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Bioclimatic Regularities of Change in the Density of Organic Carbon of the Steppe Soil in Different Regions of the World

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ABSTRACT

The bioclimatic regularities between the average annual precipitation, average annual temperatures and the density of organic carbon in the soil layer of 0-30 cm of the steppes in the regions of the world are given. They are distinguished by a high certainty of quantization by asymmetric wave equations. It turned out that, due to the vibrational adaptation of organic carbon, precipitation and temperature are dependent on each other. For example, the model of the influence of precipitation on temperature includes the first term in the form of Laplace's law (in mathematics), Mandelbrot' law (in physics), Zipf-Perl (in biology), and Pareto (in econometrics). The second term is the biotechnical law of the author of the article, which gives the maximum change in the indicator. Both components form a trend that makes it possible to divide the precipitation interval into three stages: (1) with an increase in precipitation from 0 to 60 mm, the temperature decreases according to Mandelbrot's law from 23.25 to 0.5 °C; (2) from 60 to 2100 mm, the temperature rises to 24 °C; (3) with a further increase in precipitation over 2100 mm, a slow decrease in temperature occurs. The third term is an asymmetric wavelet with a constant half-period of 367.8 mm. A positive sign shows that in the steppes there is a positive oscillatory adaptation of temperature to changes in precipitation. In the interval of precipitation 0-350 mm, an oscillatory decrease in temperature occurs. It turns out that the first oscillation at 0 mm precipitation begins with a very high temperature gradient of thermal energy. The first interval includes Mongolia and Inner Mongolia. In the second interval of 350-750 mm, an oscillatory increase in temperature occurs. Then, in the third interval 750-1050 mm, the temperature drops again. The second oscillation with a correlation coefficient of 0.9685 has clear precipitation boundaries in the range of 200-2000 mm. Due to the negative sign, the fluctuation is a crisis, inhibiting the rise in temperature. And the third fluctuation has a positive effect on the temperature. The mechanism of oscillatory adaptation in the steppe soil is so perfect that it changes for itself the conditions of the place where the grass grows. An amplitude-frequency analysis of each oscillation will make it possible to determine the specific particular effects of precipitation and temperature on each other and on the density of organic carbon. It was found that two-factor modeling of the change in the soil organic carbon density makes it possible to achieve an identification error even less than the absolute measurement error.

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1. Introduction

It is necessary to return to the scenario “Together with Nature”, which was inherent in humanity at the dawn of its formation. This return should be on a different level, based: first, on the recognition of the landscape sphere - the only suitable habitat; secondly, on the “return” of a person “inside Nature” and rejection of anthropocentrism; thirdly, on the preservation of the self-regulating structure of the enclosing landscape; fourth, on the gradual replacement of land use technologies adapted to Nature^[7]. Academician N.N. Moiseev called this scenario the coevolution of humanity with Nature.

In the era of climate deterioration (a decrease in the average annual temperature, or a decrease in the amount of precipitation, or both), the dominant tendencies were the unification of tribes and peoples, mass migrations, the formation of new states. The most severe cooling occurred in the last 2,500 years, beginning around 250 BC. Even its insignificant changes had a great impact on human economic activity. Abrupt climatic changes have intensified migration processes. The climate determines biological productivity, and it has changed over time and space. Productivity in the steppe zone varies from north to south and from west to east. Differences in the productivity of biocenoses largely determined the direction of seasonal movements of steppe nomads^[6].

Estimates of soil organic carbon storage are vital for quantifying the potential for carbon sequestration in soil. Small changes in soil organic carbon have a significant impact on the global carbon balance. The study of the accumulation of organic carbon in soil and the factors

controlling this process will be important in studies of the global terrestrial carbon cycle. In recent decades, increasing attention has been paid to the accumulation of organic carbon in soil under various scenarios of climate change and land use. Globally and regionally, temperature and precipitation are the dominant factors affecting the accumulation of organic carbon in the soil, and soil organic carbon increases with an increase in precipitation and a decrease in temperature^[12].

Purpose of the Study

According to the experimental data of article^[12] for steppes from different regions of the world to prove the influence of temperature and precipitation according to nonlinear and wave patterns in the form of sets of wavelet signals identified by the identification method^[3,9-11], on each other and on the density of organic carbon.

2. Materials and methods

Soil organic carbon accumulation in tropical savannahs is lower than in temperate grasslands, and that colder grasslands exhibit higher soil organic carbon accumulation [12, Table 3].

The data for modeling are given in Table 1. Let’s introduce the following symbols: *P* - average annual precipitation (MAP), mm; *t* - average annual temperature (MAT), °C; *S_o* - density of soil organic carbon at a depth of 0-30 cm (SOCD), kg / m².

