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Information Streams and Plants Productivity

V.K. Mukhomorov and L.M. Anikina

Agrophysical Research Institute, 14 Grazhdanskii pr., St.-Petersburg, 195220, Russia

Abstract: It is experimentally established, that at the long multi-vegetations operation of mineral substratum (granite, zeolite) resulting in their transformation, formation soil bodies and to evolutionary soil formation, productivity of plants on a measure of increase in number of vegetations is reduced. For revealing the reasons of this phenomenon the relationship of cause-and-effect between dynamics of multi-component systems of organic substance formed in an initial abiogenous mineral substance and microbiota association has been investigated. Methods of the information theory are put in a basis of the mathematical simulation describing information streams between multi-component systems. It is established, that easing of a relationship of cause-and-effect between a state of an organic substance and a state of a microbiota association in mineral substrate is the determining factor of change in dynamics of plants productivity in conditions of initial soil formation.

Key words: Information . entropy function . microbiota . organic matter . conditional probability

INTRODUCTION

The purpose of the present paper is transpiring interconnection formed in Root-inhabited Media (RM) of multi-component systems-organic matter and microbiota association with dynamics of plant productivity in conditions of initial soil formation. The carried out complex experimental researches on intensive and long time (during twenty three continuous vegetations) growing plants of a tomato and a spring wheat on initially abiogenous granite rubble have shown, that in a regulated agroecosystem there is an intensive biogenic and physical-chemical erosion inert mineral RMs. For revealing a generality of taking place processes in RM and their influences on ability to live of dynamics plants productivity a tomato also in addition was studied at its cultivation during twelve continuous vegetations on zeolite. The major consequence of it is multiple repeated increase activity of biochemical processes exogenous transformations of rocks to bioinert bodies. These processes are accompanied by accumulation and change of fractional structure of formed organic matter of RM, change of specific and numerical structure of microbiota association. We monitored the dynamics of the changes in the biochemical composition of the formation of organic matter, including cellulose, hemicellulose, alkaline-soluble and alcoholbnenzene fractions and nonhydrolyzed residue, as well as the amount of its water-soluble part in the nutrient solution. Simultaneously is analyzed the dynamics of the species composition and the amount of microorganisms (bacteria consuming mineral nitrogen, bacteria consuming organic nitrogen, spore-forming bacteria, cellulose-fermenting bacteria, fungi and actinomycetes) in RMs. In experiment the processes of transformation initial mineral RMs in like-soil bodies simulate the evolutionary processes proceeding at the initial stages of soil formation in natural conditions.

For convenience of comparison plants productivity is presented in Figures 1a and 1b productivity as the relation of productivity observable in the given vegetation to mean productivity for all time interval of the observation. It allows expressing productivity of a tomato and a spring wheat in commensurable quantities. Vegetation is chosen as the time unit. Figure 1a and 1b that demonstrate the dynamics of productivity has nonlinear behavior depending on time. Decreases of productivity usually explain accumulation in RM organic substance during evolutionary formation of soil. Therefore, for studying influence of organic substance on plants productivity in article results for the control and experiment are used. Variants 1 and 3 served as a control; in variants 2 and 4 are used complex acid-alkalline regeneration of RM in order to free it of excessive organic matter. Variants 1,2 and 3,4 are used for a tomato and a spring wheat, respectively. The regeneration method was developed by Ermakov [1].

Corresponding Author: Dr. V.K. Mukhomorov, Agrophysical Research Institute, 14 Grazhdanskii ave., St.-Petersburg, 195220, Russia

