COMPOSITION OF SPRUCE FORESTS OF THE ARKHANGELSK REGION

Report 2

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The material for this research paper consists of model trees cut on sample plots in mature stands [2] and measurements of trees on two sample plots subject to clear felling*. The research involved a total of 1611 trees in the most common forest types: wood sorrel spruce, bilberry spruce, and haircap-moss spruce forests.

Correlation between form quotient and tree height

The proven correlations between the bole form quotient and other taxation indicators (height, thickness, etc.) are of major practical importance. For example, the correlation between q_2 and the height and diameter is used for developing volume tables (V.K. Zakharov [4], D.I. Tovstoles [11]) and yield tables (V.I. Levin [5]).

Our findings indicate that the correlation between the heights and form quotients q_2 is characterised by a correlation coefficient of −0.281 ±0.008. This correlation coefficient is very small, but it still proves a correlation between these taxation indicators.

There is a certain pattern in the distribution of trees by form class. Fig. 1 shows the empirical curve adjusted to the Gauss–Laplace equation. The actual curve of the distribution of spruce boles by form quotient q_2 verges toward normal. This pattern remains the same for both an individual forest stand and large forest plots, because the series of distribution of trees based on q_2 on sample plots subject to clear felling and based on the data for a combination of model trees felled on different sample plots are identical. This information is also proven correct by the acclaimed statements by V.K. Zakharov [3], A.V. Tyurin [13] and other researchers.

We have not found any substantial influence of the forest type on the variation of the form quotient. In wood sorrel spruce forests, q_2 varies from 0.54 to 0.84, in bilberry spruce forests – from 0.51 to 0.87, and in haircap-moss spruce forests – from 0.54 to 0.87.

For the majority of the trees (80.2% of 1373 models), the form quotient varies from 0.63 to 0.75, for 6.8% of all the trees – from 0.51 to 0.60, and for 13% of the trees – from 0.78 to 0.87.

* In addition to the author, the following students of Arkhangelsk Forestry Engineering Institute participated in making the tree measurements on clear felling sample plots: N. Sokolov, P. Kaplunenko, L. Galasieva, N. Velyamidova and G. Kashina.

