NONLINEAR DYNAMICS OF PLANT COMMUNITIES:OCCURRENCE OF SPATIAL HETEROGENEITY (SPOTTINESS)

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Abstract
In this communication we consider a mathematical models imitating and analytical for spatial-temporal dynamics of plant communities. It was shown that increased intensity of competitive for resources (primarily involving light) pressure leads to processes of chaotic self-organization and rise of complexly structured heterogeneous (spotty) spatial distributions.

Key words
Spatial distribution, dynamic self-organizing, dynamic chaos, spatial-temporal dynamics.

1 Introduction

The basic difficulty researches face at the biodiversity description and study consists in its more or less expressed spatial structure and strong heterogeneity. It is most vividly expressed in phytocoenosis forasmuch as most kinds of plants fill their habitats rather non-uniformly, forming congestions and lacunas. It is not always possible to stringently explain this fact by heterogeneity of the environment conditions in corresponding areas. An impressive example of this is clear-cut spottiness of tundra phytocoenosis, though the taiga plant communities also appear to be very spotty and heterogeneous. The mechanisms of this heterogeneity have not yet been described and analyzed by now within the limits of classical biological ways of research. This work offers a comparison of the research results for two mathematical models of the plants community spatial-temporal dynamics explaining the spotty spatial distribution by nonlinearity of the character of dynamics in a community, by dynamic chaos phenomenon and the processes of chaotic self-organizing. The first model refers to the analytical class; it represents the integral-differential equations system. In constructing this model interaction of the plants located close to each other and effecting both the biomass increase (for example, new growth) and its growth restriction caused by struggle for life resources (first of all, for the light) was taken into account. The second approach represents an imitation computer model of the forest arboreal plants community dynamics. Modeling the forest stand dynamics develops of its each tree growth modeling, by means of differential equations and functions, its spatial arrangement and the other trees influence taken into account. The basic equation of the first model is as follows:

$$\dot{u}_i(x,t) = \int\limits_M \alpha_i(x,y)u_i(y,t)dy -$$

$$- u_i^{\gamma_j}(x,t)\sum_j \int\limits_M \beta_{ij}(x,y)u_j^{\rho_j}(y,t)dy$$

where $u_i(x,t)$ is the biomass density of the i-th species in point x in time t, M the physical space, the community habitat range. Parameter γ_i characterizes the sensitivity of suppressed biomass to competitive impact; parameter $\rho_j$reflects the non-linearity of dependence of degree of competitive limitation on the density of the overwhelming biomass. Kernels $\alpha_i(x,y)$ characterize the growth of the biomass of the i-th species from point y to point x. Kernels $\beta_{i,j}(x,y)$ characterize competitive impact of the biomass of the j-th species in point y for the biomass of the j-th species in point x. The kernels $\alpha_i(x,y)$ and $\beta_{i,j}(x,y)$ depend on the distance between points x and y, and may be selected in the form of Gaussian curves. The following principle notes of forest-stand modeling are in the basis of the second model construction: 1. The modeled forest-stand space is subdivided into cells on a horizontal plane and levels on a vertical line. 2 The elementary structural unit of forest community is the

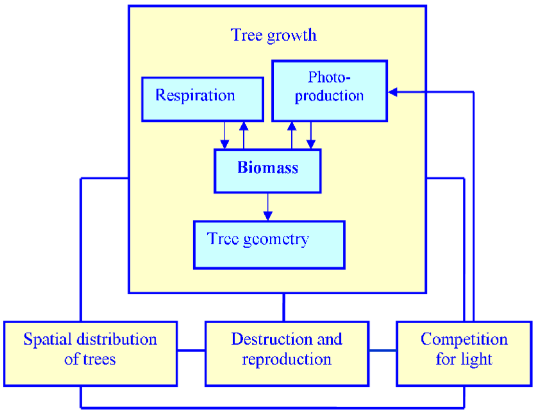

Figure 1. Structural diagram of the model describing growth of trees in a community

tree. 3. Forest-stand modeling develops of modeling separate trees dynamics. 4. In modeling a separate tree dynamics influence from other trees is considered. This set of notions is quite sufficient for getting a continuously varying in time mosaic of the local space heterogeneity. The model includes 4 main blocks (fig. 1): tree growth, competition for light, destruction and reproduction, spatial distribution of trees. All these blocks are interconnected, the arrows showing a direct influence of one block on another one.

