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Factor Analysis of the Parameters of Samples of the Steppe Soil and Grass Of Mongolia and Inland Mongolia of China on the Eastern Transsect of the Eurasian Steppe

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ABSTRACT

Regularities of rank distributions and binary relations between nine parameters are given. The most active are the geographical coordinates of 48 test sites. This proves that the geomorphology of the steppes in Mongolia and Inner Mongolia is becoming decisive. Factor analysis showed that the first four places for influencing variables and dependent indicators are the same: in the first place is the northern latitude, the second is the east longitude, the third is the average annual precipitation, and the fourth is the intensity of sheep grazing. The rest of the factors are located in different ways. The density of organic carbon was only in ninth place as an influencing variable, and in seventh place as a dependent indicator. This is based on the fact that organic carbon is an accumulative (cumulative) parameter over many years. The productivity of the biomass of steppe grass as an influencing variable is in sixth place, and as a dependent indicator (criterion) only in ninth place. This parameter is seasonal, therefore, in comparison with organic carbon, it is highly dynamic. The average annual temperature as an influencing variable is in fifth place, but as a dependent indicator only in eighth place. This was influenced by the strong averaging of the parameter (average value for the year). Plants are strongly influenced by the temperature dynamics during the growing season, and even more by the sum of temperatures during the growing season. With the productivity of steppe grass less than 75 g / m^2, the intensity of sheep grazing is zero. According to the second term of the trend, an optimum of 270 g / m^2 appears with the maximum intensity of sheep grazing on average 65 pcs / km^2. The first fluctuation shows that with an increase in grass biomass, there is a loss of stability of the grass cover with an exponential growth of the amplitude. The second oscillation is dangerous in that with an increase in the biomass of the grass, the half-period of the oscillation sharply decreases and this will also lead to the collapse of the steppe grass. From the remnants of the effect of sheep grazing on grass biomass, it can be seen that there are three clusters: (1) from 0 to 30; (2) from 30 to 95; (3) more than 95 pcs / km^2. In this case, the variability of the productivity of the grass decreases.

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1. Introduction

At the subregional level, in addition to temperature and precipitation, soil texture plays an important role in soil organic carbon storage. For example, the content of soil clay has a significant positive effect on the accumulation of organic carbon in the soil, and the accumulation of organic carbon in the soil increases with an increase in the pH of the soil. Carbon input is associated with plant productivity, while carbon output mainly depends on the decomposition of microbial organic matter. With an increase in the intensity of sheep grazing, a number of different effects were found [7].

The Mongolian Highlands steppe is located in the eastern part of the Eurasian steppe, which is the largest pasture in the world, stretching more than 8000 km from northeastern China, through Inner Mongolia, Mongolia, Russia and Ukraine, to Hungary. The Mongolian plateau is a region sensitive to climate change.

Purpose of the Study

According to [7] for the steppes of Mongolia and Inner Mongolia of China, to reveal the hierarchy among 48 test plots with rank distributions of nine bioclimatic parameters, after using the factor analysis method [1,5,6] to reveal the regularities of their paired comparisons, and then to reveal the hierarchy between these nine factors.

2. Materials and Methods

Table 1 shows a fragment of the initial data [7].

Table 1 shows the following conventions: $\beta:=\beta$-111, reduced east longitude, ^{0}; $\alpha:=\alpha$-42, normalized north latitude, ^{0}; P - average annual precipitation, mm; t - average annual temperature, ^{0}C; C - clay content in soil, %; pH - pH value (at less than 7 acidity); G - the intensity of grazing livestock (sheep), units / km^2; B - productivity of biomass of grass cover, g / m^2; S_o - density of organic carbon in soil at a depth of 0-30 cm, kg / m^2.

Oscillations (wavelet signals) are written by the wave formula [1,5,6] of the form

$$y_i = A_i \cos(\pi x / p_i - a_{8i}), A_i = a_{1i}x^{a_{2i}} \exp(-a_{3i}x^{a_{4i}}), p_i = a_{5i} + a_{6i}x^{a_{7i}} \tag{1}$$

Where y - is the indicator (dependent factor), i - is the number of the member of the model (1), m - is the number of members in the model (1), reaching 200 and more, x - is the explanatory variable (influencing factor), $a_1...a_8$ - are the parameters of the model (1), taking numerical values in in the course of structural and parametric identification in the CurveExpert-1.40 software environment (URL: http://www.curveexpert.net/), A_i - the wavelet amplitude (half) (axis y), p_i - oscillation half-period (axis x).

In the particular case when $a_{2i=1} = 0$ for the first oscillation, and $a_{5i=1,2} = \infty$ for both waves, model (1) is transformed into a two-term formula of the form

$$y = a \exp(-bx^c) + dx^e \exp(fx^g) \tag{2}$$

where y - is an indicator, x - is a variable, a-g - are parameters (2). The first term is a modified law of exponential death, and the second is a biotechnical law [5,6].

3. Object Hierarchy

When synthesizing hierarchies, we adhere to ***Barry Commoner's law*** "Everything is connected with everything" [4], that is, any factor in some quantitative measure (correlation) affects the change in the values of other quantitatively expressed factors.

Hierarchy is a kind of abstraction of the structure of the system, designed to study the functional interactions of its components and their effects on the system as a whole [3, p.12]. The method of analyzing hierarchies is widespread in the world.