The first class of soil cover according to the UN classification^[8] is grass cover and includes hayfields, pastures and bogs out of 13 types of land in Russia, the second is

Table 1. Density of soil organic carbon, average annual precipitation and temperature in various meadows (<https://doi.org/10.1371/journal.pone.0186980.t003>)^[12]

Grassland type	Country/Region	MAP (mm)	MAT (°C)	SOC _D (kg/m ²)
African savanna	Nigeria	1500	29	4.20
South American tropical grassland	Brazil	2200	25.6	3.40
Indian tropical grassland	New Delhi, India	650	28	3.80
Australian temperate grassland	Eastern Australia	1060	16	4.90
New Zealand temperate grassland	New Zealand	1900	18	6.83
North American prairie	Ohio, America	10.7	953	5.50
Eurasian steppe	Inner Mongolia	308	1.22	4.11
Eurasian steppe	Mongolia	209	0.62	5.79
Eurasian steppe	Loresstan province, Iran	450	12	6.33
Eurasian steppe	Three Rivers Source Region of the Tibetan Plateau	417	-0.64	7.40
Eurasian steppe	Sanjiang plain of China	575	2.85	10.65
Eurasian steppe	Belgium	1000	9	9.22
Eurasian steppe	Ireland	900	9.7	11.10

shrubbery (fallow and perennial plantations). The third class includes forest lands and plantations outside the forest fund. All three classes together form the vegetation cover^[1,2].

Then the steppes of the world belong to the first class of the UN soil cover.

Let us also assume that the steppes are in a dynamic ecological balance^[4]. Moreover, the hierarchy of factors in Table 1 is clearly defined^[12]. Of the three parameters, precipitation and temperature are influencing variables, and organic carbon is the dependent indicator.

Oscillations (wavelet signals) are written by the wave formula^[3,9-11] of the form

$$y_i = A_i \cos(\pi x / p_i - a_{8i}), A_i = a_1 x^{a_2} \exp(-a_3 x^{a_4}), p_i = a_5 i + a_6 x^{a_7} \quad (1)$$

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), $a_1 \dots a_8$ - are the parameters of the model (1), taking numerical values 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).

3. Mutual Influence of Variables

It turned out that average annual precipitation and average annual temperatures are dependent on each other parameters of the steppes of the world.

In this case, the influence of precipitation on temperature is determined (Figure 1) by the formula