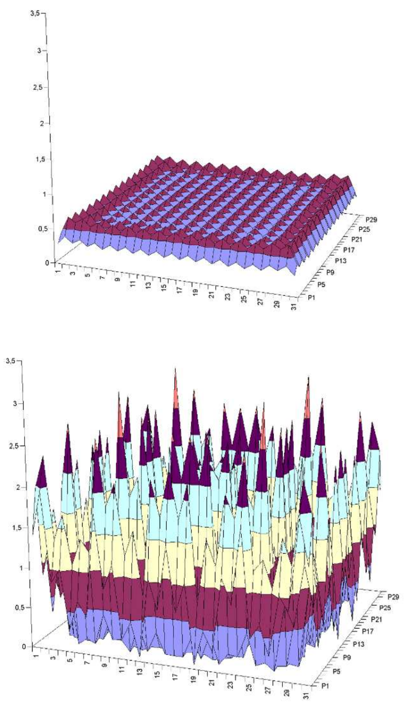

Figure 2. Examples of steady spatially heterogeneous decisions

In the first block of tree growth, the biomass increment and some geometrical parameters are calculated: volume, height, diameter of a trunk, diameter of a crone. The biomass increment is determined by the photosynthesis intensity dependent on the quantity of falling light. The quantity of light falling to a separate tree is calculated in the sub-model of competition for light, and it is determined by the degree of shade by the surrounding forest- stand. The block of destruction and reproduction is responsible for the seed and vegetative reproduction provided by corresponding stochastic processes. The probability of tree destruction as a result of competition for life resources and natural reasons are also calculated.

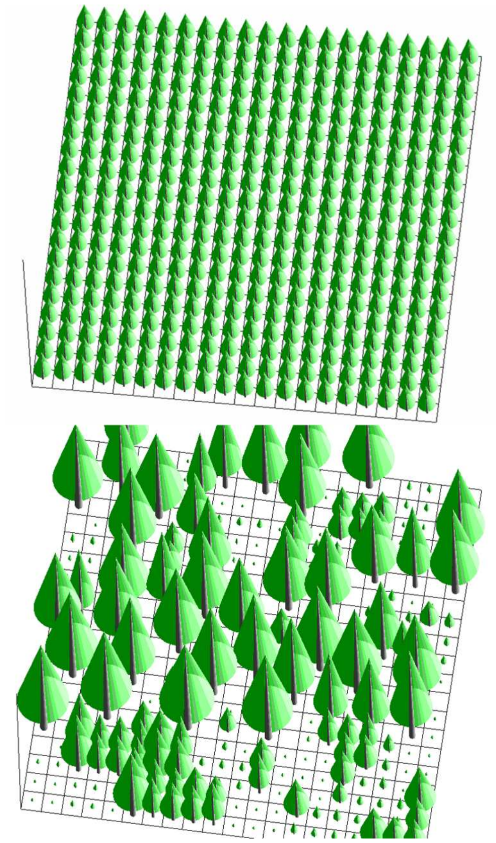

Figure 3. Example of spatially heterogeneous distribution of trees formation, as a result of internal interactions (on the top - the beginning of modeling, on the bottom - the end of modeling)

Every tree in a forest-stand has its spatial co-ordinates. The trees disposal in some modeled territory and, accordingly, calculating the spatial co-ordinates is carried out in the block of spatial distribution of trees. To build the model with the computer, corresponding software has been developed, allowing visualize trees on the coordinate plane and observe the spatial-temporal forest dynamics.

Within the limits of the first model it is shown, that intensive spatial competition for the resources initiates the processes of chaotic self-organization and appearance of aggregately structured heterogeneous (spotty) spatial distributions. The conditions for appearance of spatial plants distribution spottiness have been researched, and the analysis of spatially heterogeneous decisions structure has been made. It is shown, that the account of spatial interactions leads to appearance of spottiness (dissipative structures), both stationary and non-stationary (periodic, around the bifurcation point). The presence of only inter-species non- local competition in the model does not lead to the spottiness formation. It is the intra-species non-local competition in the system that brings about spottiness. In fig. 2 the examples of steady spatially heterogeneous decisions formation are demonstrated, at various parameters of the model.

The analysis of imitation modeling results has shown, that in the process of forest-stand structure formation, even under homogeneous external conditions, there occur processes of chaotic self-organizing leading to formation of aggregately structured heterogeneous (spotty) spatial distributions of vegetative communities. It is possible to explain the emergence of this kind of heterogeneity by only the reasons of internal spatial competition for life resources. In fig. 3 the example of spatially heterogeneous distribution of trees formation, as a result of internal interactions, is shown.

The approaches offered in the work to modeling the spatial-temporal dynamics of vegetative communities, based on two different methods, have established the identical reasons leading to the emergence of spatial plants distribution spottiness.

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