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Original Research Article

Evaluate the initial spatial structure and heterogeneity of the composition for spruce and larch stands on real data self-thinning of even-aged stands

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ABSTRACT

This work presents the results of simulation modelling of self-thinning processes in even-aged spruce and larch stands dependent on the initial spatial structure and heterogeneity of the stand composition. A previously developed individual-based model of forest stand spatiotemporal dynamics was used as the main instrumentation of the study. Estimates of the initial spatial structure and heterogeneity of the composition of spruce and larch stands are obtained from real data of self-thinning even-aged stands. The obtained estimates can be used to customize the model, for example, in modeling forest plantations or developing effective strategies for forest management.

1. Introduction

Self-thinning of even-aged stands is determined by many different factors influencing the trees growth, interaction and death in a complex and oftentimes stochastic way. A large number of works have been devoted to modeling the dynamics of even-aged stands and suggested various models of thinning (Reineke, 1933; Yoda et al., 1963; Karev, 2003; Comeau et al., 2010; Zeide, 2010; Burkhart, 2013; Vospernik and Sterba, 2015; Zhang et al., 2016; Ogawa, 2017). Most of the existing approaches to modeling of self-thinning in even-aged stands consider a homogeneous population of approximately similar trees, which is a significant simplification. In the work by G. P. Karev (Karev, 2003) has been shown that in order to obtain adequate models of forest stands thinning, it is necessary to consider heterogeneity of the plantations composition as one of the fundamental factors determining the dynamics of populations (Karev, 2010). Heterogeneity is manifested in the fact that the trees are not identical, having different probability of death, dependent on individual tree properties. However, the initial spatial arrangement of trees has a significant influence on the process of even-aged stands thinning. In real communities it can be different, as it depends on many factors. There, the total lighting resources are distributed unevenly, which, after all, determines the processes of growth and mortality in the community (Genet et al., 2014). Thus, for an adequate quantitative description of self-thinning process, you must consider both the heterogeneity of population composition, and the initial spatial structure of the stand. For these purposes, individual-based models are suitable, which allow to take into account both factors (for example, Liu and Ashton, 1998; Chave, 1999; Courbaud et al., 2001; Komarov et al., 2003; Busing and Mailly, 2004; Berger et al., 2008; Seidl et al., 2012; Lienard and Strigul, 2016).

This work presents the results of modeling the dynamics of even-aged larch and spruce forest stands, based on the previously developed individual-based model TEMFORM (Kolobov and Frisman, 2016). Parameterization of the model employed forest inventory databases. They contain real data of self-thinning of even-aged larch and spruce forest stands, growing on the Far East of Russia. However, they do not contain data describing the initial growth conditions of the stands, which determine their subsequent dynamics. Therefore, the main task of modeling was to estimate the initial heterogeneity of the composition of stands and the spatial arrangement of trees, which would provide the satisfactory compliance between the model and real data on even-aged stands thinning.

Larch and spruce forests are one of the dominant forest formations in the Far East of Russia in terms of distribution and

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economic importance (Koryakin, 2010). They represent the largest raw material base for lumber factories. Similar studies on forest ecosystems in the Far Eastern region employing simulation tools were not carried out. The evaluation of the initial spatial structure and heterogeneity of the composition of stands promotes a better understanding of the processes of formation and development of specific types of stands. This can be used to customize the model, for example, in modeling forest plantations or developing effective strategies for forest management.

2. Individual-based model of forest dynamics

The Model TEMFORM (TEMperate FORests Model) is created to conduct computational experiments with the forest, characterized by various combinations of species and different age structure, if they grow in the areas with temperate climate, where light is the main factor of the formation and development of forest ecosystems. The model contains several equations and parameters, most of which can be assessed basing on the available standard data of forest taxation. When building the model, special attention is given to the description and study of mechanisms of intraspecific and interspecific competition, which is a determining factor in the formation of definite communities of trees. We take into account a spatial structure of the stand as this is the main factor determining the competition tension. The model is based on the individual-oriented approach when modeling of the forest stand dynamics includes a description of every tree growing, taking into account its specific characteristics and locally available resources. The trees are placed on the site with the given spatial coordinates, mutually influencing each other in their competition for light. The simulated area is divided into cells of 20×20 cm, each cell containing only one tree at a time.

