Ecological Methods of Assessing the Quality of the Environment in the Fluctuating Asymmetry of Birch Leaves

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ABSTRACT

The methods of ecological assessment of the environmental quality of growing birch trees on fluctuating asymmetry of leaves after their stop in growth are briefly presented. In comparison with the average values of parameter measurements, each of the five leaves from at least three birches improves the accuracy of modeling and seven times reduces the complexity of measurements.

Key words: three birches, on five leaves, 10 parameters, factor analysis, correlation coefficient, strong regularities

1   Introduction

In environmental technology is gradually coming to an understanding of the need for modeling relationships between the parameters of structure of plant leaves identification method (Mazurkin, 2014a, b).

Our Russian inventions (Mazurkin, Semenova, 2016a, b, c, d, e, f) refers to the engineering of biology and bioindication of the environment quality measurements of the growth of the organs of different plant species, mostly woody plants, for example, samples in the form of leaves of birch trees with a simple and small leaf blades.

The technical result is an increase in the accuracy of indication of the quality of the surrounding birch leaves of the local environment, as well as simplifying and improving the performance of measurements of leaf parameters. Thus, we completely restore the principle of individuality of biological measurements on the geometry of fluctuation of each sheet.

2 The Method of Measurement and Analysis

Figure 1 shows a diagram of the dimensions of each sheet: 1 - the width of the left b' and right b'' halves of the leaf (the measurement was carried out in the middle of the leaf blade), mm; 2 - length $l'_{ж}$ and $l''_{ж}$ the second from the base of the leaf veins of the second order, mm; 3 – distance $l'_{осн}$ and $l''_{осн}$ between the bases of the first and second veins of second order, mm; 4 – distance $l'_{к}$ and $l''_{к}$ between the ends of these veins, mm; 5 – angle α' and α'' between the main vein and the second from the base of the leaf vein of the second order. Collection of material should be carried out after stopping the growth of leaves (in the middle lane since July).

For environmental assessment of anthropogenic impact on the territory take at least three birches in approximately the same conditions of growth, with each birch take at least five leaves of different sizes on the part of the estimated area, then the measurement of the five parameters of the sheet is carried out with the use of geodetic protractor with the price of dividing the measuring scale of 0.1 mm, with all at least 15 leaves are taken for the population of individual individuals, therefore, the table of measurement results without averaging the measured values is further compiled, and the resulting sample is statistically simulated and subjected to factor analysis to identify binary relations between 10 indicators, with all 100 biotechnical laws identified in the software environment CurveExpert-1.40 by the formula of the form

$$y = a_1 x^{a_2} \exp(-a_3 x^{a_4}) + a_5 x^{a_6} \exp(-a_7 x^{a_8})$$

(1)

where y - an indicator or a dependent quantitative factor (10 parameters for five indicators from two halves of the sheet); x - an explanatory variable or an influencing factor (the same 10 parameters from each sheet); $a_1...a_8$ - the model parameters obtained by identification.
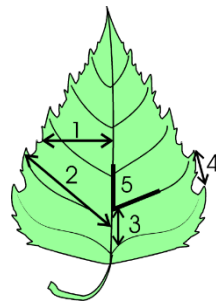

Figure 1

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According to the results of factor analysis by identifying binary relations between 10 indicators perform environmental assessment of the territory by the coefficient of correlation variation, and then from 100 biotechnical laws are selected having a correlation coefficient of at least 0,7 and consider pairwise five parameters of the sheet, as well as environmental assessment is carried out by differences between the structure and parameters of specific equations.

The results of the measurements in a clean area of the city of Zvenigovo Republic of Mari El

According to the principle of individuality of each leaf, the results of measuring the parameters of 15 leaves of only three birches in a clean area are listed in table 1.