In our case, the system (48 sample plots of soil and grass of the steppe) is known, and nine quantitative parameters have been determined for it. Next, the problem arises of synthesizing the hierarchy in the system as of a certain moment in time.

For a known system, the synthesis of the hierarchy is possible in two ways:

(1) first, the ordering of the values of the parameters by the pre-order vector of preference "better $\rightarrow$ worse" by ranks $R = 0,1,2,...$, then the sum of the ranks of the entire

Table 1. Parameters of soil and grass in Mongolia and Inner Mongolia [7]

№	$\beta, ^0$	$\alpha, ^0$	P, мм	$t, ^0$C	C, %	pH	G, шт./км^2	B, г/м^2	S_o, кг/м^2
1	4.94	0	382	2.0	9	7.69	58.30	194.62	55.61
2	5.33	0.05	384	1.7	11	7.53	126.13	361.48	30.22
3	5.74	0.18	404	2.0	49	7.57	127.28	293.24	22.28
…	…	…	…	…	…	…	…	…	…
46	3.19	5.65	153	0.5	64	7.06	4.65	325.42	70.98
47	1.74	5.87	224	0.8	55	6.31	9.25	321.11	51.73
48	2.46	6.08	172	1.1	55	6.35	8.99	138.07	57.29

list of system parameters; this is how a rating is formed, and the best will be the element with the lowest sum of ranks;

(2) by the method of analysis of hierarchies by T. Saaty [3], a pairwise comparison of all parameters of the system is performed, the identification method reveals the patterns of binary relations, then the correlation coefficients are summed up by rows and columns, then the ratings of the parameters as influencing variables and dependent indicators are identified.

Next, we will consider the first method, which is possible without the use of mathematics. Then we will reveal the regularities of rank distributions. According to the second method, the correlation coefficients of rank distributions are located in the correlation matrix along diagonal cells, which show the quality factor of the system under study for each parameter.

4. Environmental Ranking of Parameters

Each biological object strives for the best in life, therefore, only two variants of vector orientations in behavior are possible [1]: (1) less is better (but better); (2) more is better (and this is a blessing).

Table 2 shows the vector ecological reference points of the parameters from Table 1. Then, after establishing one direction of all the factors taken into account, it will be possible to add the ranks of all parameters.

Table 2. Directionality of parameters (Table 1)

Factor name	Less is better	Bigger is better
Eastern longitude	+	-
Northern latitude	+	-
Average annual precipitation	-	+
Average annual temperature	-	+
Clay, soil content	+	-
Hydrogen exponent pH	+	-
Sheep grazing intensity	+	-
Grass productivity	-	+
Density of organic carbon	-	+

The farther west and south the coordinates of the test site, the better because of the improved climate. And the more precipitation and temperature, the better the growing conditions for steppe grass.

When ranking in the function=RANK (E3;E$3:E$51;0), the following conventions are adopted for the Excel software environment: E - identifier of the ranked column; E3, E$3 - first line; E$51 - last line; $0 \vee 1$ - ranking in descending (0) or ascending (1) values of the ranged parameter.

Table 3 shows the ranking results. By the smallest sum of ranks, the first place was taken by trial site No. 1.

Table 3. Distribution of site parameters for soil and grass samples by ranks

№	R_β	R_α	R_P	R_t	R_C	R_{pH}	R_G	R_B	R_S	$\sum R$	$I_{\sum R}$
1	33	0	2	2	1	25	30	29	14	136	**1**
2	42	1	1	5	8	18	46	2	40	163	6
3	46	2	0	2	37	20	47	10	47	211	23
...	...	...	...	...	...	...	...	...	...	...	...
46	13	45	47	35	44	8	3	6	4	205	18
47	4	46	34	31	41	3	10	7	19	195	10
48	9	47	45	24	41	4	9	39	13	231	41

5. Rank Distribution Patterns

In Table 4 they are arranged (Figure 1) in descending order of the correlation coefficient. It is above the level of

Table 4. Model parameters (2) of rank distributions of soil and grass factors

Vari-able x	Indi-cator y	Trend							Coef. correl. r
		Exponential law			Biotechnical law				
		a	b	c	d	e	f	g	
R_S	S_O	78.7531e8	0.021593	1.02765	-7.11026e-21	12.37493	0	0	0.9982
R_β	β	0.96930	-0.029401	1.04792	0.13092	1.00517	5.76472e-5	2.74255	0.9979
R_α	α	0	0	0	0.073290	1.28536	0.076566	0.51008	0.9978
R_B	B	386.41938	0.0022480	1	-15.00781	0.72468	0	0	0.9964
R_{pH}	pH	5.97998	-6.28704e-5	2.17951	0.11128	1.53014	0.18525	0.81105	0.9963
R_t	t	2.12918	0.041140	0.88802	-2.54973e-12	7.06557	0	0	0.9951
R_G	G	4.74685	-0.0017373	1.95353	2.14050e-6	7.28157	0.32679	0.94126	0.9951
R_C	C	5.52602	-0.33172	0.52594	-1.15934e-75	67.41401	0.22852	1.61426	0.9944
R_P	P	406.47120	0.00030870	1	-15.32082	0.70063	0	0	0.9882
$I_{\sum R}$	$\sum R$	136.32243	-0.012847	1	1.61732	1.67501	0.043098	1.28411	0.9934

adequacy 0.95 "super strong connection".

