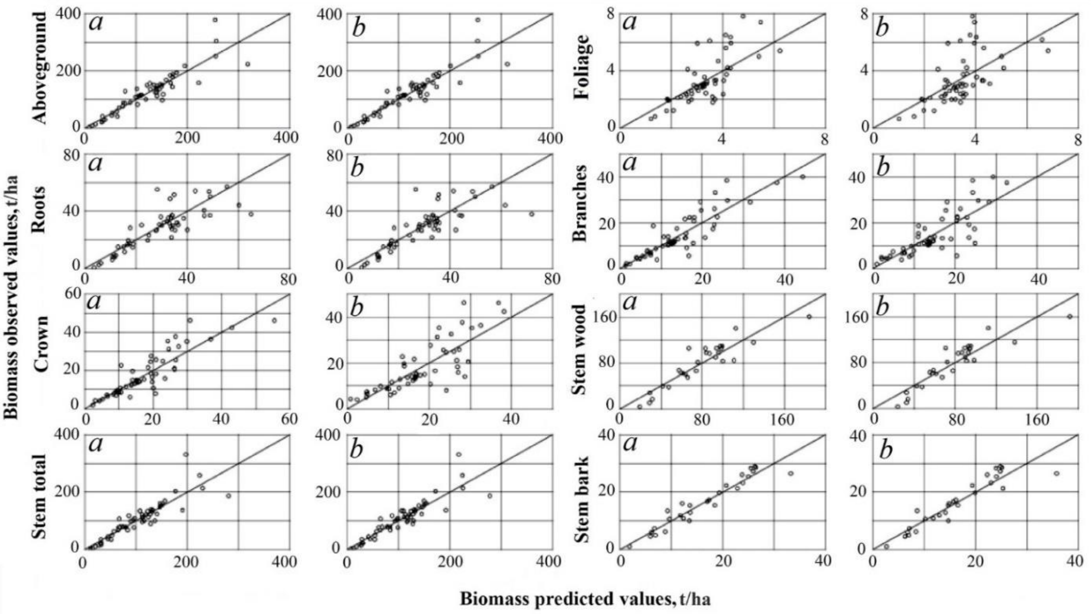

Fig. 3. The ratio of observed values and the values derived by calculation of independent (a) and additive (b) models of *Populus* stand biomass.

The additive model (4) includes four numeric independent variables. When it's tabulating, there is a problem, which is that we can know and give the value of stand age only of four variables, and the remaining three variables can be entered into the table in the form of calculated values obtained by the system of auxiliary recursive equations (Usoltsev 1989). Such equations are approximated using the original data as (7).

Characteristics of auxiliary recursive equations for mass-forming indices (7)

$H = 0.6521 + 0.6922 \ln A - 0.2786\, X1 - 0.3767\, X2 - 0.9051\, X3 - 0.2697\, X4 - 0.3819\, X5 - 0.4924\, X6 - 0.4869\, X7 - 0.5463\, X8 + 0.7180\, X9\ ;\ adjR^2 = 0.694$

$\text{In}\, D = -1.1126 + 0.2345 \ln A + 1.0652 \ln H - 0.1042\, X1 + 0.0873\, X2 + 0.2341\, X3 - 0.0549\, X4 + 0.0866\, X5 - 0.1783\, X6 + 0.0033\, X7 + 0.1607\, X8 + 0.5308\, X9\ ;\ adjR^2 = 0.938$

$\text{In}\, N = 3.6774 - 0.1809 \ln A + 0.6000 \ln H - 1.6102 \ln D \pm 0.2832\, X1 + 0.2175\, X2 - 0.6512\, X3 + 0.2654\, X4 + 0.2522\, X5 + 0.1768\, X6 + 0.6883\, X7 + 0.0698\, X8 - 0.5215\, X9\ ;\ adjR^2 = 0.867$

The results of sequential tabulations of the equations (7) and (4) give the unacceptably voluminous table, the size of which exceeds the format of journal article. Therefore, a comparative analysis of the biomass structure of *Populus* stands of different ecoregions we limit by the stand age of 40 years (Table 3). According to the Table 3, the greatest values of total biomass (467 t/ha) correspond to plantations of *P. davidiana* in Japan and of *P. tremula* in West Europe growing in regions adjacent to the Pacific and Atlantic, and the lowest (71 t/ha) – to stands of poplar white in the steppe zone of southern Russia. Slightly higher biomass values - in aspen on the northern and southern limits of Central Siberia (92-97 t/ha), and in other regions of the Eurasian area the total biomass of aspen is within 161-255 t/ha. The biomass indices of different ecoregions differed not only in absolute value but also in biomass ratios of different components; for example, the proportion of foliage in the aboveground biomass is maximum (3.7-4.1%) at *P. laurifolia* and *P. tremula* in the South of Central Siberia, minimum one (1.0%) in plantations of *P. davidiana* in Japan as well as at *P. tremula* in Western Europe and in the Turgay steppe (1.9-2.0%), and in other regions of the Eurasian area is from 2.3 to 3.0%.

Conclusion: When using the unique in terms of the volume of database on the level of a stand of the genus *Populus* sp., the trans-Eurasian additive allometric model of biomass for aspen and poplar forests is developed for the first time, and thereby the combined problem of model additivity and generality is solved. The model is harmonized in two levels, one of which provides the principle of additivity of biomass components, and the second one is associated with the introduction of dummy independent variables localizing model according to eco-regions of Eurasia. The proposed model and corresponding table for estimating stand biomass make them possible to calculate aspen and poplar stand biomass on Eurasian forests when using measuring taxation.

Table 3. Fragment of additive transcontinental table of *Populus* stand biomass for the age of 40 years, localized on the ecoregions of Eurasia.

Region	Species	*H*, m	*D*, cm	*N*, 1000/ha	Stand biomass, t/ha								
					Pt	*Pa*	*Pc*	*Pf*	*Pb*	*Pr*	*Ps*	*Pw*	*Pbk*
West and Middle Europe	*P. tremula*	24.7	23.7	0.8	270.2	216.0	30.1	4.2	25.9	54.1	186.0	160.9	25.0
European part of Russia, north	*P. tremula*	18.7	15.9	1.7	180.6	144.2	19.1	3.6	15.5	36.4	125.1	106.8	18.3
European part of Russia, south	*P. tremula*	16.9	17.3	1.3	175.4	137.8	24.9	3.4	21.4	37.6	112.9	95.3	17.6
European part of Russia, south	*P. alba*	10.0	11.4	0.8	46.9	38.1	8.2	0.9	7.3	8.8	29.8	22.1	7.7
Western Siberia, taiga	*P. tremula*	18.8	16.9	1.5	255.0	175.2	19.5	3.5	16.1	79.7	155.7	135.9	19.9
Western Siberia, forest-steppe	*P. tremula*	16.8	17.2	1.4	223.4	140.8	25.1	3.2	21.9	82.6	115.7	99.0	16.7
Middle Siberia, north	*P. tremula*	15.1	11.8	2.2	97.3	80.9	12.2	2.4	9.8	16.3	68.7	59.8	8.9
Middle Siberia, south	*P. tremula*	15.2	14.2	2.7	160.5	134.0	22.8	5.0	17.8	26.5	111.1	97.1	14.0
Middle Siberia, south	*P. laurifolia*	14.3	15.6	1.2	91.6	72.5	11.0	3.0	8.0	19.1	61.5	47.6	13.9
Japanese islands	*P. davidiana*	50.6	86.7	0.1	467.3	364.9	63.8	3.8	60.1	102.4	301.1	265.8	35.3

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