Table 1. Results of measurements of birch leaves growing in the clean zone of the city

(on 5 of leaves with 3 plants)

№ trees	№ sheet	Width b , mm		Length, $l_{ж}$,mm		Distance $l_{осн}$,mm		Distance $l_{к}$,mm		Corner α , degree	
		left b'	right b''	left $l'_{ж}$	right $l''_{ж}$	left $l'_{осн}$	right $l''_{осн}$	left $l'_{к}$	right $l''_{к}$	left α'	right α''
1	1	18	17	32	30	8	8	10	10	30	28
	2	19	21	33	36	9	8	12	13	34	39
	3	22	19	36	32	6	8	14	14	37	33
	4	17	20	31	31	5	7	13	11	44	34
	5	16	17	29	31	12	11	12	16	30	31
2	6	16	17	28	29	5	6	10	10	34	37
	7	17	15	31	29	3	2	10	9	43	37
	8	18	18	33	32	5	5	11	9	37	36
	9	16	19	28	32	5	5	10	11	38	42
	10	23	21	37	40	5	6	12	13	38	37
3	11	18	19	31	33	5	4	13	12	49	49
	12	17	16	30	30	5	4	10	11	46	43
	13	23	21	40	40	4	3	15	15	48	42
	14	16	20	37	35	6	8	13	12	44	44
	15	23	22	37	40	6	7	14	15	46	44

Full factorial analysis includes 10 factors and 10² = 100 factor relations. For all of them the equation has the form of (1).

The correlation matrix of the factor analysis for assessment of a condition of the environment is given in table 2.

Table 2. Correlation matrix of the full factorial analysis of plastic signs of leaves of a birch for assessment of a condition of the environment

The influencing factors x	Dependent factors (indicators y)										Sum Σr_x	Place I_x
	b'	b''	$l'_{ж}$	$l''_{ж}$	$l'_{осн}$	$l''_{осн}$	$l'_{к}$	$l''_{к}$	α'	α''		
Width b' , mm	1	0,6530	0,8105	0,8210	0,1700	0,0905	0,6621	0,6639	0,2740	0,1222	5,2672	6
Width b'' , mm	0,7179	1	0,7139	0,9185	0,2413	0,4052	0,7404	0,5721	0,4132	0,3913	6,1138	2
Length $l'_{ж}$,mm	0,8058	0,6806	1	0,8340	0,2299	0,1746	0,7572	0,5652	0,4036	0,2785	5,7294	5
Length $l''_{ж}$,mm	0,8175	0,9144	0,8133	1	0,3181	0,3546	0,7190	0,6315	0,3420	0,4419	6,3523	1
Distance $l'_{осн}$,mm	0,2712	0,4867	0,3173	0,2346	1	0,8960	0,1701	0,4796	0,6639	0,4962	5,0156	8
Distance $l''_{осн}$,mm	0,2776	0,4977	0,0818	0,2226	0,9262	1	0,2068	0,5337	0,6369	0,5953	4,9786	9
Distance $l'_{к}$,mm	0,5290	0,7585	0,7693	0,6791	0,4647	0,3308	1	0,7367	0,5290	0,2888	6,0859	3
Distance $l''_{к}$,mm	0,5851	0,7079	0,4921	0,6560	0,5585	0,4618	0,7553	1	0,2643	0,4204	5,9014	4
Corner α' , degree	0,2573	0,3117	0,3686	0,3450	0,7079	0,6413	0,4834	0,1871	1	0,7796	5,0819	7
Corner α'' , degree	0,1405	0,3644	0,2091	0,4233	0,4177	0,5406	0,2787	0,1283	0,7796	1	4,2822	10
Sum Σr_y	5,4019	6,3749	5,5759	6,1341	5,0343	4,8954	5,773	5,4981	5,3065	4,8142	54,8083	-
Place I_y	6	1	4	2	8	9	3	5	7	10	-	0,5480

The coefficient of correlation variation of the ecological set of 15 leaves (5 leaves from 3 trees) is 54,8083 / 10^2 = 0,5480. This criterion is used when comparing different sampling sites of birch leaves. In comparison with table 2, variability in fluctuating asymmetry increased significantly, as 0.5480.

3 Analysis of Binary Relations between Factors

To do this, we exclude monarny relations from the data 1, we leave only binary relations with strong factorial relations (table. 3). There are 22 strong binary dependencies left. The formula $l''_{осн} \to l'_{осн}$ has the highest strength. The distance between the bases of the first and second veins on the right side of the leaves most affects the distance between the bases of the first and second veins on the left side of the leaves.

