Ecological Questions 31 (2020) 2: 39–46 http://dx.doi.org/10.12775/EQ.2020.012

Additive allometric model of *Quercus* spp. stand biomass for Eurasia

Vladimir Andreevich Usoltsev[1,2], Seyed Omid Reza Shobairi[3*], Viktor Petrovich Chasovskikh[1]

[1]Ural State Forest Engineering University, 620100 Yekaterinburg, Sibirskiy Trakt, 37, Russia
[2]Botanical Garden of Ural Branch of RAS, 620144 Yekaterinburg, 8 Marta Str., 202a, Russia
[3]Nanjing University of Information Science and Technology, No.219, Ningliu Road, Nanjing, Jiangsu, China (Postcode: 210044)
[*]corresponding author's e-mail: Omidshobeyri214@gmail.com
Received: 21 March 2020 / Accepted: 15 April 2020

Abstract. When using the unique in terms of the volume of database on the level of stand of the genus *Quercus*, the trans-Eurasian additive allometric models of biomass of stands for Eurasian *Quercus* forests are developed for the first time, and thereby the combined problem of model additivity and generality is solved. The additive model of forest biomass of *Quercus* 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.

Keywords: model's harmonizing, dummy variables, biological productivity, biomass of forests, genus *Quercus*, sample plots.

1. Introduction

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. Because different biomass components are characterized by different rates both their growth and mortality, they make a different contribution to matter cycling in the forest ecosystem and should be estimated not only in total but also separately. Information on component composition of forest biomass was needed in other applications too, in particular, when assessing fire danger and modelling of forest fires (De-Miguel et al., 2014). Additivity of biomass components supposes that the total biomass (stem, branches, foliage, roots), obtained from component equations, should be equal (but usually not equal) to the value obtained using the equation for total biomass. We generated the database of forest stand biomass for the main forest species in Eurasia (Usoltsev, 2010; Usoltsev, 2013), that has enabled these modern methodologies to be implemented on the entirely different, higher level, namely on modelling additive biomass according to transcontinental level.

In this article, the first attempt to develop transcontinental harmonized allometric model of vicar species oak (genus *Quercus*) 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 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 transcontinental regional standards for evaluation biomass of forest stands.

2. Material and methods

Of the database mentioned the material in a number of 367 sample plots with estimations of *Quercus* forest stand biomass (t/ha) is extracted. Genus *Quercus* is introduced by five vicarage species (correspondingly *Q. robur* L., *Q. petraea* (Matt.) Liebl., *Q. mongolica* Fisch. ex Ledeb., *Q. mongolica* subsp. *crispula* (Blume) Menitsky and *Q. glauca* Thunb.), distributed across 6 eco-regions and designated respectively with the 6 dummy variables from X_0 to X_5 (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).

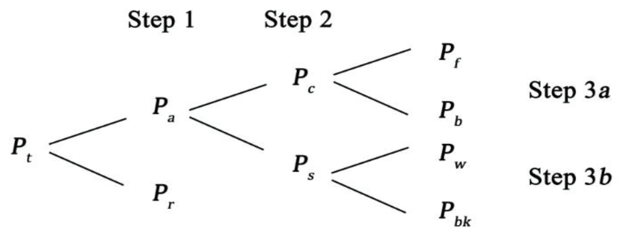

Figure 1. The pattern of disaggregating three-step proportional weighting additive model. Designation: *Pt, Pr, Pa, Pc, Ps, Pf, Pb, Pw* and *Pbk* are stand biomass respectively: total, underground (roots), aboveground, crown (leaves and branches), stems above bark (wood and bark), needles, branches,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

The distribution of sample plots, on which the oak forest biomass is measured in ecoregions of Eurasia, is shown in Figure 2.

