Journal of Siberian Federal University. Humanities & Social Sciences 8 (2016 9) 1710-1718
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УДК 0254.03:001.86:502/504

Scientometric Analysis of Dynamics of the Number of Publications on Environmental Issues

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Received 27.04.2016, received in revised form 07.07.2016, accepted 26.07.2016

In this article scientometric analysis of the data on the number of publications on six environmental issues is conducted. The following methods of analysis were applied: the method of linear interpolation, ssa method and correlation analysis.
An analytical expression to describe the changes in the number of publications over time was found by the method of linear interpolation. The degree of the data "pollution" was analyzed by SSA method. The rate of change in the number of publications in a given time interval is analyzed in details. The substantial significance of external factors on the initial number and dynamics of the publications growth is shown.

Keywords: Kyoto forests, dynamics of publications, Verhulst equation, SSA method.

DOI: 10.17516/1997-1370-2016-9-8-1710-1718.

Research area: economics.

Introduction

Global environmental problems, that are the problems concerning the entire biosphere of the Earth, are one of the most pressing ones. Our civilization must be a part of the Earth's ecosystem. Climate research has become a priority area, numerous committees are created and allocated funds are increasing [1].

Since the end of the last ice age (about 10 000 years ago) up to 1750 the content of CO_2 in the atmosphere had been almost unchanged, and after the start of the Industrial Revolution it started to grow exponentially. It is possible to compare this growth with another exponent – an increase in carbon fuel consumption, which for the recent time has been doubling every ten years. Exponential growth is very rare in nature: it means a positive feedback when an increase of a factor leads only to its further growth and inhibiting factors do not function. This happens

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during various disasters such as forest fires and avalanches. On the contrary, in human activity positive feedback occurs very often. There is no doubt that both exponential processes – the growth of carbon fuels consumption and the growth of carbon dioxide content are connected, and that the first is the cause of the second one.

Technical human activity, and especially energetics based on fossil fuel combustion, changes the composition of the Earth's atmosphere. The rate of anthropogenic residues production is 2 orders of magnitude more than the rate of natural carbon geochemical cycle capable to dispose of these residues. This change inevitably leads to climate change, which has already been observed and can be predicted for the future. The escalation of the global warming effect [2] may lead to an increase in average global temperature of the planet by 1° C. 60% of the greenhouse effect is caused by carbon dioxide. The urgency of the necessary measures is connected with the fact that CO_2 and other "greenhouse gases", once in the atmosphere, can remain there at least for hundreds of years. The greatest increase in temperature will happen between 40° and 70° *N* [3]. It was exactly in these places where the greatest warming occurred in the 20th century. For example, at the current level of carbon fuels consumption, the average temperature in July in the centre of Washington is now 30° C, and in a hundred years it will increase by 5° C [4]. To change the situation to the best scientists from different countries, with the support of the United Nations developed the Kyoto Protocol [5].

The Kyoto Protocol, signed in 1997, provides for a sharp reduction of greenhouse gases emissions into the atmosphere through the mechanism of international trade of quotas for the gases emissions. Under the protocol, industrialized countries obliged to reduce carbon dioxide emissions by 1-2%. States and separate economic entities in their territories can buy and sell quotas for greenhouse gases emissions at the international, national or regional markets. Details of market regulation mechanism of quotas for greenhouse gases emissions are given in publication [6].

The main purpose of this article is to consider the relationship between various environmental issues, and on the basis of this analysis forecast tendencies of environmental issues development in general, and each issue separately. To do this, standard methods were used: the method of linear interpolation, calculation of Pearson correlation coefficients and Caterpillar SSA method. The attempts to study relationships of different subjects on the basis of the publications analysis were made in [7-10]. Thus, in publication [7] interdisciplinary relationships are studied. Influence of immigration after the collapse of the Soviet Union on the dynamics of scientific publications is studied in works [8-10]. The main content of this work is qualitative analysis, which is mainly of descriptive nature. In this work the authors tried to complement the study of this issue with mathematical methods.