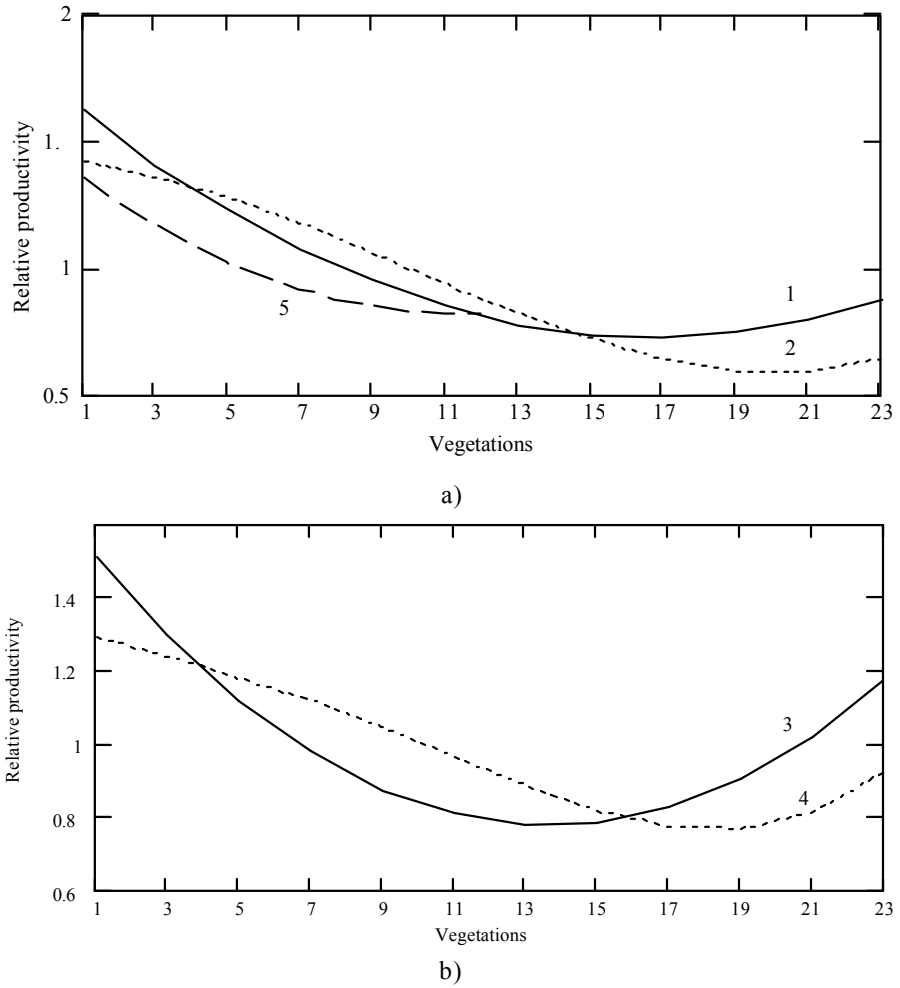

Fig. 1: Dynamics (trend) of relative production of a tomato (a) and a spring wheat (b). Numbers 1-4 indicate the variants of experiment. 5-tomato raised on zeolite

Well-known, when in agroecosystem for a long time prevails a monoculture, intensity of biological and biochemical processes is reduced. There are a sorting of separate groups and kinds of the microorganisms capable negatively have influence upon growth and development of plants. In natural conditions cumulative action of these processes usually result in weariness of soil. Result of this is decrease of plants productivity. In multi-vegetative experiment this circumstance has caused widely adopted a crop rotation in the twentieth and twenty second vegetations of plants. Well-known, that using of a crop rotation is make for increase of a biodiversity in RM and it, finally, influences positively on plants productivity.

METHODS AND MODEL

It is known the function information entropy Shannon-Wiener is a quantitative measure of a variety and structured of the multi-component system containing diverse objects, but belonging to one set. For discrete set of elements the entropy is defined as follows:

$$H(t) = -\sum_{i=1}^{n} p_i(t) \ln p_i(t)$$

under the additional conditions $0 \le p_i \le 1$? and

$$\sum_{i=1}^{n} p_i = 1$$

where n is the number of events-characters of the sequence of states that determine the space of their possible discrete values and p_i is the probability that the *i*th event-character will occur. The values p_i is determined from the data on the average composition of

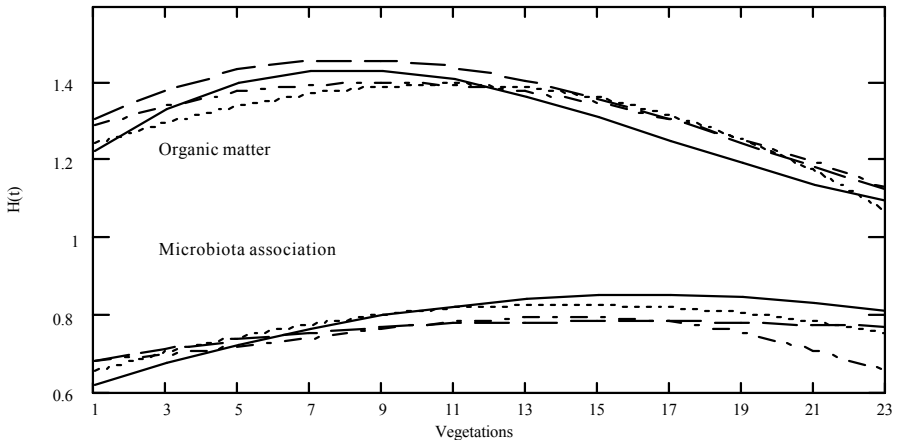

Fig. 2: Dynamics (trend) of the entropy function $H(t)$ for organic matter of RM and microbiota association. ——— variant 1, — — — variant 2,------variant 3, — · — · — variant 4