Table 1. The encoding scheme of the regional actual biomass data sets of 367 *Quercus* stands

Eco-region*	Species** of *Quercus*	Block of dummy variables					Ranges of:				Plot quantity
		X_1	X_2	X_3	X_4	X_5	stand age, yrs	tree number, 1000/ ha	mean diameter, cm	mean height, m	
WCE	*Q. robur* L.	0	0	0	0	0	5÷220	0.166÷7.00	0.9÷55.3	2.0÷32.8	170
WCE	*Q. petraea* (Matt.) Liebl.	**1**	0	0	0	0	17÷140	0.163÷14.92	2.3÷46.7	3.2÷28.8	26
ERn	*Q. robur* L.	0	**1**	0	0	0	10÷280	0.129÷41.19	1.5÷70.0	2.2÷32.4	110
ERs	*Q. robur* L.	0	0	**1**	0	0	15÷60	0.427÷5.67	3.9÷23.1	4.2÷21.5	46
SFE	*Q. mongolica* Fisch. ex Ledeb.	0	0	0	**1**	0	38÷190	1.116÷4.91	6.7÷28.8	6.2÷19.8	6
Jap	*Q. mongolica* subsp. *crispula* (Blume) Menitsky *Q. glauca* Thunb.	0	0	0	0	**1**	4÷80	0.917÷6.78	4.2÷18.9	4.3÷11.5	9

* Designates of regions hereinafter: WCE – Western and Central Europe; ERn – European Russia, northern part; ERs – European Russia, southern part;; SFE – South of Far East, Primorie; Jap – Japanese islands.

**nomenclature according to World Flora Online. An Outline Flora of All Known Plants. http://www.worldfloraonline.org

Figure 2. Allocation of sample plots with measured biomass (t/ha) of 367 stands of oak (genus *Quercus*) on the territory of Eurasia

3. 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 5 (see Table 1).

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

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

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 in the Table 2. All the regression coefficients of the equations (2) 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 (2) are modified according to the algorithm proposed by Dong et al. (2015) (Table 3), and the final transcontinental additive model of oak biomass component composition on the level of forest stand is given in the Table 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.

At the next stage of the study a comparison of the adequacy of additive model (Table 4) and independent equations shown in the Table 2. 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 in the Table 5. 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:

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{N}(Y_i - \bar{Y}_i)^2}, \quad (3)$$

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 6 and they indicate that the adequacy of the two systems of equations for aboveground biomass, underground one and stem biomass are similar.

The ratio of actual values and derived ones by tabulating independent and additive stand biomass models (Fig. 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 (see Fig. 3).

Table 2. Characteristic of initial allometric equations for *Quercus* stands

Biomass component	**Independent variables and the regression model coefficients**										***adjR²***
P_t	1.3132	$A^{0.2782}$	$H^{0.2576}$	$D^{1.0297}$	$N^{0.4448}$	$e^{0.1913\,X1}$	$e^{0.1274\,X2}$	$e^{0.4569\,X3}$	$e^{0.1768\,X4}$	$e^{0.6994\,X5}$	0.838
Step 1											
P_a	0.4328	$A^{0.2485}$	$H^{0.6724}$	$D^{1.0102}$	$N^{0.5023}$	$e^{0.0990\,X1}$	$e^{-0.0216\,X2}$	$e^{0.0113\,X3}$	$e^{-0.0220\,X4}$	$e^{0.4872\,X5}$	0.905
P_r	0.7962	$A^{0.5019}$	$H^{-0.4864}$	$D^{1.0320}$	$N^{0.4851}$	$e^{0.1441\,X1}$	$e^{0.2090\,X2}$	$e^{1.1347\,X3}$	$e^{0.5303\,X4}$	$e^{0.3496\,X5}$	0.376
Step 2											
P_c	0.7826	$A^{0.2046}$	$H^{-0.0329}$	$D^{0.9848}$	$N^{0.2594}$	$e^{0.2517\,X1}$	$e^{-0.0464\,X2}$	$e^{-0.2080\,X3}$	$e^{-0.1216\,X4}$	$e^{0.6319\,X5}$	0.701
P_s	0.1801	$A^{0.2552}$	$H^{0.8867}$	$D^{1.0191}$	$N^{0.5759}$	$e^{0.0574\,X1}$	$e^{-0.0054\,X2}$	$e^{0.0450\,X3}$	$e^{-0.0579\,X4}$	$e^{0.4558\,X5}$	0.906
Step 3a											
P_f	0.1914	$A^{0.2036}$	$H^{-0.0256}$	$D^{0.7592}$	$N^{0.4593}$	$e^{0.0914\,X1}$	$e^{0.0231\,X2}$	$e^{-0.0935\,X3}$	$e^{-0.1029\,X4}$	$e^{0.1904\,X5}$	0.403
P_b	0.5635	$A^{0.1757}$	$H^{0.0475}$	$D^{1.0089}$	$N^{0.2139}$	$e^{0.2846\,X1}$	$e^{-0.0748\,X2}$	$e^{-0.2060\,X3}$	$e^{-0.2028\,X4}$	$e^{0.7511\,X5}$	0.716
Step 3b											
P_w	0.0858	$A^{0.2494}$	$H^{1.0440}$	$D^{1.0714}$	$N^{0.6450}$	$e^{0.1402\,X1}$	$e^{0.0471\,X2}$	$e^{0.1680\,X3}$	$e^{-0.0067\,X4}$	$e^{0.6508\,X5}$	0.905
P_{bk}	0.0446	$A^{0.4244}$	$H^{0.2712}$	$D^{1.2246}$	$N^{0.6314}$	$e^{-0.0658\,X1}$	$e^{-0.1520\,X2}$	$e^{-0.4354\,X3}$	$e^{0.0362\,X4}$	$e^{-0.0696\,X5}$	0.851

