Markov-chain models of forest successions

Olga Feldman[a,*], Vladimir N. Korotkov[b], Dmitrii O. Logofet [a],

[a] *Laboratory of Mathematical Ecology, Institute of Atmospheric Physics RAS, Pyzhevsky Lane 3, Moscow, 109017, Russia*
[b] *Department of Forestry and Information, All-Russian Research Information Centre for Forest Resources, Novocheremushkinskaya Street 69, Moscow 117418, Russia*

Corresponding author: e-mail address: **thefeldmans@tiscali.co.uk*

Prediction of the future dynamics in natural resources, including forest, and comparison of alternative strategies in the nature management, are widely recognised nowadays to be a matter of modelling. Traditional (i.e., *time-homogeneous*) Markov chain models, have long been known as a means to describe, in formal and quantitative terms, the successional series in vegetation and their final states typical to a given bioclimatic zone or a given edaphotope. Markov models are attractive because they are simple, probabilistic and history-independent. They does not require deep insight into the mechanisms of dynamic change, but it can help to specify areas where such insight would be valuable and therefore act as both a guide and stimulant to further research.

Our research efforts were aimed at further development of nonabsorbing-chain models able to describe management/rehabilitation successions. A class of nonabsorbing-chain models has been constructed and analysed, which enables description of successions under alternative forest management sustaining biodiversity in the forest. With an aggregated model comprising 7 diverse types of forest, a hierarchy of economic values among those types is shown to be compatible with, and achievable by, an ecologically sound strategy of forest management.

Our modelling approach is based on a new method proposed for evaluating the transition probabilities of the model from expert-given data on duration times of successional stages, based on a fundamental result of Markov-chain theory. The method is free of the ergodic hypothesis behind, and bulky statistical routines inherent in, the former approach of landscape ecology. However, the new method required a deeper insight into how long it takes for a particular stage of forest succession to change into the next one. To evaluate this *stage duration time*, a technique has been developed that uses modern views on, and the ensuing classification of, the ontogenetic states in the population of a tree *edificator*[1] species. The method and the technique, while serving the core of the novel methodology of Markov chain modelling, still leave some uncertainties in the model construction, to be eliminated by means of model calibration on pertinent data. Supplied with the calibration techniques, the novel methodology has turned the (new generation of) Markov chain models of forest successions from a good didactic means into a well-grounded tool for ecological predictions.

Management strategies towards plantation of a commercially profitable spruce monoculture and a long-term strategy of forest management, in which a variety of forest types to be planted or naturally developed at the place of felled areas, are studied in this paper. The spruce monoculture strategy yields logically an absorbing chain in which the spruce forest type is the sole absorbing state. The alternative strategy yields, on the contrary, a regular Markov chain with a steady-state distribution (in terms of the relative area for the forest type) in which all the most types are present. It thus illustrates qualitatively the biodiversity paradigm in forest management and can be related quantitatively with geobotanic views of what should be the shares of small-leaved, coniferous, and broad-leaved tree spp. in weakly disturbed coniferous-broadleaf forest.

[1] A dominant species rendering the most influence on community composition

This research investigates mathematical properties of the Markov-chain formalism in the time-heterogeneous case, contrasting them with the homogeneous analogues. A method for restoring the model from empirical evidence is proposed for the heterogeneous cases, and simulation experiments with the model and calculation of risk profiles under hypothetical management scenarios are conducted. Two models of successions are proposed. The first model mirrors the current policy of forest management in "Russkii Les" Experimental Forestry (Moscow Region, Russia). Spruce monocultures represent an absorbing state in this model. An alternative model of forest management suggests rotation of the dominant tree species in the forestry cycle and accounts for the relative economic value of different forest stands. The current area distribution among the forest types has been calculated by means of a GIS-technology.

Keywords: Forest management; Succession; Markov-chain models; Estimation; Prediction