Table 3. Correlation matrix of strong binary relations of plastic signs of birch leaves under condition $r \geq 0,7$

The influencing factors x	Dependent factors (indicators y)									
	b'	b''	$l'_{жс}$	$l''_{жс}$	$l'_{осн}$	$l''_{осн}$	$l'_{к}$	$l''_{к}$	α'	α''
Width b', mm			0,8105	0,8210						
Width b'', mm	0,7179		0,7139	0,9185			0,7404			
Length $l'_{жс}$, mm	0,8058			0,8340						
Length $l''_{жс}$, mm	0,8175	0,9144	0,8133				0,7190			
Distance $l'_{осн}$, mm						0,8960				
Distance $l''_{осн}$, mm					0,9262					
Distance $l'_{к}$, mm		0,7585	0,7693					0,7367		
Distance $l''_{к}$, mm		0,7079					0,7553			
Corner α', degree					0,7079					0,7796
Corner α'', degree									0,7796	

For example, figure 2 shows a graph of the effect of $l''_{осн} \to l'_{осн}$ the distance between the bases of the first and second veins on the right side of the leaves by the distance between the bases of the first and second veins on the left side of the leaves when measured by the proposed method on 15 leaves in three birches.

Figure 3 shows a graph of the result $b'' \to l''_{жс}$ of the influence of the width on the right side of the leaves on the length of the second vein on the right side of the leaves.

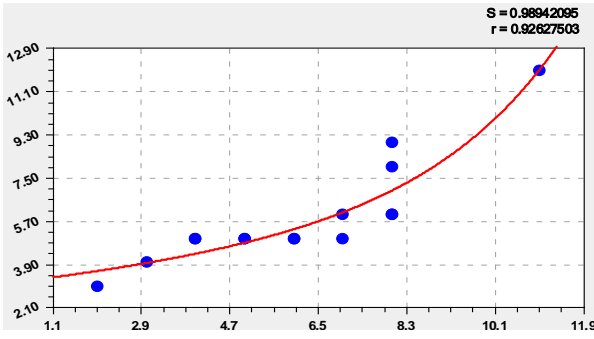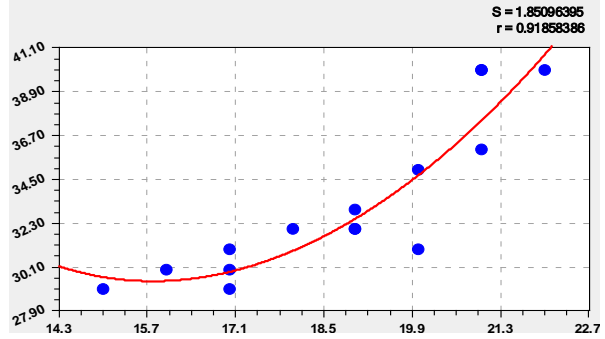**Figure 2. Graph of the formula** $l''_{och} \rightarrow l'_{och}$

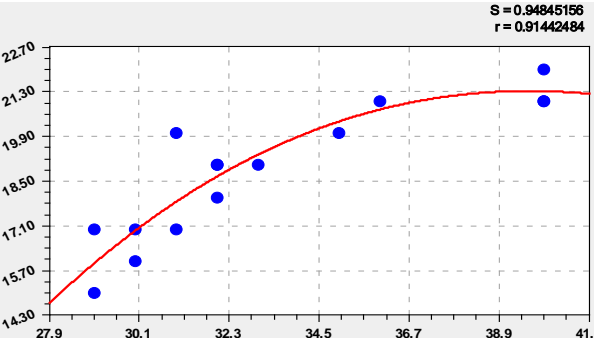**Figure 3. Graph of the formula** $b'' \rightarrow l''_{\text{ж}}$
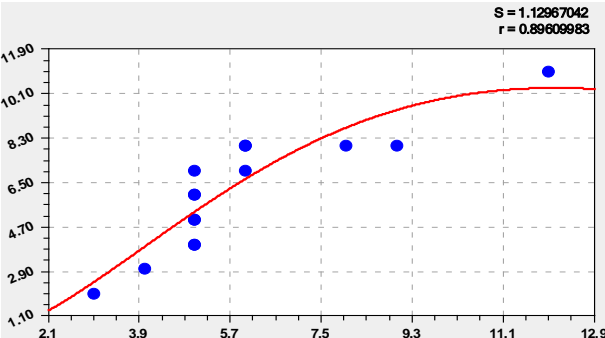
Figure 4. Graph of the formula $l''_{\text{ж}} \rightarrow b''$