Density of organic carbon

Eastern longitude

Northern latitude

Grass productivity

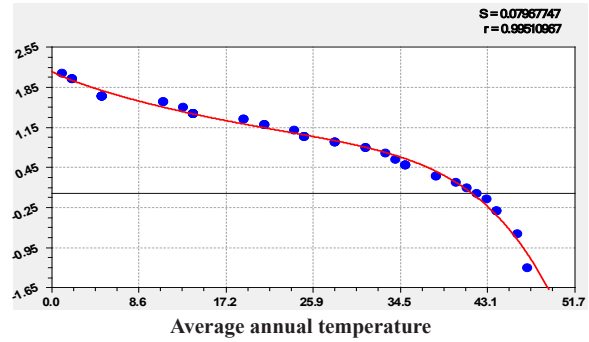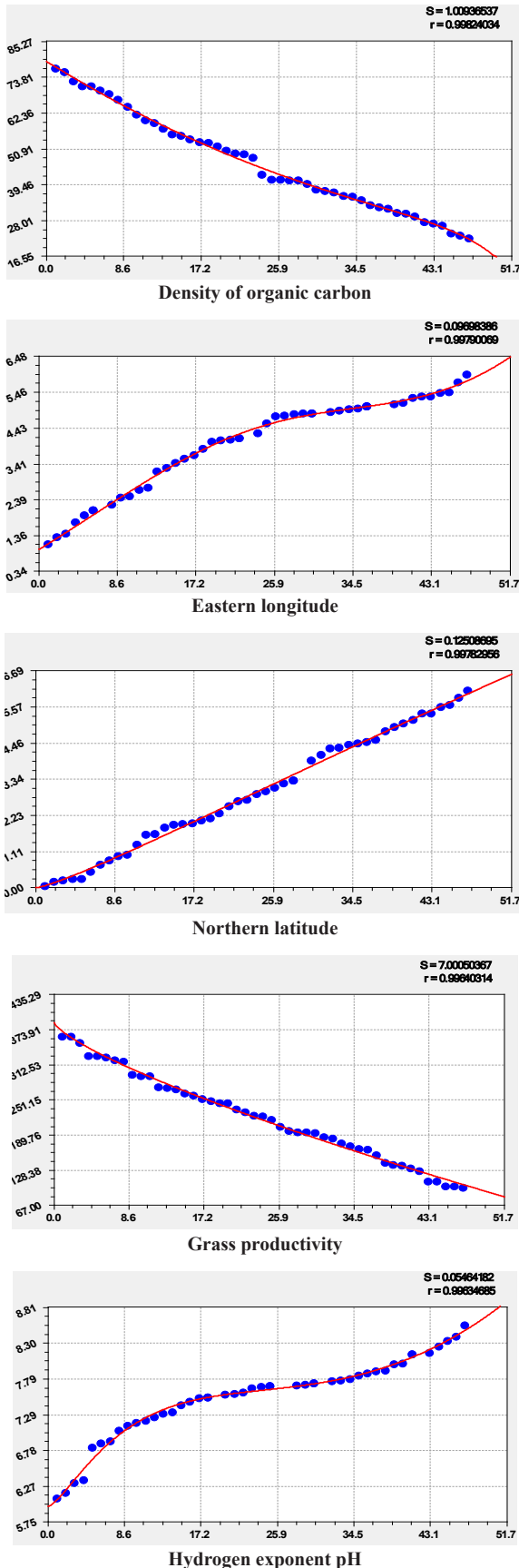Hydrogen exponent pH

Average annual temperature

Figure 1. Graphs of rank distributions of parameters of soil and grass samples

Note: In the upper right corner: S - standard deviation; r - correlation coefficient)

All rank distributions have additional asymmetric wavelets (1). This fact shows the difference between bioclimatic parameters (areas for three points of soil and grass of the steppe) from meteorological parameters [5,6], between which there is a high uncertainty of quantization for asymmetric wavelet signals.

As an example, we will show two fluctuations (1) of northern latitude by ranks (Figure 2).

First asymmetric wavelet

Second asymmetric wavelet
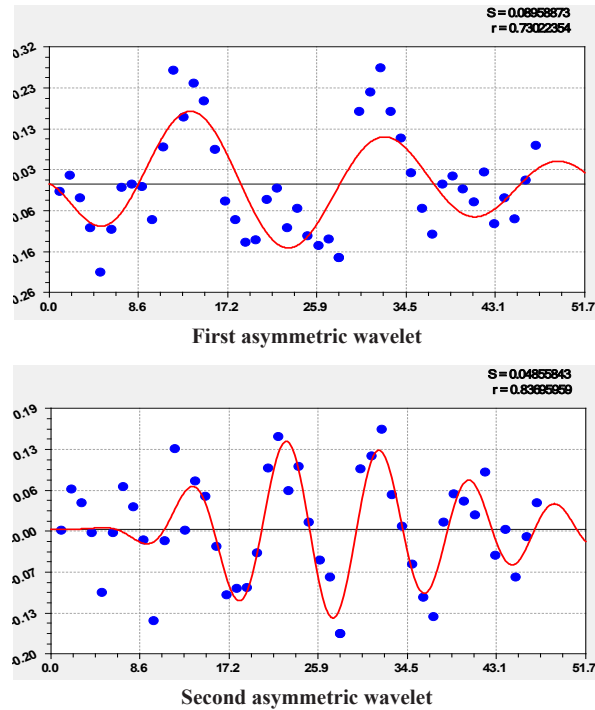
Figure 2. Graphs of oscillatory adaptation of the latitude of the test sites

Then it turns out that the steppe grass for almost 450 million years of its evolution "learned" to oscillate adapt to the terrain and the changing climate, spreading over the land according to wave laws. In the forest-meadow phyto-

cenosis, the grass is much stronger in comparison with the productivity of trees [2]. Therefore, steppe grass even indirectly affects the change in the geographical parameters of its place of growth.