Table 3. The structure of three-step additive model built by proportional weighting (Dong et al., 2015). Symbols here and further see Figure 1 and equation (1)

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

Table 4. Three-step additive model of biomass component composition for *Quercus* forest stands, built by proportional weighing.

	$Pt = 1.3132\, A^{0.2782} H^{0.2576} D^{1.0297} N^{0.4448} e^{0.1913X1} e^{0.1274X2} e^{0.4569X3} e^{0.1768X4} e^{0.6994X5}$
Step 1	$Pa = \dfrac{1}{1+1.1083\, A^{0.4080} H^{-1.0937} D^{-0.0159} N^{0.1075} e^{-0.0548X1} e^{-0.0186X2} e^{0.8852X3} e^{0.3569X4} e^{-0.5778X5}} \times Pt$
	$Pr = \dfrac{1}{1+0.9023\, A^{-0.4080} H^{1.0937} D^{0.0159} N^{-0.1075} e^{0.0548X1} e^{0.0186X2} e^{-0.8852X3} e^{-0.3569X4} e^{0.5778X5}} \times Pt$
Step 2	$Pc = \dfrac{1}{1+0.5161\, A^{0.0744} H^{0.4267} D^{0.2012} N^{0.1906} e^{-0.5491X1} e^{0.0384X2} e^{0.6473X3} e^{0.1583X4} e^{-0.3692X5}} \times Pa$
	$Ps = \dfrac{1}{1+1.9377\, A^{-0.0744} H^{-0.4267} D^{-0.2012} N^{-0.1906} e^{0.5491X1} e^{-0.0384X2} e^{-0.6473X3} e^{-0.1583X4} e^{0.3692X5}} \times Pa$
Step 3*a*	$Pf = \dfrac{1}{1+1.1188\, A^{-0.0203} H^{0.5680} D^{0.1137} N^{-0.1704} e^{0.4780X1} e^{-0.1106X2} e^{-0.4056X3} e^{0.0355X4} e^{1.3189X5}} \times Pc$
	$Pb = \dfrac{1}{1+0.8938\, A^{0.0203} H^{-0.5680} D^{-0.1137} N^{0.1704} e^{-0.4780X1} e^{0.1106X2} e^{0.4056X3} e^{-0.0355X4} e^{-1.3189X5}} \times Pc$
Step 3*b*	$Pw = \dfrac{1}{1+0.5197\, A^{0.1749} H^{-0.7728} D^{0.1532} N^{-0.0136} e^{-0.2060X1} e^{-0.1991X2} e^{-0.6034X3} e^{0.0429X4} e^{-0.7204X5}} \times Ps$
	$Pbk = \dfrac{1}{1+1.9240\, A^{-0.1749} H^{0.7728} D^{-0.1532} N^{0.0136} e^{0.2060X1} e^{0.1991X2} e^{0.6034X3} e^{-0.0429X4} e^{0.7204X5}} \times Ps$

Table 5. The characteristics of "methodized" independent allometric equations for *Quercus* stands.