Results

Data of publications on 6 environmental issues for the period 1980-2013 is given in Table №1. All the represented curves (Figure 1) are well approximated by the equation, which is a product of two functions: $y = f_1(x) \cdot f_2(x)$, where $f_1(x)$ is Verhulst equation and $f_2(x)$ is damped exponential curve. Function $f_1(x)$ characterizes "generation" of works on the selected subject, $f_2(x)$ – "oblivion" of a particular publication. Thus, the equation is as follows:

$$y = exp(-ax)\frac{Kx_0exp(rx)}{K + x_0exp(rx) - x_0}, \quad (1)$$

where K is the maximum amount of articles; r – growth parameter; x_0 – number of articles

at the initial time. Coefficients K, r, x_0, a, are respectively equal: $K_2 = 1164$, $r_2 = 0{,}003163$, $x_{02} = 1$, $a_2 = 0{,}003163$; $K_3 = 2064$, $r_3 = 0{,}003448$, $x_{03} = 1$, $a_2 = 0{,}003448$; $K_4 = 10670$, $r_4 = 0{,}002855$, $x_{04} = 17$, $a_4 = 0{,}004264$; $K_5 = 39892$, $r_5 = 0{,}003383$, $x_{05} = 22$, $a_5 = 0{,}004775$; $K_6 = 4402$, $r_6 = 0{,}002444$, $x_{06} = 22$, $a_6 = 0{,}003825$. Approximation of the curves in Fig. 1, solution of Verhulst equation with delay is also possible:

$$\frac{dy}{dx} = c_1 y(x) - c_2 y^2(x) + \\ +c_3 y(x-\tau) - c_4 y^2(x-\tau), \quad (2)$$

where τ is delay time.

Let us analyze graphs in Fig. 1 in details.

All the curves, except curve 1 (Kyoto forest), demonstrate the same exponential nature of growth after 1993. The similar behavior of the curves is observed in 1984-1987, and the curves CO_2 forest, Climate warming and Climate change have the common peaks in about 1987, and the curves CO_2 forest and Climate warming have the common minimums in 1988 respectively. The local minimum of Climate warming curve in 1983 coincides with a local maximum of Green house effect curve. Thus, during the period 1980-1990s the interest to these environmental issues remained practically constant.

Synchronous maximums of 1992 are observed in almost all the curves, what is explained by holding the famous conference in Rio de Janeiro.

Further, we see a slight decline of the interest to environmental issues in the period of 1993-1995. Starting from 1997 an increase of publications is observed again.

Analysis of the data graphs with accumulation (Fig. 2-3) demonstrates a tendency of increase in the number of publications in the future for all environmental issues, with the exception of Kyoto forest, for which there is a tendency of decline. It can be seen (Fig. 3) that the topics of Climate warming, Climate change and Greenhouse effect are developing simultaneously throughout the time period. Starting from 1992, synchronism, as mentioned above, is presented in the development of all these topics.

Against this background, Kyoto forest, where minimums in 1992 and 1995-1997 and maximums in 1991, 1993-1994 respectively are observed stands out. These minimums coincide with holding of the global environmental congresses of 1992 and 1997.

In Fig. 3 two groups with the same dynamics of development are clearly distinguished. These are Carbon forest, Climate warming, Climate change and CO2 forest and Greenhouse effect groups. For the first group it is possible to forecast a sharp increase in the number of publications in the future. The similar forecast can be made for the second group; however, the rate of growth in the number of publications will be slightly slower in comparison with the first group. For Kyoto forest, as mentioned above, on the contrary, a sharp decline of publications is predicted in the future.

Let us consider the graph of derivative $\frac{dy}{dt}$ alteration over time (Fig. 4). Synchronous maximums of 1992 are observed in almost all the curves, what is explained by holding the famous conference in Rio de Janeiro. In Fig. 4 this process is displayed by the presence of the derivative extremums on the curves. Fig. 4 confirms that approximately from 1980 to 1990 the interest to all environmental issues remained constant.

Derivative maximums, falling on the period of 1992 coincide in almost all the curves.

The next major maximums account for 1997. The presence of this maximum coincides with the emergence of the Kyoto Protocol.