6. Hierarchy of Factors by Correlation Matrix

Table 5 shows the results of a full factorial analysis of nine adopted parameters for a system of 48 sample plots of soil and grass samples from Mongolia and Inner Mongolia of China.

The first four places for influencing variables and dependent indicators are the same. In the first place is the northern latitude, the second is the eastern longitude, the third is the average annual precipitation, and the fourth is the intensity of sheep grazing. The rest of the factors are located in different ways. For example, the average annual temperature as an influencing variable is in fifth place, and as a dependent indicator in eighth place.

The geodetic coordinates of the test plots are the most significant. Then the disadvantage of the experiments carried out is the lack of measurements of the height above the level of the Baltic Sea. In Mongolia, even a small difference in height above the sea can be decisive.

The coefficient of correlative variation of the properties of a physical object of research in the form of 48 test sites and 9 factors is equal to the ratio of the total sum of the correlation coefficients to the square of the number of factors. According to Table 5, the coefficient of correlative variation will be $43.6648 / 9^2 = 0.5391$. It evaluates the functional connectivity of the system elements. This criterion allows you to compare dissimilar systems with each other.

7. Strong Factor Relationships

From table 5, we exclude diagonal cells and those cells in which the correlation coefficient is less than 0.7 (the level of adequacy "strong connection").

Table 6. Strong relationships $r \geq 0.7$

x	Indicators			
	β	α	P	G
β		0.8829	0.8891	0.8040
α	0.8992		0.9382	0.8347
P	0.7661	0.9109		0.7997
t		0.7348		
C	0.7260			
pH		0.7919		
G	0.8542	0.8958	0.8656	

Among the strong binary relations, four indicators and seven influencing variables remained (parameters, and were added to the main variables pH, t and C). A total of 15 strong pairs formed.

Table 7 shows the parameters of strong trends (Figure 3), containing two terms, and which are arranged in descending order of the values of the correlation coefficient.

In the future, they should be compared with each other weak (the level of adequacy from 0.3 to 0.5 according to the correlation coefficient), medium (from 0.5 to 0.7) and strong (more than 0.7) factorial relationship. Moreover, the analysis of weak ties can lead to the emergence of productive ideas and scientific and technical solutions.

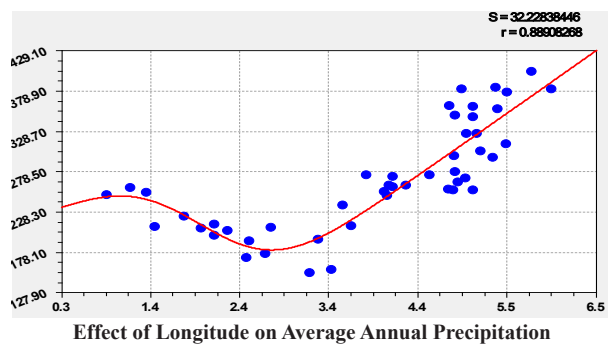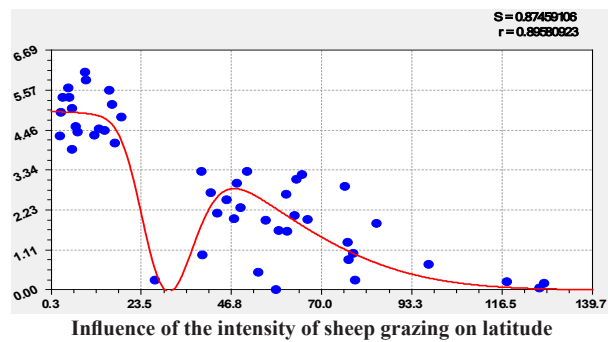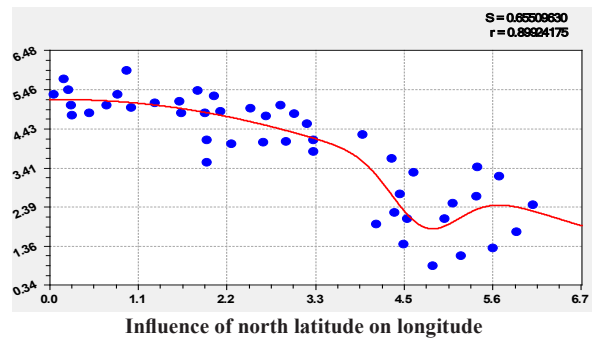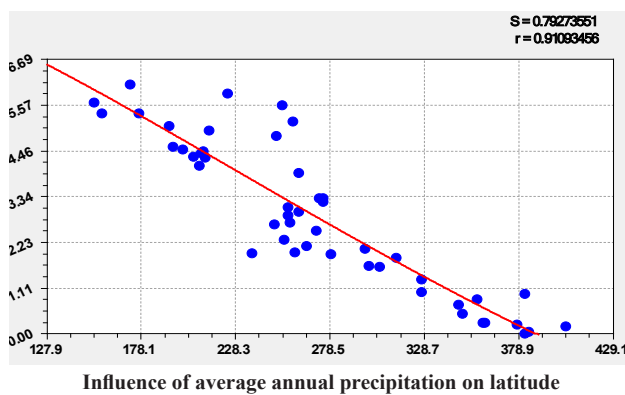**Table 5.** Correlation matrix by trends (2) and rating assessment of factors