Biomass component	**Independent variables and the regression coefficients of the model**										***adjR²***
P_t	1.3132	$A^{0.2782}$	$H^{0.2576}$	$D^{1.0297}$	$N^{0.4448}$	$e^{0.1913X1}$	$e^{0.1274X2}$	$e^{0.4569X3}$	$e^{0.1768X4}$	$e^{0.6994X5}$	0.838
					Step 1						
P_a	0.6902	$A^{0.1988}$	$H^{0.5292}$	$D^{1.0256}$	$N^{0.4270}$	$e^{0.2022X1}$	$e^{0.0782X2}$	$e^{0.2566X3}$	$e^{0.0937X4}$	$e^{0.8562X5}$	0.886
P_r	0.7649	$A^{0.6067}$	$H^{-0.5645}$	$D^{1.0096}$	$N^{0.5345}$	$e^{0.1474X1}$	$e^{0.0596X2}$	$e^{1.1419X3}$	$e^{0.4506X4}$	$e^{0.2784X5}$	0.376
					Step 2						
P_c	0.6916	$A^{0.1242}$	$H^{0.1710}$	$D^{0.9070}$	$N^{0.2832}$	$e^{0.6328X1}$	$e^{0.0668X2}$	$e^{-0.2691X3}$	$e^{-0.0123X4}$	$e^{1.1285X5}$	0.627
P_s	0.3569	$A^{0.1986}$	$H^{0.5977}$	$D^{1.1082}$	$N^{0.4738}$	$e^{0.0837X1}$	$e^{0.1052X2}$	$e^{0.3782X3}$	$e^{0.1459X4}$	$e^{0.7593X5}$	0.900
					Step 3a						
P_f	0.3497	$A^{0.1277}$	$H^{-0.2342}$	$D^{0.8072}$	$N^{0.4222}$	$e^{0.1817X1}$	$e^{0.1405X2}$	$e^{0.0908X3}$	$e^{0.0037X4}$	$e^{0.0145X5}$	0.254
P_b	0.3912	$A^{0.1074}$	$H^{0.3338}$	$D^{0.9208}$	$N^{0.2518}$	$e^{0.6598X1}$	$e^{0.0300X2}$	$e^{-0.3148X3}$	$e^{0.0392X4}$	$e^{1.3335X5}$	0.658
					Step 3b						
P_w	0.0858	$A^{0.2494}$	$H^{1.0440}$	$D^{1.0714}$	$N^{0.6450}$	$e^{0.1402X1}$	$e^{0.0471X2}$	$e^{0.1680X3}$	$e^{-0.0067X4}$	$e^{0.6508X5}$	0.905
P_{bk}	0.0446	$A^{0.4244}$	$H^{0.2712}$	$D^{1.2246}$	$N^{0.6314}$	$e^{-0.0658X1}$	$e^{-0.1520X2}$	$e^{-0.4354X3}$	$e^{0.0362X4}$	$e^{-0.0696X5}$	0.851

Table 6. The comparison of adequacy indices of independent and additive equations for *Quercus* 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	0.746	0.798	0.571	0.292	0.570	0.249	0.803	0.856	0.643
Additive equations									
R^2	0.746	0.799	0.571	0.293	0.571	0.238	0.804	0.871	0.660

Table 7. Characteristics of auxiliary recursive equations for mass-forming indices

Mass-forming indices	**Independent variables and the regression coefficients of the model**									***adjR²***
H	-15.9489	8.6068 ln*A*	-	-	-1.9231 *X1*	0.4346 *X2*	-3.5626 *X3*	-5.3695 *X4*	-8.6083 *X5*	0.768
ln*D*	-1.0586	0.3531 ln*A*	0.9160 ln*H*	-	-0.0426 *X1*	-0.0567 *X2*	0.1867 *X3*	-0.1181 *X4*	-0.0180 *X5*	0.936
ln*N*	3.9068	-0.0184ln*A*	0.6613 ln*H*	-1.9590 ln*D*	0.0798 *X1*	-0.0923 *X2*	-0.2702 *X3*	0.4303 *X4*	0.4947 *X5*	0.913

Table 8. Fragment of additive transcontinental table of *Quercus* stand biomass for the age of 60 years, localized on the ecoregions of Eurasia