From 2000-2004, the interest to the problems of climate change, CO_2 emissions and

Table 1. Environmental Publications for the Period of 1980-2013

1980	0	0	1	17	22	16
1981	0	0	1	11	25	18
1982	0	0	0	15	26	26
1983	0	0	0	16	36	29
1984	0	0	1	9	35	37
1985	0	0	3	15	17	21
1986	0	0	8	27	40	19
1987	0	0	4	21	51	37
1988	0	0	2	44	66	44
1989	0	0	7	50	131	50
1990	0	0	18	90	287	90
1991	4	1	102	312	860	312
1992	1	5	153	319	1012	319
1993	6	18	157	330	1146	330
1994	6	11	156	364	1257	481
1995	2	32	238	518	1661	551
1996	2	34	271	553	1840	626
1997	2	39	270	635	2232	687
1998	9	37	300	696	2432	707
1999	23	43	345	759	2636	661
2000	28	64	361	848	2932	693
2001	30	76	410	960	3245	780
2002	40	125	440	1041	3551	879
2003	35	135	470	1181	4084	967
2004	48	174	508	1321	4490	976
2005	36	152	579	1476	5165	1074
2006	45	202	602	1611	5941	1214
2007	53	235	592	1979	7532	1317
2008	53	280	610	2431	9240	1474
2009	53	335	599	2924	11353	1744
2010	64	372	679	3190	13117	1723
2011	58	446	732	4032	15565	2131
2012	58	512	938	4527	17316	2273
2013	35	582	1032	5335	19946	2201

global warming remains practically constant, since the rate of increase in the number of publications on these topics is close to zero. Relatively large synchronous maximums are observed for Kyoto forest, Carbon forest and Greenhouse effect in 2003. There is a small maximum for CO_2 forest in 2004. On the contrary, synchronous minimums correspond to the topics of Kyoto forest, Carbon forest and Greenhouse effect in that year. Since 2004, interest in climate change has sharply increased as well, which is reflected by exponential growth of the curve for the period of 2004-2010 in the graph. There is the same tendency