x	Dependent factors (indicators)									Amount Σr	A place
	β	α	P	t	C	pH	G	B	S_o		
β	0.9979	0.8829	0.8891	0.6702	0.6724	0.6324	0.8040	0.4041	0.4736	5.7942	2
α	0.8992	0.9978	0.9382	0.6603	0.6670	0.6637	0.8347	0.4743	0.6447	6.1162	**1**
P	0.7661	0.9109	0.9882	0.5122	0.6161	0.5266	0.7997	0.3666	0.4056	5.3654	3
t	0.6046	0.7348	0.6983	0.9951	0.3850	0.3198	0.5591	0.1943	0.5942	4.7654	5
C	0.7260	0.5148	0.4298	0.2769	0.9944	0.6236	0.3680	0.2323	0.2402	3.7824	8
pH	0.6984	0.7919	0.4924	0.3482	0.4161	0.9963	0.6446	0.3507	0.4930	4.2353	7
G	0.8542	0.8958	0.8656	0.4672	0.6399	0.5379	0.4951	0.4244	0.5733	5.2155	4
B	0.6537	0.5731	0.5228	0.3300	0.4315	0.3825	0.5842	0.9964	0.5369	4.6286	6
S	0.4458	0.4924	0.3903	0.5437	0.1710	0.4202	0.5069	0.2135	0.9982	3.7618	9
Σr	6.6459	6.7944	6.2147	4.8038	4.9934	5.1030	5.5963	3.6566	4.9597	43.6648	-
	2	**1**	3	8	6	5	4	9	7	-	0.5391

Table 7. Parameters of the model (2) of strong binary relations

Vari-able x	Indi-cators y	Trend							Coef. correl. r
		Exponential law			Biotechnical law				
		a	b	c	d	e	f	g	
α	P	385.27012	0.11416	1.04779	-0.68619	7.18676	0.082281	3.86027	0.9382
P	α	8.75718	4.51102e-5	1.69628	-0.0035065	1.12627	0	0	0.9109
α	β	5.20774	0.015651	2.19343	-1.48679e-31	76.70776	3.92152	1.61019	0.8992
G	α	4.97550	4.59469e-5	2.39778	-3.17873e-16	13.45200	0.042402	1.56237	0.8958
β	P	227.43422	0.081611	3.17747	521.80321	1.94134	2.59545	0.20711	0.8891
β	α	4.62951	-0.084064	1.72524	-0.12172	3.04712	0	0	0.8829
G	P	179.82970	-0.030662	0.66942	2.83370e-11	9.95352	0.0025368	2.20668	0.8656
G	β	5.41800	0.15922	1	2.21819e7	5.28734	21.38249	0.13380	0.8542
α	G	90.62763	0.044913	2.38597	0	0	0	0	0.8347
β	G	2.19517	-6.48788	0.77000	-1423.2456	0.52794	0	0	0.8040
P	G	-22.20055	7.85812e-5	1.44296	2.57436e-8	4.29437	0.0091525	0.91535	0.7997
pH	α	0.58173	-1.49638	0.21969	-1.1458e-122	266.9847	34.29715	0.99741	0.7919
P	β	2.38333	0	0	2.87128e-41	19.34954	0.047959	1.01997	0.7661
t^1	α	2.21930	-0.0079905	3.02811	-1.07756e-6	8.95285	0	0	0.7348
C	β	4.71908	4.67296e-5	2.20971	-6.5156e-132	113.8644	2.91223	1.00095	0.7260

Note: $^1 t := t + 5$.

There are 67 such trends in total in Table 5. The number of medium and strong connections is 43. Above the level of the correlation coefficient of 0.8 there are 10 patterns in the form of two-term trends, and above 0.9 - only two formulas.
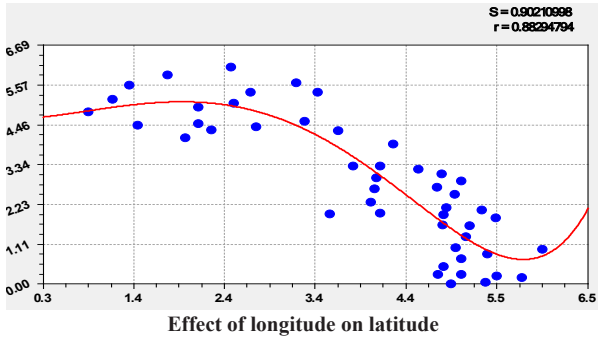