Eco-region	**Species of *Quercus***	***H*, m**	***D*, cm**	***N*, 1000/ha**	**Stand biomass, t/ha**								
					Pt	***Pa***	***Pc***	***Pf***	***Pb***	***Pr***	***Ps***	***Pw***	***Pbk***
WCE	*Q. robur* L.	19.3	22.5	0.774	193.7	164.1	30.3	3.5	26.8	29.7	133.8	113.9	19.9
WCE	*Q.* ***petraea*** (Matt.) Liebl.	17.4	19.6	1.027	224.4	185.1	40.3	4.4	35.9	39.2	144.8	125.9	18.9
ERn	*Q. robur* L	19.7	21.7	0.769	212.6	174.0	30.6	3.9	26.7	38.6	143.4	125.8	17.6
ERs	*Q. robur* L	15.7	22.5	0.517	242.4	141.8	27.5	3.3	24.2	100.6	114.2	102.7	11.6
SFE	*Q. mongolica* Fisch. ex Ledeb.	13.9	14.8	2.172	218.9	151.4	26.3	4.6	21.6	67.6	125.1	102.8	22.3
Jap	***Quercus mongolica*** subsp. ***crisp-ula*** (Blume) Menitsky *Q. glauca* Thunb.	10.7	12.9	2.570	320.9	246.4	60.3	6.5	53.8	74.5	186.1	165.9	20.1

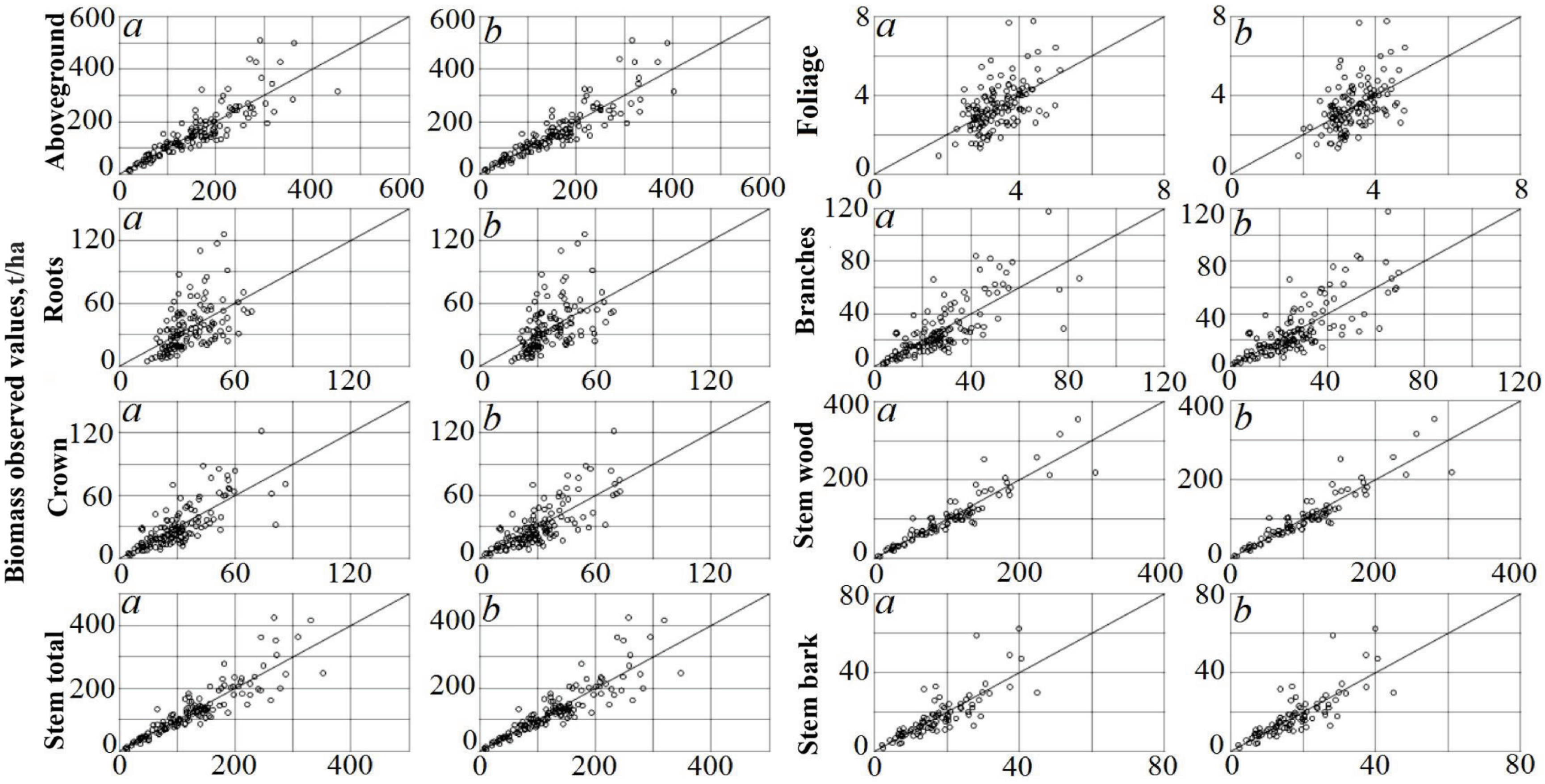

Figure 3. The ratio of observed values and the values derived by calculation of independent (a) and additive (b) models of *Quercus* stand biomass