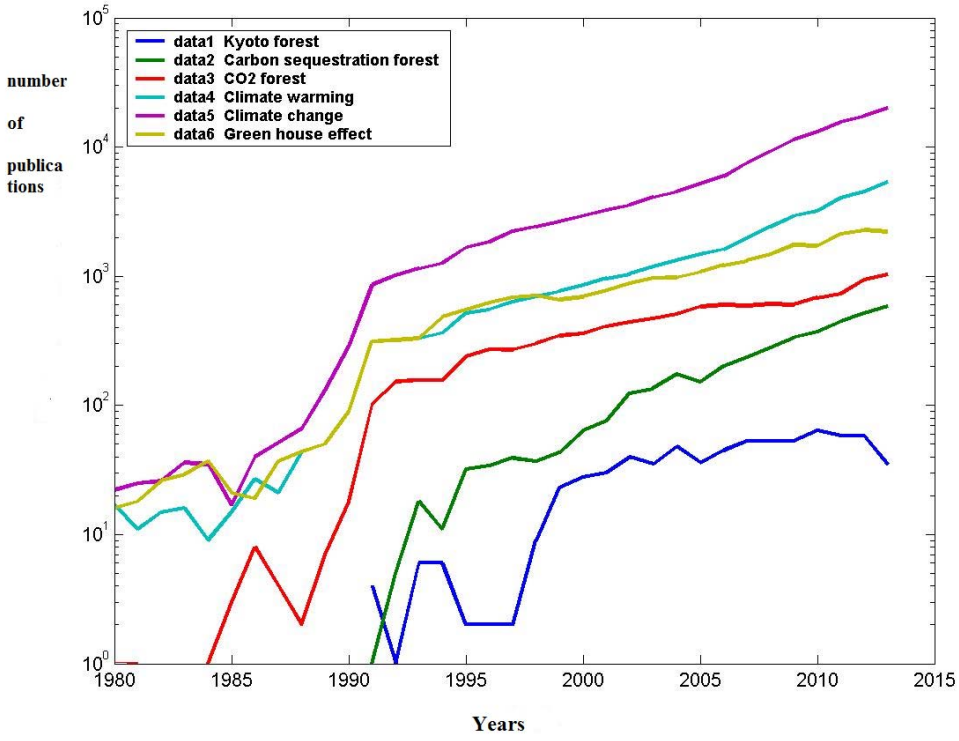

Fig. 1. Publications for the Period of 1980-2013

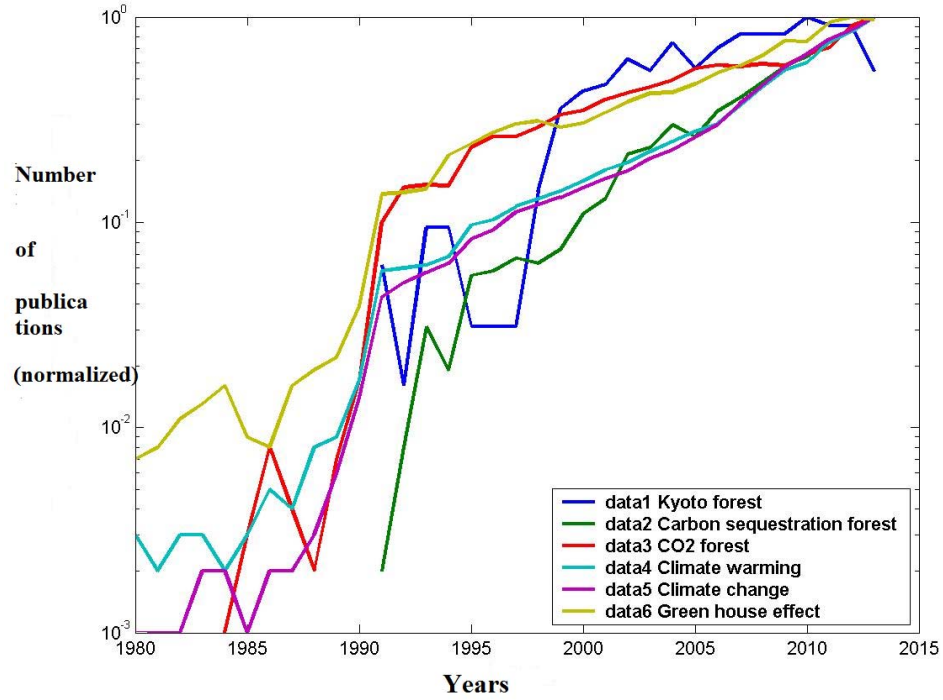

Fig. 2. Publications for the period of 1980-2013 (normalized graph with accumulations).

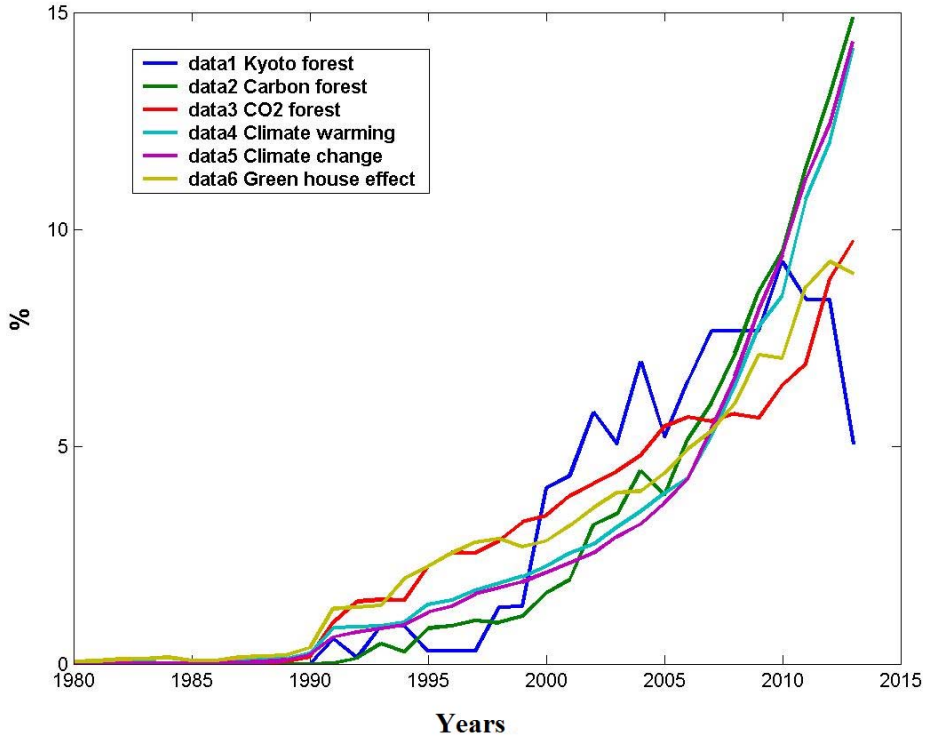

Fig. 3. Publications for the Period of 1980-2013 (graph with accumulations in percentage)