the biotic complex and the element structures of the organic matter of RMs. The maximum H(t) corresponds to the minimum diversity of the multi-component system. The value H(t) there is less, the structured of multi-component system is higher [2]. Similar the entropy approach is frequently used in ecology [3-5]. The community consisting of individuals of various kinds is described by structure of set with fragmentation where classes of fragmentation correspond, for example, to populations of community and elements of set correspond to organisms. In according to Mac Arthur [3] diversity of many-component systems and its stability are interrelated, thus stability of system can be expressed through its complexity (heterogeneity) that is through information function H(t).

Figure 2 represents the dynamics of the function of information entropy for organic matter and microbiota association of RMs. This figure demonstrates clearly, that the exhaustion of RM is connected with a diversity of formed organic matter and microbiota association in RM is reduced. However, after a crop rotation a diversity of these systems grows, thus the entropy is decreased and the information grows [6]. It is possible contend that verge towards of multi-component system in the position with maximum of entropy has deteriorated functioning of system.

The statistical researches executed in this work specify that comparison with dynamics of entropy functions for organic substance and microbiota association with productivity of plants not expediently though function entropy reflects important for biology of development the phenomenon-dynamics of change of a diversity of multi-component systems. Value of the entropy function for last vegetations is lower (Fig. 1 and 2), than on initial vegetations. However, though there is a tendency to increase of plants productivity, nevertheless it appreciably below of level productivity on initial vegetations and does not comply with a level of increase of a diversity in systems organic substance in RM and microbiota association. Therefore, in this article is lead research on detecting of the quantitative characteristics that are taking into account joint action of these two systems on functioning of plants.

The formed organic substance and the microflora containing set of components are open systems that exchange substance with an environment, energy and the information. In this work are used the methods of the information theory and as dynamic parameters is accepted unconditional and conditional information entropy. In this work is offered the method, allowing obtaining the quantitative characteristics of information streams between interacting multi-component systems. If a random variable $X = \{x_k, p(x_k)\}$ takes on a values x_k with probability $p(x_k)$ then the quantity of the information contained in X is equal

$$H(X) = -\sum_{k} p(x_k) \ln p(x_k)$$

The information communicated from X to system Y can be defined through initial uncertainty of event X as a difference between a unconditional or *a priori* measure of the source information X:

$$H(X;t) = -\sum_{i=1}^{n} p(x_i;t) \ln p(x_i;t)$$

and conditional (*a posteriori*) information entropy

$$H(X|Y;t) = -\sum_{i=1}^{n}\sum_{j=1}^{m} p(x_i, y_j;t) \ln p(x_i|y_j;t)$$

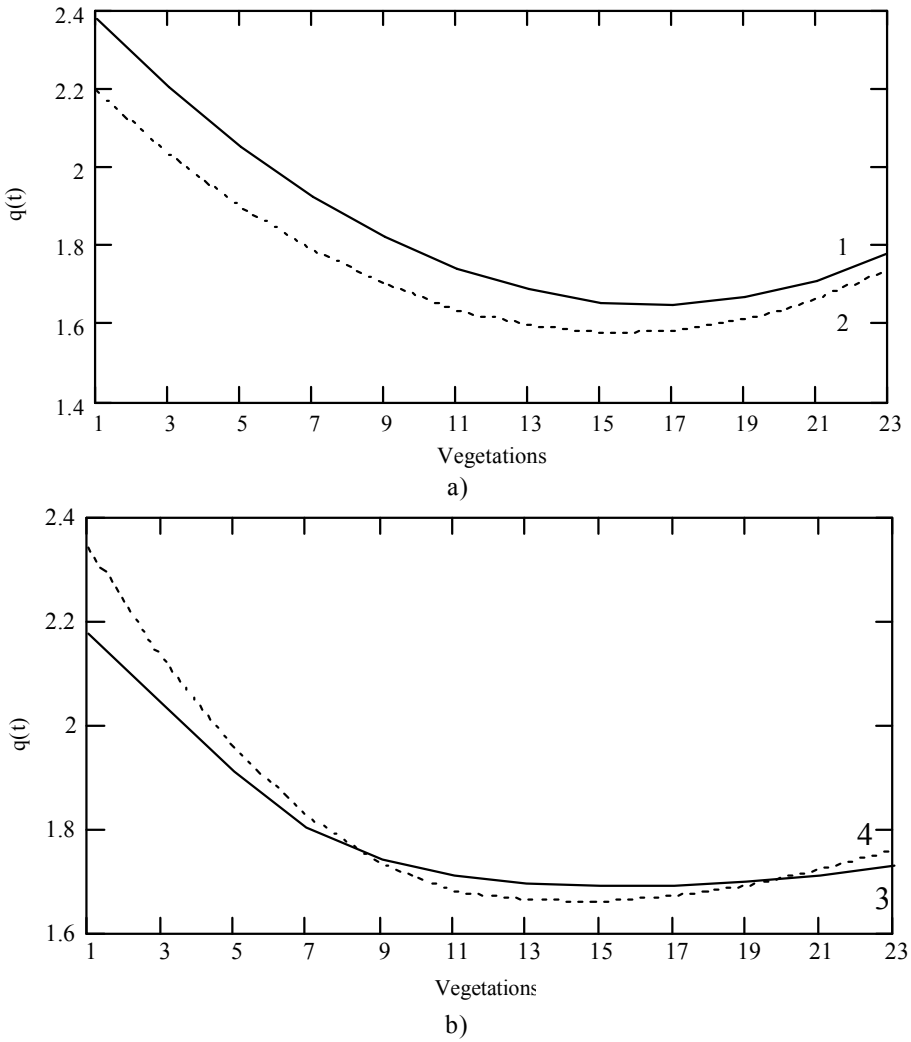

Fig. 3: Dynamics (trend) of information parameter q(t) for a tomato (a) and a spring wheat (b)

Here $p(x_i;t)$ is the probability of occurrence of event x_i in the discrete moment of time t; $p(x_i|y_j;t)$ is the probability of that the source of the information is in a discrete state x_i and system Y is in a discrete condition y_j; $p(x_i|y_j;t)$ is a joint probability of event x_i of the source X and event y_j the receiver Y. Obviously, conditional entropy less or it is equal to unconditional one: $0 \le H(Y|X) \le H(Y)$ also satisfies to the requirement of convertibility of the information: $H(Y) - H(Y|X) = H(X) - H(X|Y)$. The low bound of last inequality corresponds to unambiguous dependence of consequence Y from reason X, in other words the result of event X defines a result of event Y. The high bound of this inequality corresponds to full independence of process Y of process X.

The information transmitted from source X to receiver Y can be determined as the difference: $I(X \to Y;t) = H(X;t) - H(X|Y;t)$. The transmitted information from system Y to system X is similarly defined: $I(Y \to X;t) = H(Y;t) - H(Y|X;t)$. The integral information coming from two opposite directions streams is equal: $q(t) = I(X \to Y;t) - I(Y \to X;t)$. If the integral information from counter streams $q(t) > 0$ the processes resulting in system X are the reason and event Y is a sequent of this reason. The quantitative measure of this connection is defined by value of q(t). The more the value q(t), the stream of the information from X to Y is more and by that the cause-and-effect relation is stronger. Designating through X the state of organic substance of RM and through Y the state of microbiota association, it is possible to define the value of an information stream q(t) between these systems (Fig. 3).

RESULTS

Dynamics q(t) demonstrates, that the relationship of cause-and-effect remains positive for all time of

Table 1: Statistical characteristics of the connection of plants productivity with values of the information parameter q(t)

Student criterion			
Tomato		Spring wheat	
Variant 1	Variant 2	Variant 3	Variant 4
$t = 56.3 >> t^{cr}_{0.95} = 1.8$	$t = 15.3 >> t^{cr}_{0.95} = 1.8$	$t = 10.7 >> t^{cr}_{0.95} = 1.8$	$t = 16.1 >> t^{cr}_{0.95} = 1.8$
$R = 0.99 > R^{cr}_{0.95} = 0.53$	$R = 0.91 > R^{cr}_{0.95} = 0.53$	$R = 0.90 > R^{cr}_{0.95} = 0.53$	$R = 0.91 > R^{cr}_{0.95} = 0.53$