The additive model built (Table 4) includes four numeric independent variables. When its 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 and are shown in the Table 7.

The results of sequential tabulations of the equations of the Tables 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 *Quercus* stands of different ecoregions we limit by the stand age of 60 years (Table 8). According to the Table 8, the greatest values of total biomass (321 t/ha) correspond to oak forests *Q. crispula* and *Q. glauca* in Japan, and the lowest (194 t/ha) – to stands of oak forests *Q. robur* in West Europe. The intermediate position in terms of total biomass (213-242 t/ha) is occupied by oak stands in other ecoregions.

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 (2.6-3.0%) at oak forests of Primorie and Japan, and minimum one (2.1%) in oak forests of Western and central Europe, and in other regions it is at a stable level of 2.2-2.4%.

4. Conclusions

When using the unique in terms of the volume of database on the level of a stand of the genus *Quercus*, the trans-Eurasian additive allometric model of biomass for oak 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 ecoregions of Eurasia. The proposed model and corresponding table for estimating stand biomass make them possible to calculate *Quercus* stand biomass on Eurasian forests when using measuring taxation.

Acknowledgments

We thank the anonymous referees for their useful suggestions. This paper is fulfilled according to the programs of current scientific research of the Ural Forest Engineering University and Botanical Garden of the Ural Branch of Russian Academy of Sciences.

References

Baskerville G.L., 1972, Use of logarithmic regression in the estimation of plant biomass. Canadian Journal of Forest Research 2: 49-53.

Bi H., Long Y., Turner J., Lei Y., Snowdon P., Li Y., Harper R., Zerihun A. & Ximenes F., 2010, Additive prediction of aboveground biomass for *Pinus radiata* (D. Don) plantations. Forest Ecology and Management 259: 2301-2314.

Budyko M.I., 1977, Global ecology. "Mysl" Publishing, Moscow, 328 pp.

De-Miguel S., Mehtätalo L. & Durkaya A., 2014, Developing generalized, calibratable, mixed-effects metamodels for large-scale biomass prediction. Canadian Journal of Forest Research 44: 648-656.

Dong L., Zhang L. & Li F., 2015, A three-step proportional weighting system of nonlinear biomass equations. Forest Science 61(1): 35-45.

Fu L.Y., Zeng W.S., Tang S.Z., Sharma R.P. & Li H.K., 2012, Using linear mixed model and dummy variable model approaches to construct compatible single-tree biomass equations at different scales – A case study for Masson pine in Southern China. Journal of Forest Science 58(3): 101-115.

Jacobs M.W. & Cunia T., 1980, Use of dummy variables to harmonize tree biomass tables. Canadian Journal of Forest Research 10(4): 483-490.

Tang S., Zhang H. & Xu H., 2000, Study on establish and estimate method of compatible biomass model. Scientia Silvae Sinica 36: 19-27 (in Chinese with English abstract).

Usoltsev V.A., 1989, Recurrent regression system as a base for tree and stand biomass tables, [in:] Proceedings of the IUFRO Project Group P3.05-00 Meeting "Harvesting and utilization of tree foliage", Riga, 217-245 pp. Available from: LVMI Silava: Rīgas iela 111, Salaspils LV-2169 Latvia.

Usoltsev V.A., 2010, Eurasian forest biomass and primary production data. Ural Branch of Russian Academy of Sciences, Yekaterinburg, 574 pp. http://elar.usfeu.ru/handle/123456789/2606

Usoltsev V.A., 2013, Forest biomass and primary production database for Eurasia. CD-version. The second edition, enlarged and re-harmonized. Ural State Forest Engineering University, Yekaterinburg. http://elar.usfeu.ru/handle/123456789/3059

World Flora Online. An Outline Flora of All Known Plants. http://www.worldfloraonline.org