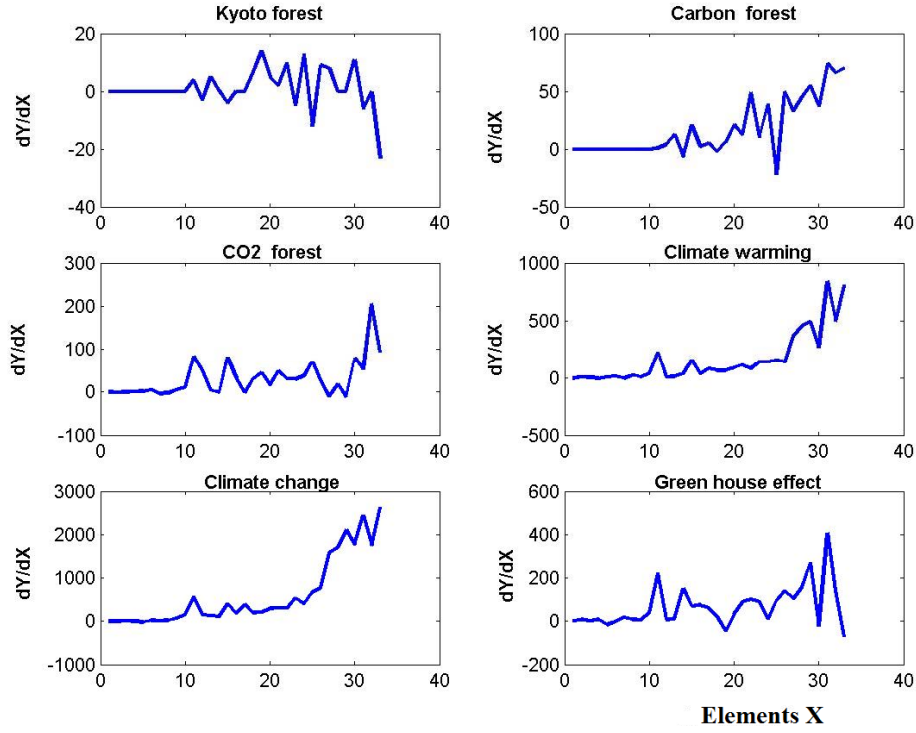

Fig. 4. Dynamics of the Number of Publications

for Greenhouse effect, where a sharp decline (minimum) is observed in 2010.

The following synchronous minimums fall on 2011, they are observed in all the curves except Carbon forest. A brief analysis of dynamics of the publications rate of change shows synchronous change of growth rate in the number of publications due to the external factors influence. Calculation of Pearson correlation coefficient shows a very close correlation of the environmental issues data k_{12} (y_1, y_2) = 0,84, $k_{13}(y_1,y_3)=0{,}89, k_{14}(y_1,y_4)=0{,}82, k_{15}(y_1,y_5)=0{,}82,$ $k_{16}(y_1,y_6)=0{,}89, k_{23}(y_2,y_3)=0{,}99, k_{24}(y_2,y_4)=0{,}99,$ $k_{25}(y_2,y_5)=0{,}99, k_{26}(y_2,y_6)=0{,}99, k_{34}(y_3,y_4)=0{,}94,$ $k_{35}(y_3,y_5)=0{,}93, k_{36}(y_3,y_6)=0{,}98, k_{45}(y_4,y_5)=0{,}99,$ k_{46} (y_4, y_6) = 0,97, k_{56} (y_5, y_6) = 0,96.

It especially concerns the issues of carbon dioxide absorption by forests (CO_2 forest), global warming (Climate warming), the issues of climate change (Climate change) and the greenhouse effect (Greenhouse effect).