$$t = t_1 + t_2 + t_3 + t_4 + t_5, \quad (2)$$

$$t_1 = 23.24908 \exp(-0.083351P),$$

$$t_2 = 4.43613 \cdot 10^{-7} P^{2.83616} \exp(-0.0019535P)$$

$$t_3 = A_1 \cos(\pi P / p_1 + 0.80556),$$

$$A_1 = 40582.8981 P^{14.18576} \exp(-43.84162 P^{0.12818}),$$

$$p_1 = 367.79102, \quad t_4 = A_2 \cos(\pi P / p_2 + 0.24128),$$

$$A_2 = -1.45601 \cdot 10^{-31} P^{25.08716} \exp(-13.87317 P^{0.28698}),$$

$$p_2 = 61.44064 + 0.0021944 P^{1.31379}$$

$$t_5 = A_3 \cos(\pi P / p_3 + 2.62283)$$

$$A_3 = 8.58519 \cdot 10^{-8} P^{2.97195},$$

$$p_3 = 2.17996 + 0.020338 P^{1.05851}$$

In this case, the correlation coefficient of the first three

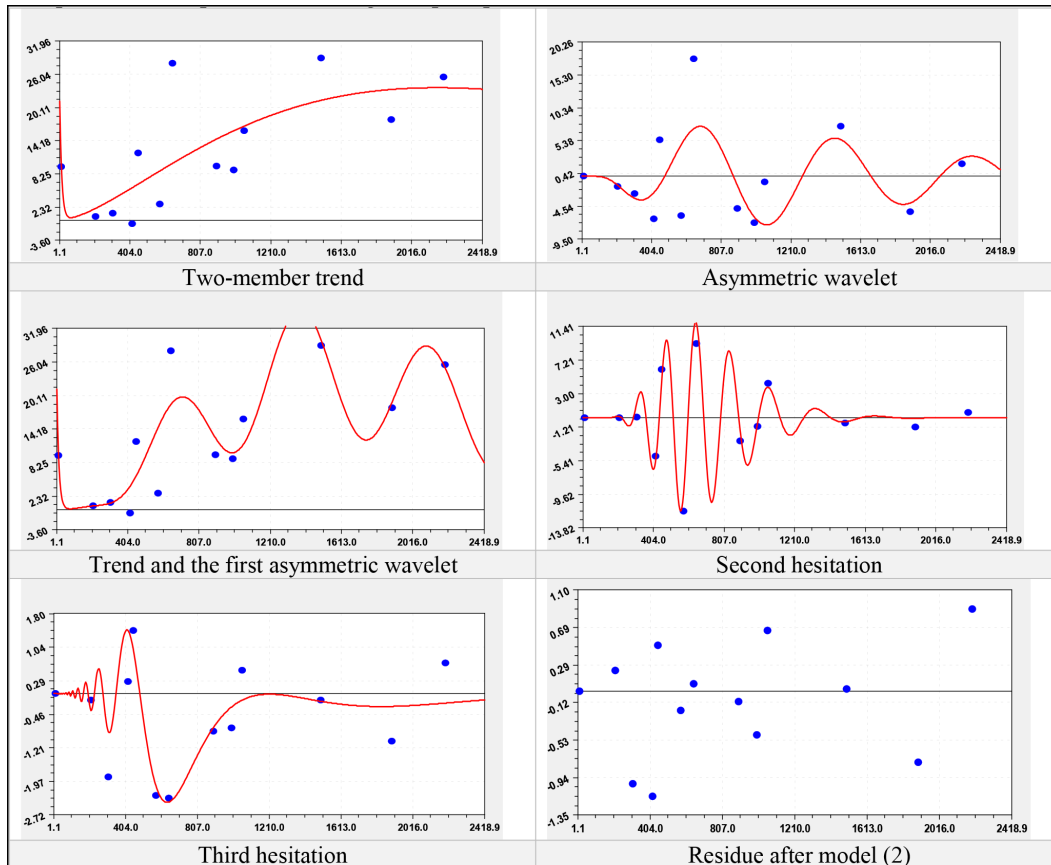


Figure 1. Graphs of the influence of average annual precipitation on average annual temperature (in the upper right corner: S - standard deviation; r - correlation coefficient)

terms of formula (2) is 0.8697. Adequacy level with a correlation coefficient of more than 0.7 is defined as “strong factor relationship”.

The first term of model (2) is the exponential law of Laplace (in mathematics), Mandelbrot (in physics), Zipf-Perl (in biology) and Pareto (in econometrics). The second term is the biotechnical law [1-3,9-11], which gives the maximum change in the indicator. Both components form a two-term trend that allows dividing the precipitation interval into three stages: (1) with an increase in precipitation from 0 to 60 mm, the steppe temperature decreases according to Mandelbrot’s law from 23.25 °C to about 0.5 °C; (2) from 60 to 2100 mm / year, the temperature rises to 24 °C; (3) with a further increase in precipitation over 2100 mm, a slow drop in temperature occurs.

The third term is an asymmetric finite-dimensional wavelet with a constant half-period of 367.8 mm. A positive sign in front of component (2) shows that in the steppes a positive oscillatory adaptation of temperature to changes in precipitation occurs.

In the first precipitation interval 0-350 mm, there is an oscillatory decrease in temperature. In this case, according to formula (2), the first parameter of the amplitude of the third term (defined as a strange attractor) is equal to 40583 °C. It turns out that the first oscillation at 0 mm precipitation begins with a very high temperature gradient of thermal energy in the surface air layer. The three-term graph shows that Mongolia and Inner Mongolia are located in the 1st interval.

In the second interval of changes in average annual pre-

cipitation in the range of 350-750 mm, there is an oscillatory increase in temperature. Then, in the third interval of 750-1050 mm, an oscillatory drop in temperature occurs again.

The second oscillation with a correlation coefficient of 0.9685 (super-strong connection with a correlation coefficient of more than 0.95) has clear precipitation boundaries in the range of 200-2000 mm with a strange attractor -1.46e-31. Due to the negative sign, the fluctuation is a crisis one, inhibiting the rise in temperature. And the third fluctuation has a positive effect on the temperature, here the strange attractor is only 8.6e-8.

The inverse effect of temperature on precipitation (Figure 2) is identified by the formula

$$P = P_1 + P_2 + P_3, \tag{3}$$

$$P_1 = 94.31036 \exp(1.01235(t+4)^{0.25479}),$$

$$P_2 = 1.76093 \cdot 10^{-149} (t+4)^{151.08014} \exp(-3.92897(t+4)^{1.09851}),$$

$$P_3 = A_1 \cos(\pi(t+4) / p_1 + 2.85378),$$

$$A_1 = -108.06846(t+4)^{0.86816} \exp(-0.17785(t+4)^{0.60870}),$$

$$p_1 = 0.69881 + 0.00010870(t+4)^{1.35345}$$

The first three terms (according to the computing capabilities of the CurveExpert-1.40 software environment) gave the “strongest connection” adequacy level with a correlation coefficient of 0.9623.

The first term in formula (3) is our modified Mandelbrot’s law by introducing the third parameter. It shows an increase in precipitation with increasing temperature. The