This simulation model is a set of computational algorithms; to implement them on computers we have used the object-oriented programming language Delphi 7.0. Fig. 1 shows a block diagram of the model. The values of model parameters (block 1 in Fig. 1) are selected dependent on the species of trees growing in certain climatic conditions. They are specific coefficients of tree growth and light transmittance equations, a minimum amount of light for germination, coefficients of dieback, age of fruiting, etc. The initial spatial structure of the forest stand (block 2 in Fig. 1) is a combination of various species of trees of different age, located on a coordinate grid. It can either correspond to the actual data on trees distribution, or be specified, dependent on the objectives of the study. The forecast period is unlimited, assuming that climatic and soil conditions do not change over time. At each step of the simulation, which is one year, it is calculated an increase in mass, diameter and size of the trunk, dependent on the degree of shading from neighbouring trees (block 9 in Fig. 1). The tree dieback occurs due to the following factors: competition for light, age limit; the

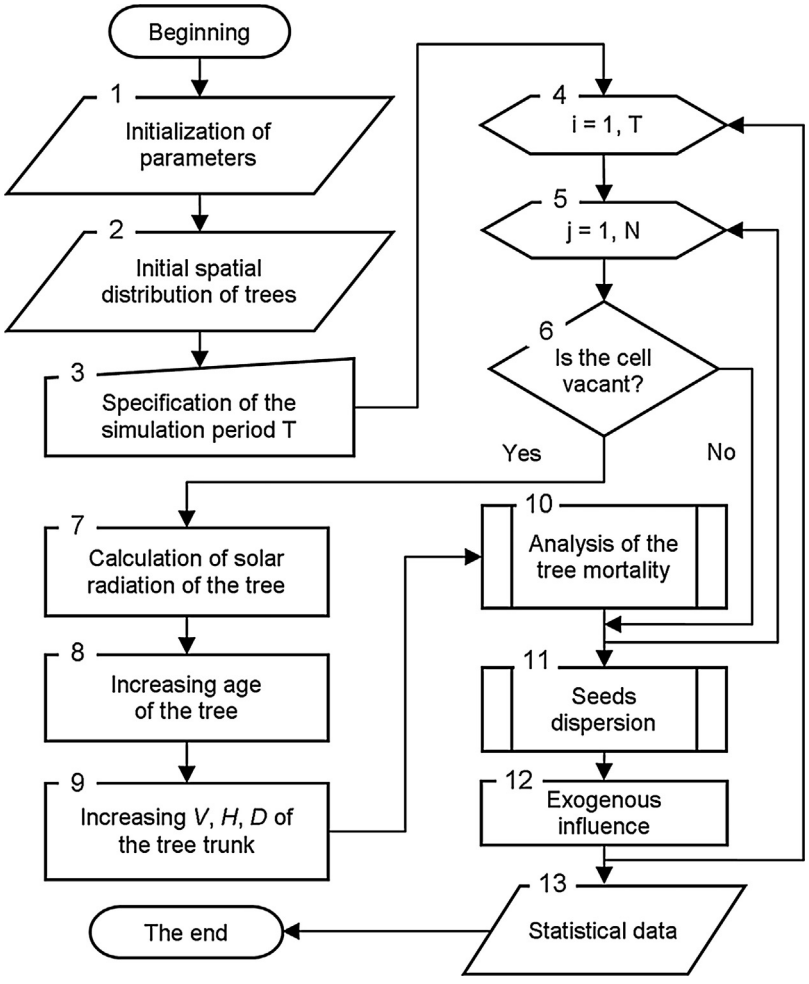

Fig. 1. Model dynamics of forest stands.

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