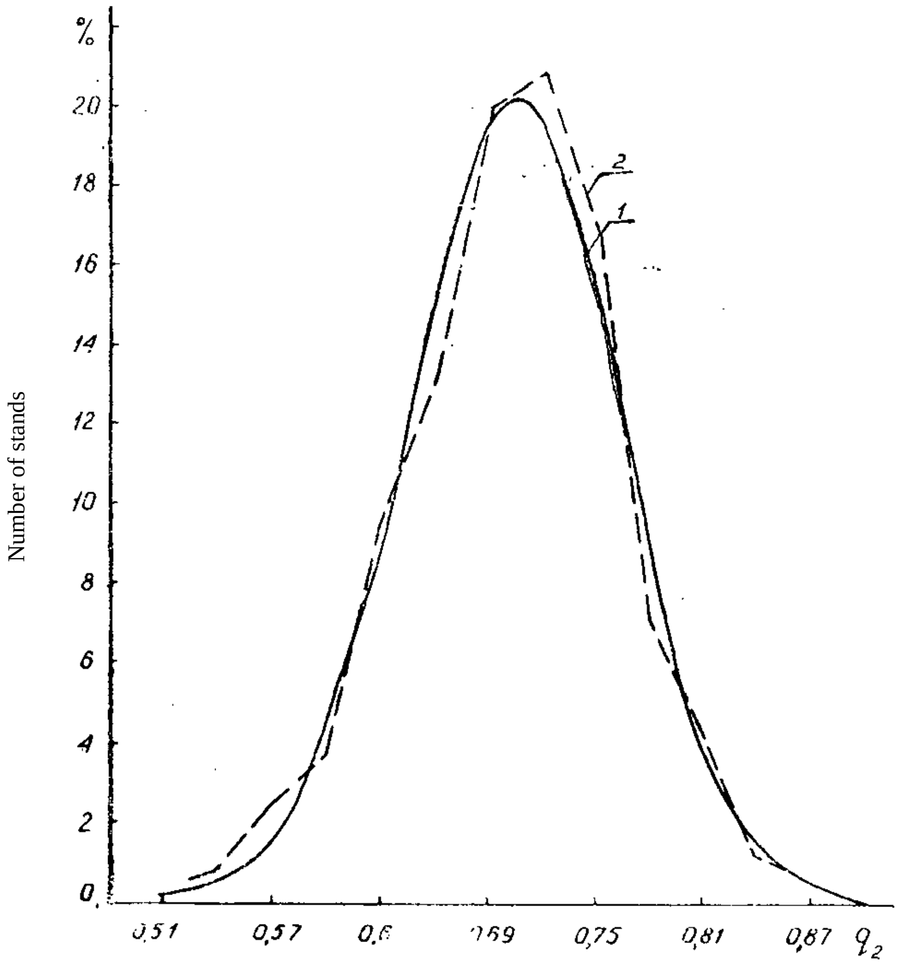

Fig. 1. Distribution of spruce boles by form quotient q_2.
1 – frequencies adjusted to Gauss–Laplace equation; 2 – average true frequencies.

Identification of the form quotient q_2 for each taxation plot is, therefore, impractical during taxation of forest stands based on the volume tables, because volume tables with a mean form quotient can be used just as well. The error P resulting from the variance of the mean form of a given plantation from the mean form of the wood species in general will equal $P = \frac{v}{\sqrt{N}}$, where v is the variation coefficient and N is the number of stands evaluated.

For the wood sorrel spruce, bilberry spruce and haircap-moss spruce forests, we calculated the mean form quotients with key statistical indicators (σ, v, m, p).

Within one certain forest type, the form quotients were identified based on height classes (see Table 1).

The specified unadjusted form quotients q_2 consistently decrease in all forest types as the height increases. The variation of the form quotients depending on height in all forest types under study demonstrates a pattern allowing us to express such variation in one general series, thereby giving us the following equation: $q_2H = aH + b$.

For spruce forests of the Arkhangelsk Region, V.I. Levin [6] derived the following specific equation: $q_2H = 0.647H + 0.898$. The form quotients found using this equation are little different from our calculated mean (general) q_2 values, testifying to the accuracy of the correlation.

Table 1

Height, m	Wood sorrel spruce forest		Bilberry spruce forest		Haircap-moss spruce forest		General mean q_2
	nmr of boles	mean q_2	nmr of boles	mean q_2	nmr of boles	mean q_2	
8	11	0.77	27	0.76	28	0.75	0.756
11	18	0.73	50	0.75	56	0.71	0.732
14	37	0.73	62	0.73	89	0.69	0.710
17	58	0.72	145	0.72	88	0.67	0.704
20	93	0.70	177	0.70	43	0.66	0.695
23	131	0.69	124	0.70	3	0.64	0.695
26	64	0.68	36	0.68	–	–	0.682
29	24	0.67	5	0.71	–	–	0.675
32	2	0.60	1	0.57	–	–	0.590
Total	438	0.70	628	0.712	307	0.687	0.704
σ		±0.050		±0.061		±0.063	±0.059
v (%)		7.1		8.6		9.2	8.4
m		±0.0024		±0.0024		±0.0036	±0.0005
p		0.34		0.34		0.52	0.07

Mean form quotients in wood sorrel and bilberry spruce forests are not the same; the variance significance factor is t = 3.5. Compared to these, the mean form quotient in haircap-moss spruce forests is slightly lower, with t = 5.8 and 3.0.

A decrease in q_2 as a result of deterioration in the habitat conditions was observed by K.B. Lositsky [9], A.P. Charkina [15] and R.G. Sinelschikov [10]. The mean form quotient for all types of spruce forest we examined equals 0.704±0.0005.

We must also note a relatively insignificant variation of the form quotient across the studied forest types (see Table 1). On average, the variation coefficient for spruce forests of the Arkhangelsk Region equals 8.4%.

Correlation between crown length and tree diameter

To identify the correlation between crown length and tree diameter, we developed correlation tables for individual forest types.

In all the studied forest types, the correlation coefficients demonstrate a strong correlation between crown length and tree diameter (see Table 2).

Table 2

Statistical indicators	Forest type		
	Wood sorrel spruce forest	Bilberry spruce forest	Haircap-moss spruce forest
Number of trees	438	628	307
Correlation coefficient *r* with error	0.762±0.020	0.680±0.022	0.716±0.028
Mean crown length *M*±*m*	1.00±0.18	10.8±0.16	9.3±0.17
Fundamental deviation	3.75	3.96	3.04
Variation coefficient *v*	34.1	36.5	32.6
Experiment accuracy factor *p*	1.64	1.48	1.84