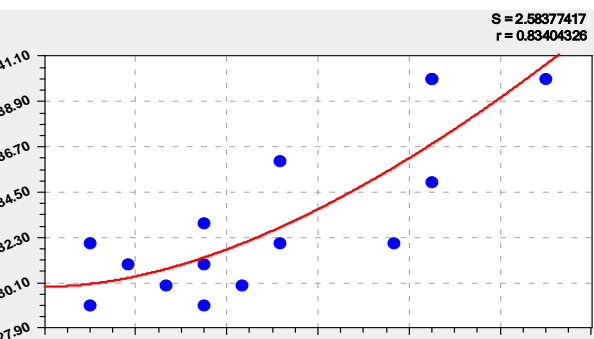**Figure 5. Graph of the formula** $l'_{och} \rightarrow l''_{och}$

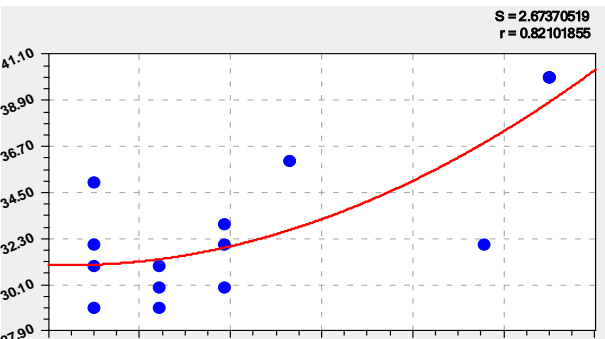**Figure 6. Graph of the formula** $l'_{\text{ж}} \rightarrow l''_{\text{ж}}$

Figure 7. Graph of the formula $b' \rightarrow l''_{\text{ж}}$

On figure 4 - graph of the result $l''_{\text{ж}} \rightarrow b''$ influence of the length of the second vein on the right side of the leaves on the width on the right side of the leaves. On a figure 5 shows the graph of the result $l'_{och} \rightarrow l''_{och}$ of the influence of the distance between the bases of the first and second veins on the left side of the leaves on the distance between the bases of the first and second veins on the right side of the leaves. On a figure 6 - graph of the result $l'_{\text{ж}} \rightarrow l''_{\text{ж}}$ influence of the length of the second vein on the left side of the leaves on the length of the second vein on the right side of the leaves. On a figure 7 shows the graph of $b' \rightarrow l''_{\text{ж}}$ effect of width on the left side of leaves on the length of the second vein on the right side of leaves

4 Comparison of the Proposed Methods with the Prototype

Thus, the comparison shows that the proposed information technology for processing the values of the same parameters in individual leaves 57 / 22 = 2,59 times stricter than the prototype.

The correlation coefficient is also 0,7538 / 0.5480 = 1,38 times less, which indicates better variability. Therefore, it can be concluded that the adoption of the arithmetic mean values of the parameters of birch leaves up to 100 (10 trees for 10 leaves) is artificial, smoothing the variability of fluctuating asymmetry. In reality, it is much more variable.

All 22 strong links in table 3 are arranged without the loss of a row and form a geometric pattern. This fact also points to the application of the principle of individuality, that is, without averaging the results of environmental measurements.

Write out the formula 22 binary factor strong ties, ranging in table 4 in descending order of correlation coefficient.