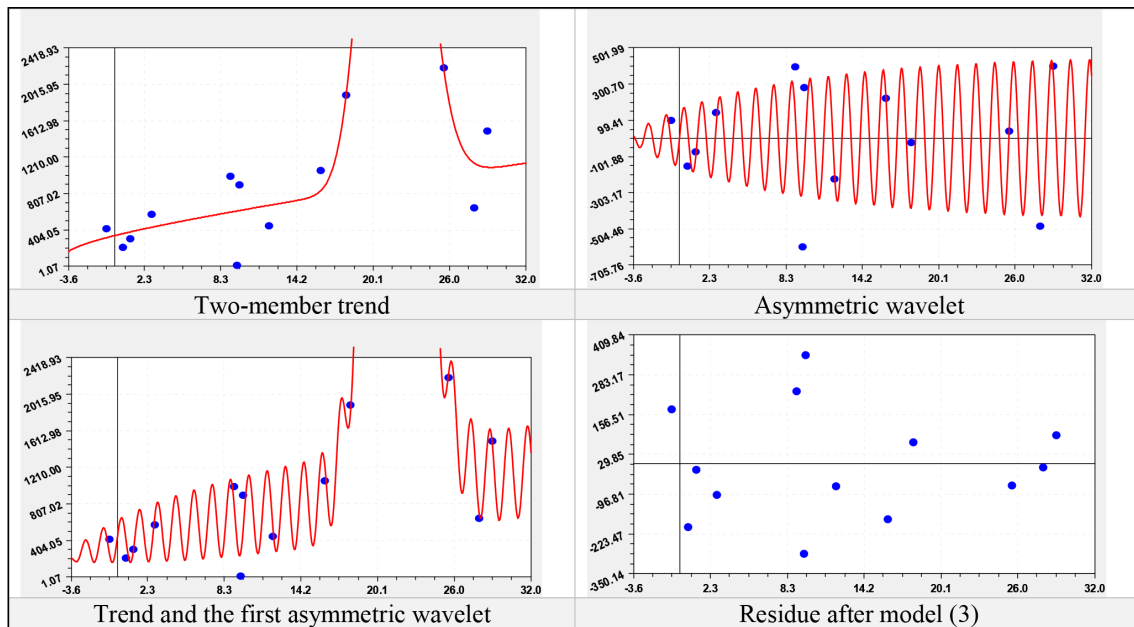


Figure 2. Graphs of the influence of average annual temperature on average annual precipitation

second term of the trend, according to the biotechnical law, gives a temperature interval of 15.5-28.5 °C with a maximum precipitation of 22.0 °C. It is known from bioclimatology that these temperatures are also optimal for human habitation. Oscillation with increasing half-period is negative for precipitation growth.

Thus, both influencing parameters of the world's steppes from Table 1 are highly dependent on each other. The first three terms gave correlation coefficients 0.8697 and 0.9623.

4. Influence of Average Annual Temperature

Consider the dependence $S_o=f(t)$.

With an increase in temperature, evaporation increases, and the productivity of plants decreases, which ultimately leads to a decrease in the supply of organic carbon to the soil. On the contrary, the activity of soil microbial decomposition increases with increasing temperature, which leads to a higher release of organic carbon from the soil^[12].

These conclusions were derived from linear equation modeling. In our method, the linear model is only the initial stage of the identification process.

After identifying the model (1), we obtained (Figure 3) the equation

$$S_o = S_{o1} + S_{o2} + S_{o3}, \tag{4}$$

$$S_{o1} = 4.48938 \exp(-0.0028175(t + 4)),$$

$$S_{o2} = 4.30353 \cdot 10^{-8} (t+4)^{62.53688} \exp(-63.73003(t+4)^{0.40139}),$$

$$S_{o3} = A \cos(\pi(t + 4) / p - 5.11595),$$

$$A = 1.77224(t + 4)^{0.68345} \exp(-0.078823(t + 4)),$$

$$p = -11.32163 + 13.16477(t+4)^{0.022728}.$$

According to Mandelbrot's law, with increasing temperature, the density of organic carbon in the steppe soil decreases. The second term is a biotechnical law showing stress excitement of the activity of soil microbial decomposition in the temperature range from +1 to +12 °C. Outside this interval of 11 °C, the activity of soil microbial decomposition is almost zero.

It can be seen from the residuals in Figure 3 that they do not allow identifying the model (1). This proves the statement^[11] that the temperature of the surface air layer gets a high quantum uncertainty. Decomposition into tens and hundreds of wavelets (1) or, into so-called quanta of behavior, allows only the dynamic series of air temperature^[10].

5. Influence of average annual rainfall

Next, consider the impact $S_o=f(P)$.