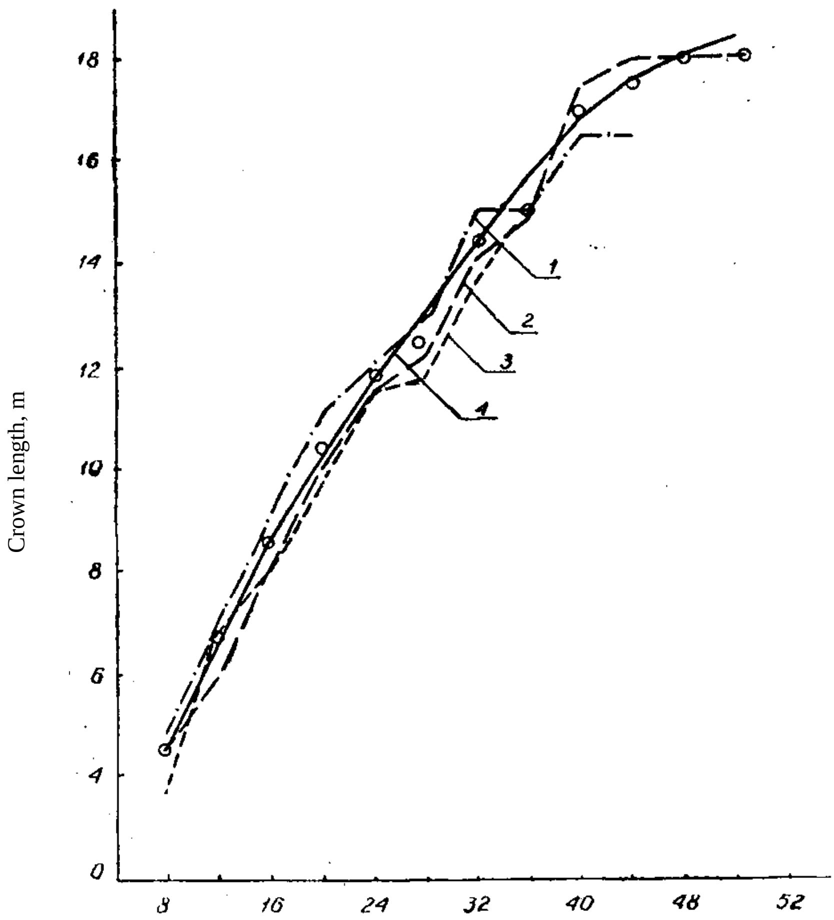

Fig. 2. Correlation between crown length and tree diameter.
1 – wood sorrel spruce forest; 2 – bilberry spruce forest;
3 – haircap-moss spruce forest; 4 – mean adjusted curve.

The crown length varies widely in all the forest types. The coefficients of variation of crown length in different forest types do not differ much, varying from 32.6% in haircap-moss spruce forests to 36.5% in bilberry spruce forests.

We found the mean crown length for each forest type depending on the diameter class. It appears that crown length does not depend much on forest type. It remains almost constant for the same tree diameter in different types of forest (see Fig. 2). For this reason, the correlation between crown length and tree diameter can be characterised using general figures after some graphical adjustment (see Table 3).

Table 3

Diameter classes	Crown length, m
8	4.5
12	6.7
16	8.6
20	10.2
24	11.8
28	13.0
32	14.4
36	15.7
40	16.6
44	17.5
48	18.1
52	18.4

Correlation between crown length and form quotient q_2

There is no general consensus regarding this matter. N.V. Tretyakov stated that there could be no strong correlation between crown length and bole form q_2 and that the bole form changes much faster than the crown [12]. V.I. Levin, who studied pine forests of the Arkhangelsk Region, made the same statement [7]. In contrast, A.V. Tyurin believes that “low form quotients are typical of a low-hanging, generally thick crown, and high form quotients – of a high-hanging, generally poor crown” [14].