Table 4. Options patterns binary strong ties factors

№ п/п	$x \rightarrow y$	$y = a_1 x^{a_2} \exp(-a_3 x^{a_4}) + a_5 x^{a_6} \exp(-a_7 x^{a_8})$								Correlation coefficient r
		The first component				Second component				
		a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	
1	$l''_{осн} \rightarrow l'_{осн}$	3,071555	0	0,071176	1	0,037407	0,39827	0,36397	1	0,9262
2	$b'' \rightarrow l''_{ж}$	216,90035	0	0,18129	1	0,48931	0,82839	0,079967	1	0,9185
3	$l''_{ж} \rightarrow b''$	0,13005	2,26719	0,057208	1	35,24084	0	0	1	0,9144
4	$l'_{осн} \rightarrow l''_{осн}$	0,37763	2,21272	0,18243	1	0	0	0	1	0,8960
5	$l'_{ж} \rightarrow l''_{ж}$	285,55703	0	0,13188	1	0,61588	0,94539	0,016692	1	0,8340
6	$b' \rightarrow l''_{ж}$	83,922	0	0,10854	1	0,62999	0,88169	0,050474	1	0,8210
7	$l''_{ж} \rightarrow b'$	429,19236	0	0,15290	1	0,25493	0,89348	0,028748	1	0,8175
8	$l''_{ж} \rightarrow l'_{ж}$	9,96212	0	0,019433	1	0,74876	1,025059	0,00041489	1	0,8133
9	$b' \rightarrow l'_{ж}$	45,87364	0	0,081235	1	0,85588	0,92382	0,029908	1	0,8105
10	$l'_{ж} \rightarrow b'$	0,0097932	2,10278	0,0099842	1	7,62307	0	0	1	0,8058
11	$\alpha' \rightarrow \alpha''$	5,52381	0	0,0057460	1	2,68220	0,62964	0,0054722	1	0,7796
12	$\alpha'' \rightarrow \alpha'$	1,99219	0	0,039772	1	1,065425	1,035282	0,010853	1	0,7796
13	$l'_{к} \rightarrow l'_{ж}$	33,97637	0	0,041107	1	0,39111	0,61879	0,15405	1	0,7693
14	$l'_{к} \rightarrow b''$	0,098318	3,010187	0,19554	1	2,58419	0	0	1	0,7585
15	$l''_{к} \rightarrow l'_{к}$	0,017059	3036064	0,19256	1	4,97922	0	0	1	0,7553
16	$b'' \rightarrow l'_{к}$	110,10051	0	0,40834	1	0,60848	1,01504	0,00041684	1	0,7404
17	$l'_{к} \rightarrow l''_{к}$	4,27876	0,78319	0,023133	1	10,46382	0	0	1	0,7367
18	$l''_{ж} \rightarrow l'_{к}$	0,087963	2,27808	0,058024	1	25,015367	0	0	1	0,7190
19	$b'' \rightarrow b'$	125,22754	0	0,16146	1	0,13403	0,73296	0,12324	1	0,7179
20	$b'' \rightarrow l'_{ж}$	138,011555	0	0,16128	1	0,75209	0,91987	0,043949	1	0,7139
21	$l''_{к} \rightarrow b''$	0,14397	3,050669	0,22213	1	0	0	0	1	0,7079
22	$\alpha' \rightarrow l'_{осн}$	33,68506	0	0,044599	1	0	0	0	1	0,7079

Matrix representation of the model (1) is compact, but for clarity we will write the first three binary relationships separately in the form of formulas:

- effect of the distance between the bases of the first and second veins on the right side of the leaves on the distance between the bases of the first and second veins (Figure 2) on the left side of the leaves

$$l'_{och} = 3,071555 \exp(0,071176 l''_{och}) +$$

$$+ 0,037407 l''^{0,39827}_{och} \exp(0,39827 l''_{och}) \; ; \tag{2}$$

- effect of width on the right side of the leaves on the length of the second vein (Figure 3) on the right side of the leaves

$$l''_{жc} = 216,90035 \exp(0,18129 b'') + \quad + 0,48931 b''^{0,82839} \exp(0,079967 b'') \; ; \tag{3}$$

- the effect of the length of the second vein on the right side of the leaves on the width on the right (Figure. 4) side of the leaves

$$b'' = 0,13005 l''^{2,26719}_{жc} \exp(-0,057208 l''_{жc}) - 35,24084 \tag{4}$$

5 Conclusion

Thus, fluctuating asymmetry can be captured by statistical modelling from a much smaller volume of measurements. The smallest volume of measurements we recommend 15 (three trees of five different leaf sizes from different places). This will reduce the volume of measurements 100 / 15 ≈ 7 times. However, this increases the accuracy of the analysis of fluctuating asymmetry.

The advantage of the proposed method is the technical simplicity of execution, since the equipment requires only a measuring pair of compasses and surveying protractor with scale division 0,1 mm. Therefore, the invention can be widely implemented in school environmental clubs, school forestries, and even kindergartens, as well as in geographical and other expeditions with additional study of the quality of the territory on the properties of the leaves of the birch trees.

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