After identifying the general model (1), an equation (Figure 4) of the form

$$S_o = S_{o1} + S_{o2} + S_{o3}, \tag{5}$$

$$S_{o1} = 5.64043 \exp(-0.00010453P),$$

$$S_{o2} = 2.03630 \cdot 10^{-22} P^{8.87595} \exp(-0.0043967P^{1.13722}),$$

$$S_{o3} = A \cos(\pi P / p - 5.67315),$$

$$A = -5.48174 \cdot 10^{-17} P^{7.33642} \exp(-0.039817P^{0.82367}),$$

$$p = 178.76625 + 0.00017617P^{1.66452}.$$

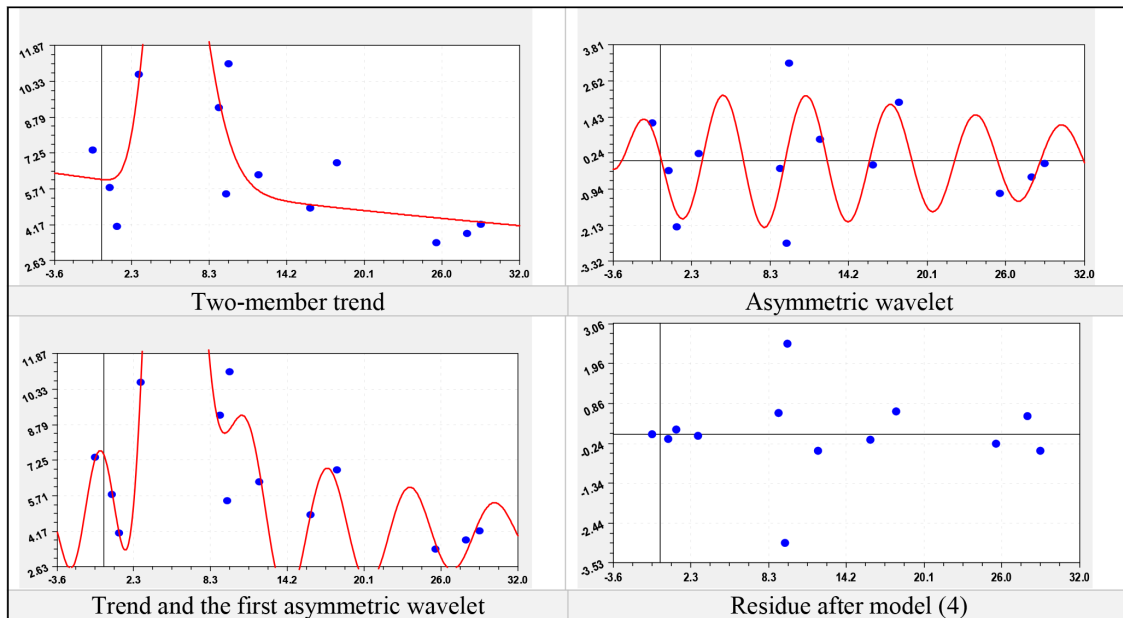


Figure 3. Graphs of the effect of temperature on the density of organic carbon

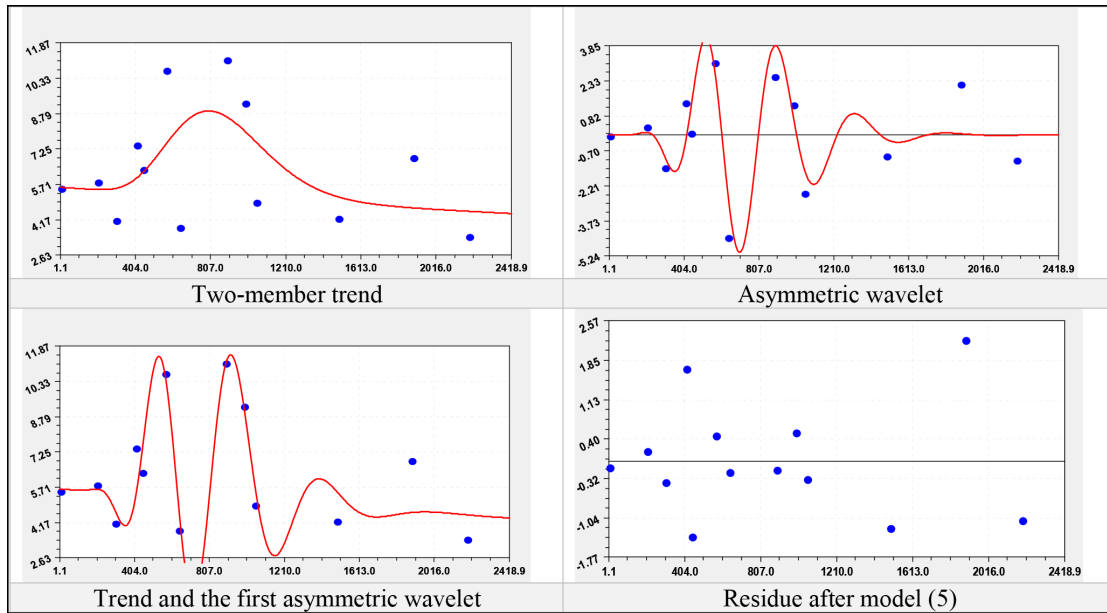


Figure 4. Graphs of the influence of average annual precipitation on the organic carbon density

The average annual precipitation, in comparison with the average annual temperatures, has a higher quantum certainty and, according to the correlation coefficient of the three-term model (5), is 0.9112.

The two-part trend, as for temperature, gives rise to the excitation of organic carbon to a change in the average annual precipitation approximately in the range from 300 to 1700 mm. However, according to the asymmetric wavelet in the precipitation interval from 200 to 2000 mm, organic carbon enters into the process of negative vibrational adaptation.

This proves our hypothesis that living matter adapts to the climate through the mechanism of oscillatory adaptation

Further, the two-factor effect on the density of organic carbon in soil with a thickness of 0-30 cm can be constructed in two ways, taking into account the previous one-factor equations. For this, one-factor trends with correlation coefficients are used:

- (1) The effect of precipitation on the density of organic carbon 0.5489;
- (2) The effect of temperature on the density of organic carbon 0.7871.

Then it becomes possible to identify the two-factor equation twice: first, as dependence $S_o=f(P,t)$; secondly, as a formula $S_o=f(t,P)$.

6. Two-factor Model $S_o=f(P,t)$

In this case, the first factor is the average annual pre-

cipitation. We take the remnants of the trend of the influence of precipitation (4) and put the values of the average annual temperature in the abscissas (Table 2, Figure 5).

In Table 2, the first two terms are shown in Figure 4 and are given in formula (5). Wavelets 3-5 together gave a correlation coefficient of 0.9219. Other wavelets received high correlation coefficients from 0.6626 to 0.9972. Such statistical indicators were obtained by the regularity of the influence on the density of organic carbon sequentially by the factors of the average annual precipitation and the average annual temperature.

7. Two-factor Model $S_o=f(t,P)$

When the first factor becomes the average annual temperature, and the second place is the average annual precipitation, after identifying the general model (1), it contains 18 members (Table 3).