Influence of northern latitude on precipitation

Influence of average annual precipitation on latitude

Influence of north latitude on longitude

Influence of the intensity of sheep grazing on latitude

Effect of Longitude on Average Annual Precipitation
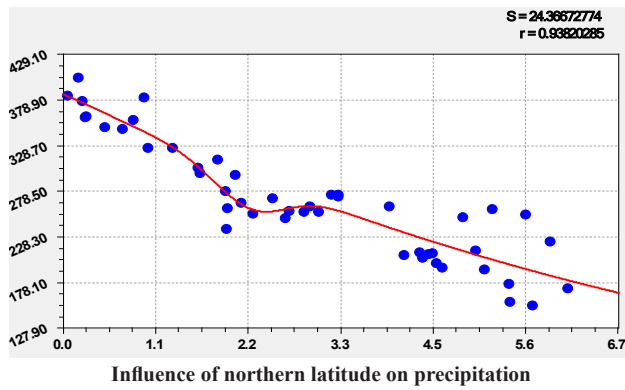
Figure 3. Graphs of strong binary relations

8. The Behavior of the System under Study

Each system under study has its own character that is different from others. It can be identified (Table 8) by increasing the admissible level of the correlation coefficient, in our example from 0 to 0.9382.

Table 8. Correlation coefficient

$[r]$	Number of formulas N	Number of lines N_-	Number of columns $N_|$
0	72	9	9
0.1	72	9	9
0.2	72	9	9
0.3	67	9	9
0.4	57	9	9
0.5	43	9	8
0.6	30	8	8
0.7	15	7	4
0.8	10	4	4
0.9	2	2	2
0.9382	1	1	1

As the correlation coefficient increases, the number of elements in the correlation matrix decreases.

Were identified (Figure 4):

- number of formulas ($r = 0.9992$)

$$N = 72.28562\exp(-4.66149[r]^{3.20637}) ; \qquad (3)$$

- number of lines ($r = 0.9983$)

$$N_- = 9.04746\exp(-3.33716[r]^{6.78032}) ; \qquad (4)$$

- number of columns ($r = 0.9826$)
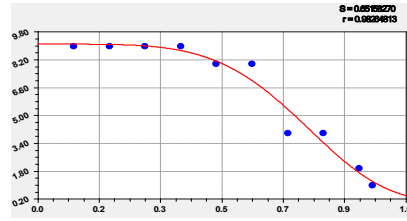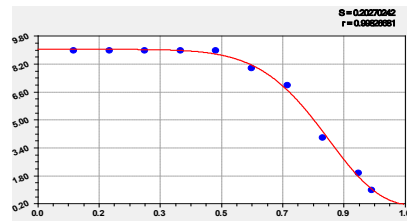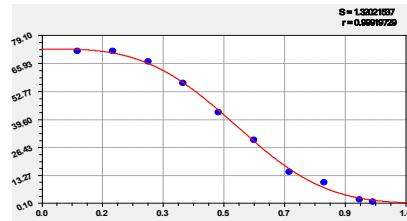
$$N_| = 9.10864\exp(-2.69066[r]^{4.56332}) . \qquad (5)$$

Number of formulas

Number of lines

Number of columns

Figure 4. Graphs of the influence of the level of the correlation coefficient on the elements of the matrix

Table 9. Parameters (1) of the effect of grass productivity on the intensity of sheep grazing

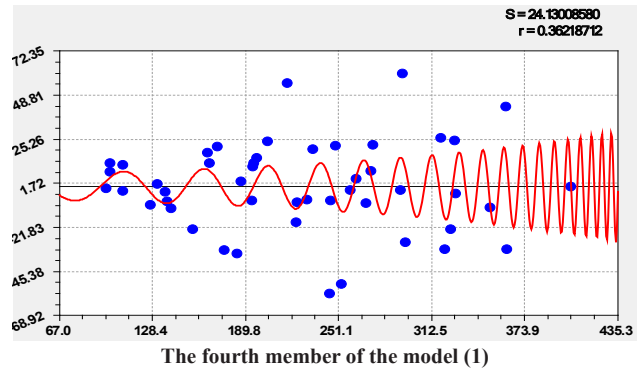| i	Asymmetric wavelet $y_i = a_{1i}x^{a_{2i}}\exp(-a_{3i}x^{a_{4i}})\cos(\pi x(a_{5i} + a_{6i}x^{a_{7i}}) - a_{8i})$								Coef. correl. r
	Amplitude (half) oscillation				Half-cycle			Shift	
	a_{1i}	a_{2i}	a_{3i}	a_{4i}	a_{5i}	a_{6i}	a_{7i}	a_{8i}	
1	-2.01689e-5	0	-0.036456	1	0	0	0	0	
2	4.42987e-14	7.61296	0.024339	1.02741	0	0	0	0	0.7056
3	1.30194	0	-0.00073656	1.44782	15.42255	0.016374	0.98593	0.98593	
4	-6.53119	0	-0.00031845	1.39411	46.59723	-0.10305	0.96038	-0.23871	0.3622
...	...	...	...	...	...	...	...	...	...
40	5.34235e-39	18.76901	0.051556	1.03614	1.61095	0	0	4.06617	0.4142

The quality factor of the initial data in Table 1 is very high.

9. Wavelet Analysis of Bioclimatic Pairs

Many binary relations, in addition to two-term trends, receive additional oscillatory disturbances. For example, several wavelets have pairs α-α (rank distribution), β-α (vibrational geomorphology), P-β (climatic geomorphology), pH-P (soil science). The number of asymmetric wavelets is even greater in pairs P-α (climatic geomorphology) and P-G (sheep breeding).