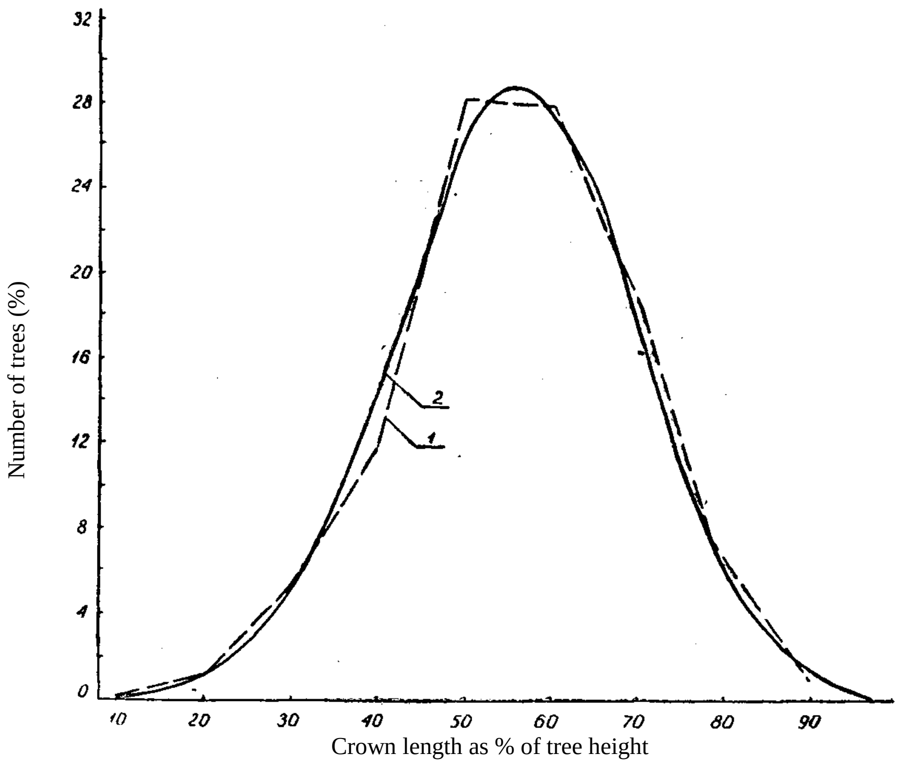

Fig. 3. Distribution of spruce trees by class of relative crown length.
1 – based on actual data; 2 – adjusted to Gauss–Laplace equation.

To identify the correlation between crown length and form quotient q_2, we expressed the crown length as a proportion of the tree height. Next, we found the mean series of form quotient q_2 by height class, depending on the relative crown length (see Table 4).

Table 4

Height, m	Crown length as a proportion of tree height							
	less than 1/4		1/4 to 1/2		1/2 to 3/4		more than 3/4	
	nmr of boles	q_2	nmr of boles	q_2	nmr of boles	q_2	nmr of boles	q_2
10	6	0.744	81	0.740	106	0.703	26	0.665
15	5	0.750	132	0.724	260	0.700	41	0.684
20	4	0.733	195	0.702	388	0.694	39	0.694
25	–	–	94	0.700	194	0.693	19	0.690
30	–	–	4	0.665	17	0.665	–	–
Mean	–	0.740		0.712		0.696		0.684

Table 4 demonstrates that some decrease of q_2 is observed as relative crown length increases in all height classes. The crown has a more obvious influence on the value of the form quotient in low height classes (10 and 15 m). In higher classes (20 and 25 m), the form quotients remain almost unchanged while the crown length varies. This is why, on average, they decrease very insignificantly with the increase in crown length. If we disregard the mean form quotient for the crown length of more than ¼ of the height due to an insufficient number of model trees (15 pieces), we see that the mean maximum and minimum values of the form quotient differ by 0.028. This insignificant decrease of q_2 for relative crown lengths of ¼ to ¾ is of no major practical value.

A pattern has been detected in the distribution of the number of trees by class of relative length of crown: the actual series of distribution of the number of trees by class of relative crown length verges toward the theoretical series found using the Gauss–Laplace formula (see Fig. 3). The mean value of relative crown length is 56.2±0.34, the fundamental deviation σ = 13.5 and the variation coefficient v = 24.0%.

Correlation between the form of trees and the normality

Many researchers believe that there is a correlation between tree form and normality (A.V. Tyurin [14], V.K. Zakharov [4], V.I. Levin [7], etc.).

While studying mature and over-seasoned spruce forests of the Arkhangelsk Region, we obtained the following results (see Table 5).

Table 5

Indicators	Number of growth plots	Height, m										
		10		15		20		25		30		mean
		nmr of boles	q_2	nmr of boles	q_2	nmr of boles	q_2	nmr of boles	q_2	nmr of boles	q_2	
Normality												
1.0	25	48	0.756	75	0.714	106	0.707	60	0.700	6	0.694	0.715
0.9	26	71	0.736	139	0.675	188	0.707	92	0.704	7	0.672	0.700
0.8	28	46	0.718	136	0.700	226	0.691	127	0.690	5	0.660	0.695
0.7	18	27	0.722	53	0.666	78	0.689	26	0.679	3	0.650	0.685
0.6–0.5	10	27	0.665	35	0.658	28	0.671	2	0.685	–	–	0.663
Decrease in q_2 with a normality variation of from 1.0 to 0.5–0.6			0.091		0.061		0.036		0.015			0.052

The decrease in normality from 1.0 to 0.5–0.6 in all height classes is followed by a decrease in the form quotients. The influence of normality on the bole form is more obvious in small-diameter trees and less obvious in large-diameter trees.