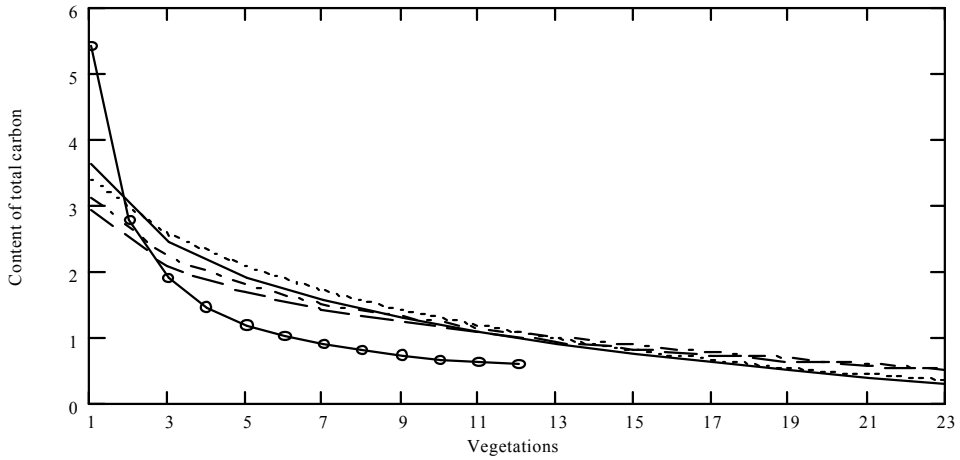

Fig. 4: Dynamics (trend) of inverse value of accumulation formed organic substance in RM. —— variant 1,---- variant 2, — · — variant 3, — — variant 4, —o— tomato raised on zeolite

observation, that is the orientation of the information transfer between these systems does not change during evolutionary soil formation. It is necessary to note, that traditional methods of processing experimental data-regression analysis, variance analysis, spectral and other statistical approaches establish only conformity of investigated processes and without attraction of intuition or knowledge of the researchers do not allow establishing unequivocally a relationship of cause and effect between the phenomena. Presence of correlation between time series testifies only high degree accordance in development of characteristics in time. However, this correlation speaks nothing about cause-and-effect relations in dynamics of characteristics. Well-known, that the highest measure of closeness of connection between levels can be obtained even at absence of relationships of cause-and-effect between the phenomena. For this purpose sufficiently presence of steady tendencies in development of the phenomena, that is possible autocorrelation inside each time series. Processes can be correlated, but at the same time not be causally-connected, as correlation is necessary, but not a sufficient condition of coherence of events. Under causal dependence of two events we mean an opportunity appear of one of characteristics from appearing of other characteristic. Under independence or absence of a causal relationship of two characteristics we have in mind, that presence of one of them does not mean presence of another.

It is established that easing of the cause-and-effect relation caused by an integral information stream between state of a organic substance diversity and a diversity of microbiota association of RM, that is a decisive importance of statistically established factor of the decrease of plant productivity in the initial stages of evolutionary soil formation. In the table are resulted statistical characteristics of connection the plants productivity of a tomato and spring wheat with value of an information stream between systems of formed organic substance and microbiota association of RM. Change in dynamics is resulted of cause-and-effect relations correlated with change of plants productivity (Table 1).

Accumulation of the contents of total organic substance at operation of mineral RM can be the limiting factor for dynamics of plants productivity. However statistical comparison of curves presented on Fig. 1 and 4 does not confirm existence of statistically significant connection between them. Moreover, it is easily to see from these figures the

monotonous reduction of the inverse contents of the total carbon is kept and for last vegetations, for which productivity of plants statistically authentically grows.

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REFERENCES

1. Ermakov, E.I. and V.K. Mukhomorov, 2001. Evolution of diversity measures as a reflection of the process of primary soil formation in a model soil-plant system. Doklady Biochemistry and Biophysics, 379 (6): 297-301.
2. Haken, H., 1991. Information and Self-Organization. A Macroscopic Approach to Complex Systems. Springer-Verlag, Berlin.
3. Mac Arthur, R.H., 1955. Fluctuations of animal populations and a measure of community stability. Ecology, 36: 533-536.
4. Alexeyev, V.L. and A.P. Levich, 1997. A search for maximum species abundances in ecological communities under conditional diversity optimization. Bull. Math. Biology, 59: 649-677.
5. Gaucherel, C., 2006. Influence of spatial patterns of ecological applications of extremal principles. Ecological Modeling, 193: 531-542.
6. Shannon, C. and W. Weaver, 1949. The Mathematical Theory of Communication, Univ. of Illinois Press, Urbana.