And, finally, 40 wavelets (Table 9, Figure 5) were found in the pair B-G(grass - sheep).

Taking into account other factors, it is possible to distinguish individual groups in different scientific areas of steppe studies (geography, geomorphology, climatology, sheep breeding, etc.).
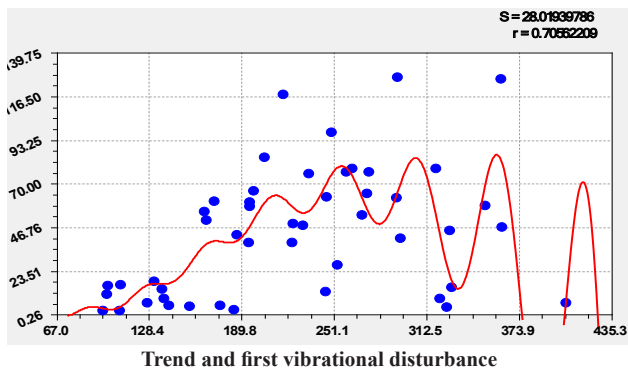

A trend with two components

First hesitation

Trend and first vibrational disturbance

The fourth member of the model (1)

39th asymmetric finite-dimensional wavelet

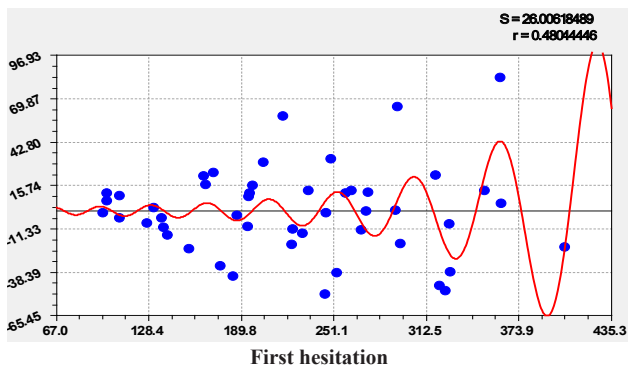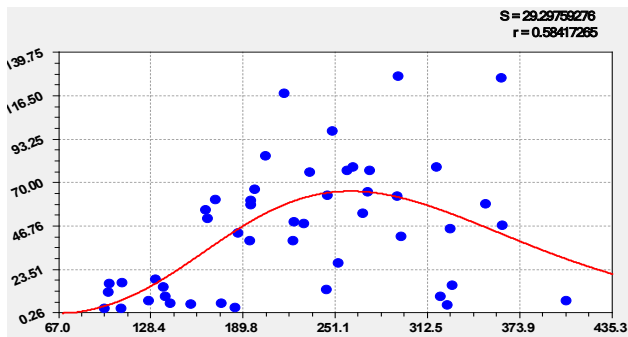Distribution of error after the 40th term
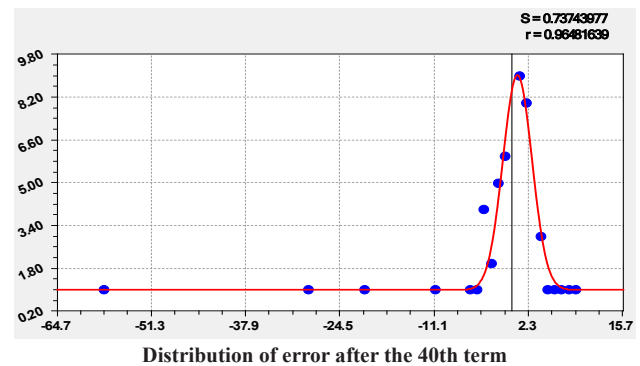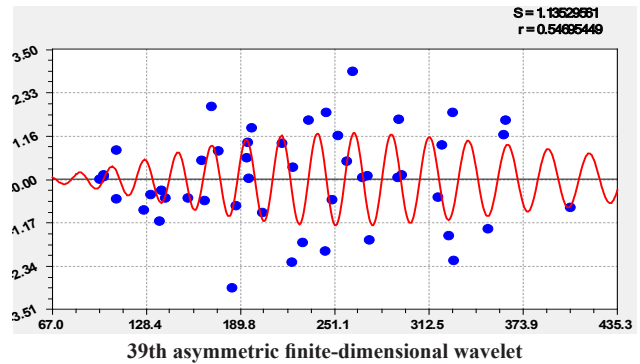
Figure 5. Graphs of the effect of grass productivity on the intensity of sheep grazing

The first term in the trend with a negative sign shows that when the productivity of steppe grass is less than 75 g/m^2, the intensity of sheep grazing is zero. Then, for the second member, an optimum of 270 g/m^2 occurs, at which a maximum of 65 sheep grazing intensity is possible on average, 65 pcs/km^2. The first fluctuation shows that with an increase in grass biomass, there is a loss of stability of the grass cover with a sharp exponential growth of the amplitude. The second fluctuation is dangerous in that with an increase in the productivity of the grass biomass, the half-period of the fluctuation sharply decreases and this will also lead to the collapse of the steppe grass cover.