The first three terms of the influence of precipitation gave a correlation coefficient of 0.9511 (Figure 6).

Each term in the form of a wavelet is a quantum of behavior, in our case, the density of organic carbon. Then the quantum definiteness is revealed by the relative error of identification of the general model (1). Table 4 compares the two two-factor models.

Brazil - maximum relative error of 0.05% modulo for the model $S_o = f(P,t)$ false. And for the model $S_o = f(t,P)$ false, the maximum relative error is 0.02% for Eastern Australia. In both cases, Mongolia was identified with an error of 0.01% (Data for Mongolia and Inner

Table 2. Parameters (1) of the influence of precipitation and temperature on organic carbon

$$\text{Asymmetric wavelet } y_i = a_{1i}x^{a_{1i}} \exp(-a_{3i}x^{a_{4i}}) \cos(\pi x / a_{5i} + a_{6i}x^{a_{7i}}) - a_{8i}$$

<i>i</i>	Amplitude (half) oscillation				Half-cycle			Shift	Coef. correl. <i>r</i>	
	<i>a</i> _{1i}	<i>a</i> _{2i}	<i>a</i> _{3i}	<i>a</i> _{4i}	<i>a</i> _{5i}	<i>a</i> _{6i}	<i>a</i> _{7i}			<i>a</i> _{8i}
1*	5.64043	0	0.00010453	1	0	0	0	0	0.5489	
2*	2.03630e-22	8.87595	0.0043967	1.13722	0	0	0	0		
3	0.020932	0	-2.88216	0.26593	0	0	0	0		
4	-0.034328	1.96563	0	0	0	0	0	0		0.9219
5	1.49013	0	-0.0087925	1.36051	2.39824	0.00018488	2.00398	3.39849		
6	-0.13813	1.17749	0.00094915	2.46966	0.50199	0	0	1.18993		0.7551
7	-1.6658e-34	45.67627	0.79806	1.48782	0.17411	0	0	-5.72953		0.9626
8	-2.19039e-42	45.57898	2.09087	0.99957	-4.94903	0.41565	0.99885	-6.11330		0.8855
9	-6.65131e-12	6.86572	0	0	2.67534	0	0	1.64998		0.6640
10	-0.69270	2.04338	1.04411	1	2.97543	0	0	1.66816		0.9972
11	-2.46286e-5	2.53902	0.11108	0.99899	6.85492	0.053690	1.03528	0.29295		0.6626
12	3.81808e-6	3.00025	0.10957	1.04020	5.56560	-0.0084703	1.08698	0.99859		0.6260
13	1.28506e-5	2.90917	0.16902	1.00492	2.07597	-0.012625	0.99559	0.89306		0.7963

Note:

* The variable is *P*, and in other wavelets - the temperature *t*:*t*+4.

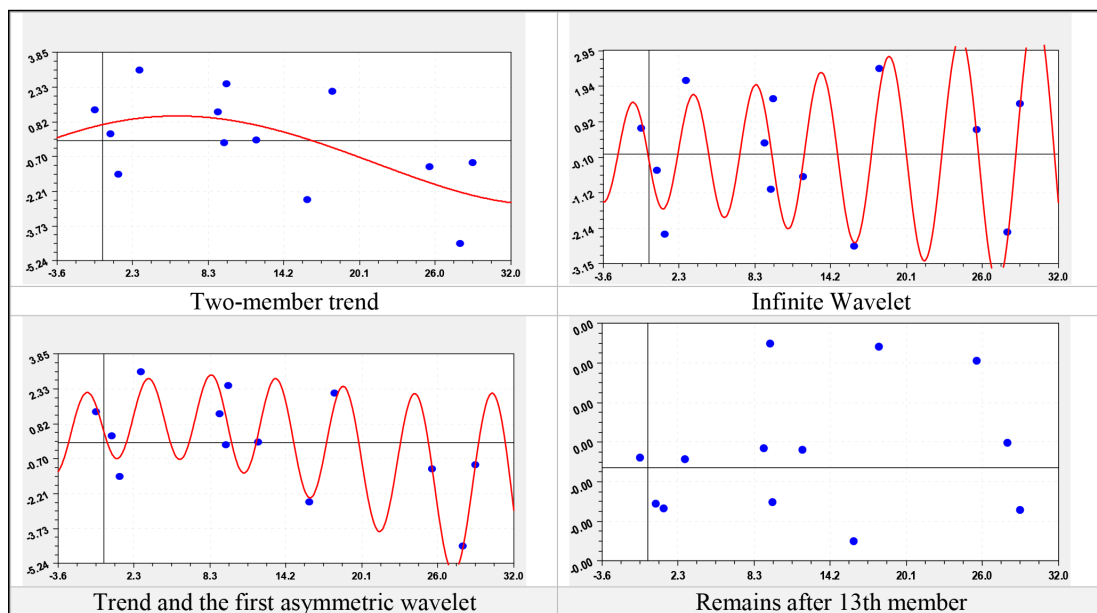


Figure 5. Influence of temperature on the density of organic carbon in residues from precipitation

Table 3. Parameters (1) of the influence of temperature and precipitation on organic carbon