Correlation between crown width and tree thickness

Identification of a correlation between crown width and thickness of trees is important for deciphering aerial photographs of the forest, which is why many researchers have devoted themselves to studying this correlation (N.I. Baranov, G.G. Samoilovich, V.I. Levin and V.I. Kalinin, M.K. Bocharov, A.M. Berezin and I.A. Trunov, and others).

V.I. Levin [8] found a correlation between crown diameter D_k and the cross-section area of a tree at chest height g, expressed through the following straight-line equation:

$$Dk = ag + b$$

A.M. Berezin and A.I. Trunov [1] demonstrated that crown size depends chiefly on the normality and composition of the stand, specifically in spruce plantations. In different physical and geographical environments, a different crown width was observed on trees of identical diameter, which dictated the need for research in different regions of the Soviet Union [1].

To study the correlation between crown width and tree thickness, we measured the crown diameters and the diameters of tree boles at chest height (402 trees) in a high-density, age class VII spruce stand in a bilberry spruce forest with a mean height of 21 m and a mean diameter of 22 cm. These measurements were used to develop a correlation table to demonstrate the dependence of crown diameter on the cross-section area of the bole at chest height. The correlation coefficient was found to be 0.678±0.025; the mean crown diameter is 2.94±0.032 m; the fundamental deviation is 0.69, the variation coefficient is 23.5% and the error is 1.09%. Based on our findings, the correlation between the mean diameters of tree crowns and the cross-section area of spruce tree boles at chest height can be expressed by a straight line (see Fig. 4) corresponding to the equation $D_k = 18.449\ g + 2.274$ or $D_k = 14.482\ d^2_{1,3} + 2.274$. We used this equation to calculate the probable thickness of trees at chest height for different crown diameters (see Table 6).

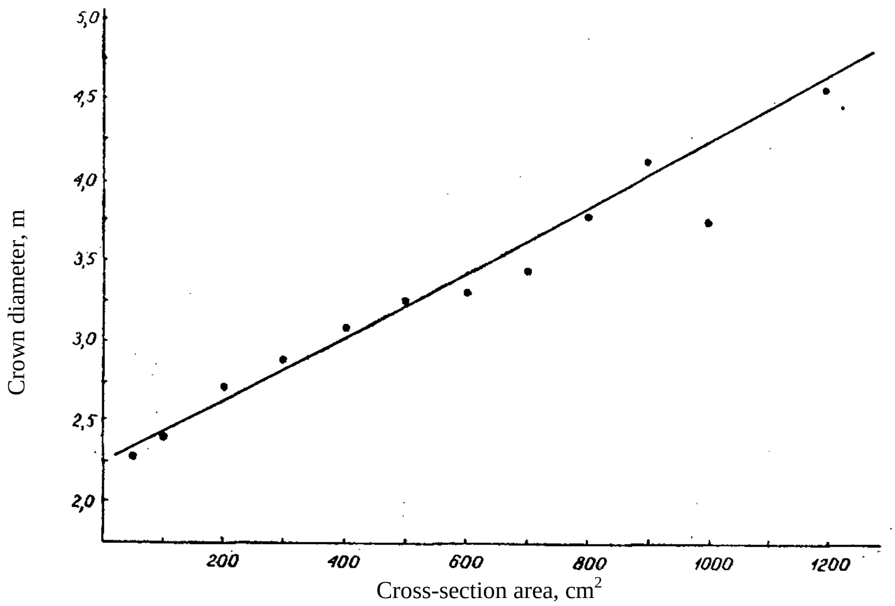

Fig. 4. Correlation between crown width and the cross-section area of trees at chest height (1.3 m).

Table 6

Crown diameter, m	Probable bole diameter at chest height, cm
2.50	12.3
2.75	18.1
3.00	22.4
3.25	26.0
3.50	29.1
3.75	31.9
4.00	34.6
4.25	37.0
4.50	39.2
4.75	41.4
5.00	43.4

The tree diameters found for different crown width values in high-density stands of bilberry spruce forest can be used for approximate calculations during instrument-aided deciphering of aerial photographs of forests.

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