After the 40th term, the distribution of the amount n of relative error Δ (Figure 5) changes according to the

Gauss law (the so-called normal distribution law)

$$n = 1 + 8.02576 \exp(-0.11715(\varDelta - 0.66006)^2) . \qquad (6)$$

Environmental and technological experiences are valid when $[\varDelta] = \pm 30\%$. This condition is not satisfied only by one test site No. 44 with a maximum relative error of -57.36%. Then the representativeness of all experiments is 100 (48-1) / 48 = 97.9%.

Of interest is also the reverse effect (Figure 6) of sheep on grass G - B according to the formula

$$B = 1.34422 \cdot 10^{-11} \exp(0.23425 G^{0.99779}) + 142.76037 G^{0.13788}$$
$$\exp(-1.17222 \cdot 10^{-5} G^{1.93557}) \qquad (7)$$

with a correlation coefficient of 0.4204. From the point distribution of residues in Figure 6, it can be seen that there are three clusters in the intervals of sheep grazing intensity: (1) from 0 to 30 pcs / km^2; (2) from 30 to 95 units / km^2; (3) more than 95 pcs / km^2. In this case, the variability of the productivity of the grass decreases.
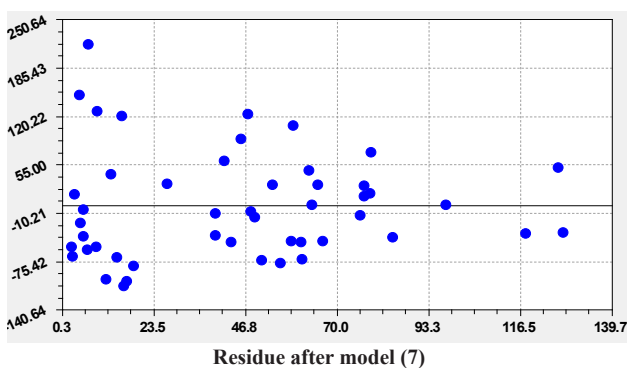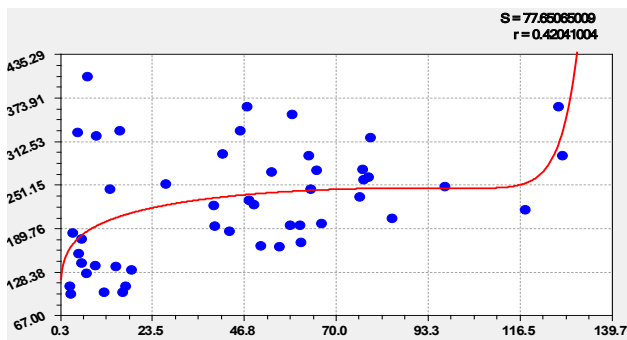

Figure 6. Graphs of the influence of the intensity of sheep grazing on grass productivity

In the first cluster, apparently, the best quality grass grows, and in the third cluster, due to overgrazing of sheep, the species composition and quality of the grass deteriorate. At the same time, according to the first term of formula (7), the biomass of steppe grass increases

sharply. It can be seen from the second term that stress excitation of the grass cover occurs as a positive response to an increase in the intensity of sheep grazing. Without sheep, biomass is below 80 g/m^2. With an optimum grazing intensity of 70 pcs/km^2, on average, the productivity of grass biomass increases 2.5 times.

10. Conclusion

Of the nine factors taken into account, the most active are the geographic coordinates of 48 test sites. This circumstance proves that the geomorphology of the steppes on the eastern section of Eurasia in Mongolia and Inner Mongolia of China is becoming decisive in climatic geomorphology and other scientific areas.

Factor analysis showed that the first of the nine four places for influencing variables and dependent indicators are the same: in the first place is the north latitude, the second is the east longitude, the third is the average annual precipitation, and the fourth place is the intensity of sheep grazing. The rest of the factors are located in different ways. For example, the average annual temperature as an influencing variable is in fifth place, but as a dependent indicator only in eighth place.

The density of organic carbon was found to be only in ninth place as an influencing variable, and in seventh place as a dependent indicator. This is based on the fact that organic carbon is an accumulative (cumulative) parameter over many years.

The productivity of the biomass of steppe grass as an influencing variable is in sixth place, and as a dependent indicator (criterion) only in ninth place. This parameter is seasonal, therefore, in comparison with organic carbon, it is highly dynamic.

The average annual temperature as an influencing variable is in fifth place, after the intensity of grazing of sheep, and as a dependent indicator only in eighth place. This was influenced by the strong averaging of the parameter (average value for the year). Plants are strongly influenced by the temperature dynamics during the growing season [6], and even more by the sum of temperatures during the growing season.

When the productivity of steppe grass is less than 75 g/m^2, the intensity of grazing of sheep is zero. According to the second term of the model, an optimum of 270 g/m^2 appears with a maximum of sheep grazing intensity on average 65 pcs/km^2. The first fluctuation shows that with an increase in grass biomass, there is a loss of stability of the grass cover with an exponential increase in the amplitude. The second fluctuation is dangerous because with an increase in the grass biomass, the half-period of the fluctuation sharply decreases and this

will also lead to the collapse of the steppe grass cover. From the remnants of the effect of sheep grazing on grass biomass, it can be seen that there are three clusters: (1) from 0 to 30; (2) from 30 to 95; (3) more than 95 pcs/km^2. In this case, the variability of the productivity of the grass decreases.

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