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

<i>i</i>	Amplitude (half) oscillation			Half-cycle			Shift	Coef. correl. <i>r</i>	
	<i>a</i> _{1i}	<i>a</i> _{2i}	<i>a</i> _{3i}	<i>a</i> _{4i}	<i>a</i> _{5i}	<i>a</i> _{6i}	<i>a</i> _{7i}		
1*	4.48938	0	0.0028175	1	0	0	0	0.7871	
2*	4.30353e8	62.53688	63.73003	0.40139	0	0	0		
3	-3.25615	0	-0.00030907	1.01417	0	0	0		
4	0.20706	0.48208	0	0	0	0	0	0.9511	
5	1.30670	0	-0.00039679	1	192.5627	-4.67628e-5	1.50926		1.78009
6	1.50128e-15	8.96792	0.97061	0.49604	68.19754	0.00022823	1.85420	-4.58507	0.8039
7	2.23132e-85	31.47602	0.019964	1.01839	9.71896	0.029693	1.00256	5.61435	
8	-3.72938e-6	1.57055	0.00082499	0.98966	132.4215	-8.43392e-5	1.22040	-0.90872	0.3396
9	1.89053e-31	11.62749	0.0089153	1.03282	335.7489	0	0	2.42720	
10	3.23071e-11	3.59698	0.0024079	1.04194	63.31560	0.0035099	1.14875	1.91439	0.8662
11	-0.13015	0	0.072560	1	229.2375	-0.086206	1	0.006391	
12	-5.28445e-7	1.96200	0.0023916	1.06687	1156.982	0	0	-2.22979	0.5501
13	-1.33204e-9	2.76456	0.0026256	1.00302	120.5748	0.084430	1.00044	1.41807	
14	-4.63035e-7	2.13347	0.0061757	0.99997	117.0009	-0.060853	0.99999	-2.34569	0.8272
15	6.79520e-10	2.38990	0.00027418	1.08094	58.60886	2.23143e-5	1.13239	-0.27134	
16	-4.69747e-7	1.87107	0.0073374	0.93877	360.9170	0.077513	1.01111	-0.90774	0.6904
17	-4.57770e-9	2.08217	0.00099215	1.00848	219.9889	0.0031583	1.03278	-0.09514	
18	-3.49240e-9	2.53586	0.0042876	1.00235	125.95363	0.017996	0.99727	-0.19541	0.8679

Note:

* Variable is *t*:*t*+4, and in other wavelets - precipitation *P*

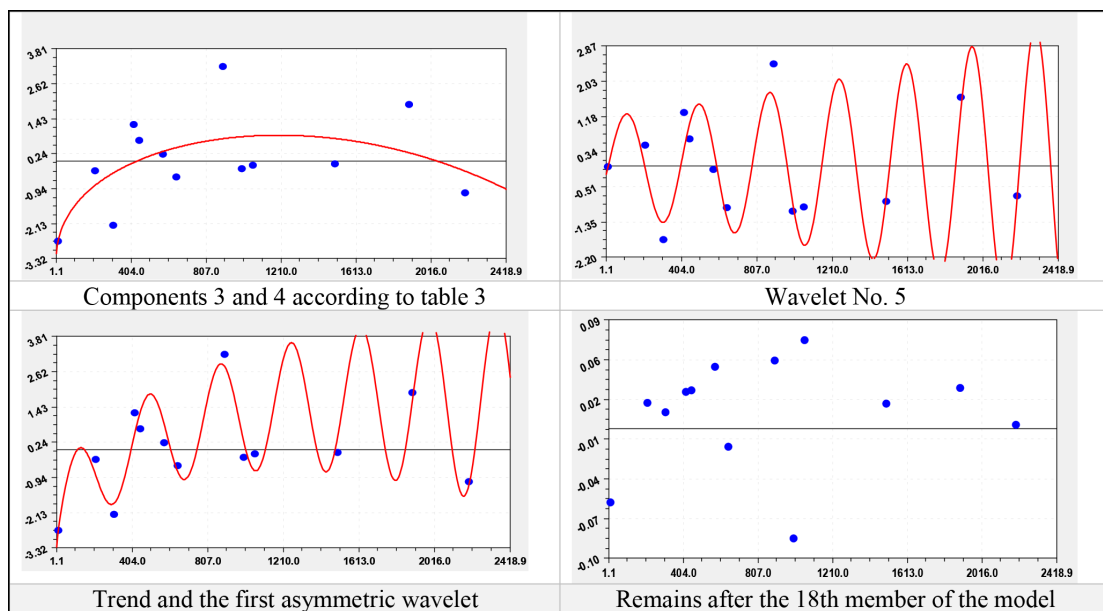


Figure 6. Graphs of the influence of average annual precipitation on organic carbon density