"Caterpillar method" will be used for a more in-depth analysis of various environmental issues. Caterpillar method consists in decomposition of the time series into simple components: periodic and oscillatory components, as well as noise components. The resulting decomposition serves as a basis for time series and its individual components forecasting. We decompose our time series into several components. In each "box" the largest value will be chosen, and each value will be numbered. Next, we will take the natural logarithm of each value and its number and make a graph of dependence of the highest value of the natural logarithm on the natural logarithm of the number. We will find slope coefficients of the lines obtained. The slope coefficients of the lines are respectively equal: k_1 = 1,84, k_2 = 3, k_3 = 1,86, k_4 = 1,18, k_5 = 4,48, k_6 = 2,65.

Analysis of the data obtained by the caterpillar SSA method evidences the presence of "grey noise" (Fig. 5), which can be interpreted as the presence of

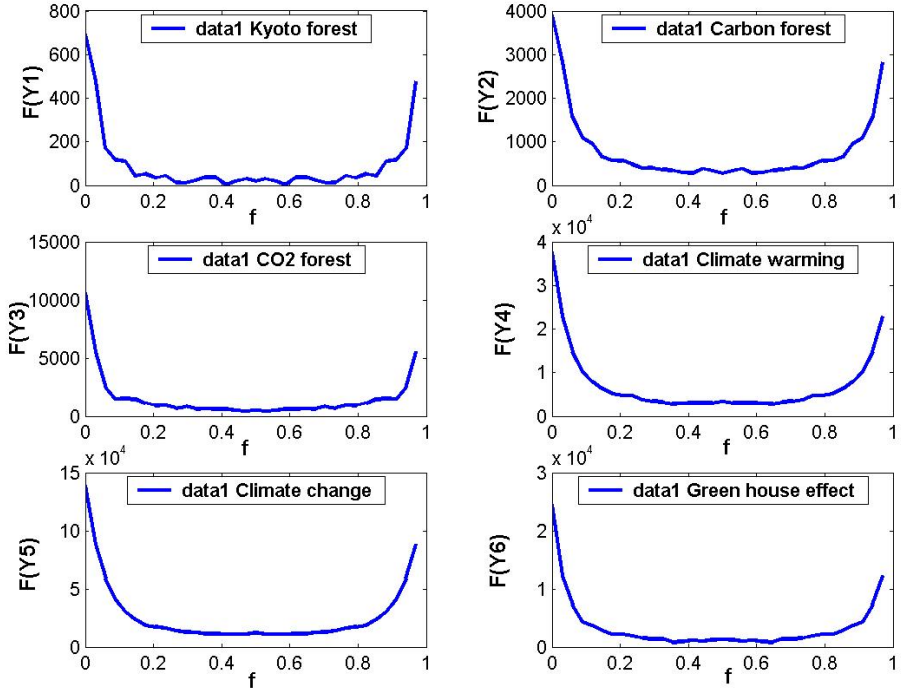

Fig. 5. The Fourier Transform

an initial surge of interest in this topic, after which a "constant rate" of scientific community's attention is established. This fact once again indicates of the decisive effect of external factors.

Resume

Change in the number of publications over time is well approximated by the function: $y = exp(-ax)\frac{Kx_0 exp(rx)}{K + x_0 exp(rx) - x_0}$, which means that initial period of a scientific issue development is characterized by active "extension" of the number of publication, followed by a period of neglect.

Analysis of the dynamics of change in the speed of publication on the selected six environmental issues reflects the important role of an initial external factor, after which influence, a certain "natural frequency" of public interest is established for each issue.

Maximums and minimums of the rate of change in the number of publications for all the curves coincide with important social events such as major conferences on environmental issues of 1992 and 1997, which once again indicates of the crucial role of external factors.

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Наукометрический анализ динамики числа публикаций по экологическим тематикам

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В данной статье проведен наукометрический анализ данных числа публикаций по шести экологическим тематикам. Использовались следующие методы анализа: метод линейной интерполяции, метод ssa, корреляционный анализ.

Методом линейной интерполяции найдено аналитическое выражение для описания изменения числа публикаций со временем. Степень ''зашумленности'' данных проанализирована методом ssa.

Подробно проанализирована скорость изменения числа публикаций на заданном временном интервале. Показано существенное значение внешних факторов на первоначальное число и динамику роста публикаций.

Ключевые слова: киотские леса, динамика публикаций, уравнение Ферхюльста, метод ssa.

Научная специальность: 08.00.00 – экономические науки.