Table 4. Influence of two factors on the density of organic carbon

Actual values ^[12]			Model $S_o = f(P,t)$		Model $S_o = f(t,P)$	
P , MM	t , °C	S_o , KG/M^2	ϵ , KG/M^2	Δ , %	ϵ , KG/M^2	Δ , %
1500	29	4.20	-0.000676822	-0.02	-0.000594248	-0.01
2200	25.6	3.40	0.00174021	0.05	-0.000424308	-0.01
650	28	3.80	0.00040834	0.01	-3.99E-05	0.00
1060	16	4.90	-0.0011885	-0.02	0.00109485	0.02
1900	18	6.83	0.00197084	0.03	0.000356222	0.01
10.7	9.53	5.50	2.02E-03	0.04	-7.17E-05	0.00
308	1.22	4.11	-0.000657739	-0.02	0.000476229	0.01
209	0.62	5.79	-5.80E-04	-0.01	0.000664236	0.01
450	12	6.33	0.000300081	0.00	-0.000499665	-0.01
417	-0.64	7.40	1.71E-04	0.00	0.000107779	0.00
575	2.85	10.65	0.0001479	0.00	-0.00100647	-0.01
1000	9	9.22	0.000319983	0.00	-0.000579258	-0.01
900	9.7	11.10	-0.000546682	0.00	0.00115619	0.01

Mongolia China are in bold).

The division price of the density of organic carbon according to the records of Table 1 is 0.01 kg / m². Then the measurement error is equal to half the scale division of ± 0.005 kg / m². The maximum absolute error ϵ according to table 4 for the model $S_o = f(P,t)$ is 2g / m², and for the model $S_o = f(t,P)$ it is only 1.16g / m². Then the identification of the wavelets is completed, since the simulation error is more than 2.5 times less than the measurement error.

8. Conclusion

Bioclimatic regularities between the parameters of the steppes by regions of the world in the form of average annual precipitation, average annual temperature and density of organic carbon in the soil layer of 0-30 cm are distinguished by a high certainty of quantization by asymmetric wave equations.

The radical difference from the meteorological parameters, the paired relations between which are identified only by nonlinear two-term trends and therefore do not have asymmetric wavelets, is that the living matter of the steppes over 450 million years of grass cover evolution has adapted to changes in weather and climate by oscilla-

tory adaptation.

The mechanism of oscillatory adaptation in the soil layer of the steppes is so perfect that the soil cover of the steppes partially changes the conditions of the growing place for itself so that many wavelets of the mutual influence of precipitation and temperature appear.

An amplitude-frequency analysis of each fluctuation will allow to determine the specific particular effects of average annual precipitation and average annual temperatures on each other and on the density of organic carbon. At the same time, it was found that two-factor modeling of changes in the density of organic carbon in the soil layer makes it possible to achieve an identification error even less than the absolute measurement error.

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References

[1] Mazurkin P.M. Land plots of federal districts of the Russian Federation. Success of modern natural science, 2020. No. 4. S. 106-113. (in Russia)

- DOI: 10.17513 / use.37370**
- [2] Mazurkin P.M. Land plots of the Siberian Federal District of Russia. Success of modern natural science, 2020(6): 75-82. (in Russia)
DOI: 10.17513 / use.37414
- [3] Mazurkin P.M., Mikhailova S.I. Territorial ecological balance: analyte. overview. Novosibirsk: GPNTB SO RAN, Ser. Ecology., 2010(94): 430. (in Russia)
- [4] Reimers N.F. Nature management: Dictionary-reference. M.: Mysl', 1990.637 p. (in Russia)
- [5] Saati T. Decision-making. Hierarchy analysis method. M.: Radio and communication, 1993: 274. (in Russia)
- [6] Tairov A.D. Climate changes in the steppes and forest-steppes of Central Eurasia in the II-I millennium BC: Materials for historical reconstructions. Chelyabinsk: Rifey, 2003: 68. (in Russia)
- [7] Chibilev A.A., Velmovsky P.V., Grudin D.A. From the transformation of nature to the optimization of landscapes: "experiments" by F.N. Milkov and the testament of F. Engels. Questions of steppe studies. Orenburg: IS UB RAS, 2018(XIV): 45-51. (in Russia)
DOI: 10.2441 / 9999-006A-2018-00002.
- [8] Fischer G., Velthuizen H., Shah M., Nachtergaele F. Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results. International Institute for Applied Systems Analysis, Laxenburg, Austria. Food and Agriculture Organization of the United Nations. Rome, Italy. 2002. URL: <http://webarchive.iiasa.ac.at/Research/LUC/SAEZ/index.html>
- [9] Mazurkin P.M. Wave patterns of annual global carbon dynamics (according to information Global_Carbon_Budget_2017v1.3.xlsx). Materials of the International Conference "Research transfer" - Reports in English (part 2), Beijing, PRC, November 28, 2018: 164-191.
- [10] Mazurkin P.M. Wavelet analysis of annual dynamics of maximum temperature from 1878 to 2017 and forecast data Hadley center Central England temperature (Hadcet). International Journal of Current Research, 11(09), 7315-7324.
DOI: <https://doi.org/10.24941/ijcr.36626.09.2019>
- [11] Mazurkin P.M., Kudryashova A.I. Quantum meteorology // International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2019, 19 (5.1): 619-627.
DOI: 10.5593/sgem2019/5.1/S20.077
- [12] Zhao Y., Ding Y., Hou X., Li F.Y., Han W., Yun X. Effects of temperature and grazing on soil organic carbon storage in grasslands along the Eurasian steppe eastern transect. PLoS ONE. 2017, 12(10).
DOI: <https://doi.org/10.1371/journal.pone.0186980>