DOI 10.18699/SBB-2022-145

Study, storage and visualization of data on the ontogenesis of dwarf shrubs and herbaceous plants (CAMPUS program)

Zubkova E.V.*, Frolov P.V.
Institute of Physicochemical and Biological Problems in Soil Science, Pushchino Center for Biological Research, RAS, Pushchino, Russia
** elenazubkova2011@yandex.ru*

Key words: forest, plant growth, plants of ground cover, simulation modeling

Motivation and Aim: Geobotanists have described more than 2000 plant ontogenies (the period of development from zygote to death). The concept of discrete description of individual plant development was formulated in the middle of the twentieth century [1, 2]. Studies have also been conducted on the modularity of plant structure [3, 6]. The combination of these two approaches with the modeling of cellular automata has become the basis of a mathematical model that allows you to visualize the development and predict the timing of the occupation of the territory by plant cenopopulations and predict interactions between different plants.
Methods and Algorithms: The CAMPUS model (Cellular Automata Model of Plants' United Spread) is an individual-based and spatially-explicit discrete simulation model [4, 5]. Since the model is intended to be able to treat a dynamics of population of as clonal plants as well as seeds plants we use a term "plant unit" (PU) for either a partial formation (i.e. a shoot together with rhizome) or for an individual plants (Figure). To be realistic enough for many species of forest ground vegetation the spatial resolution of CAMPUS model should be no less than 1×1 cm. In our program it is limited only by computer capacity. The time step of the model is 1 calendar month which is appropriate to represent all growth phases of plants. The features of the model are as follows: plant ontogenesis is encoded by 10 ontogenetic states; plants of different stages and different life forms may have different schemes of morphological structures, both aboveground and underground (rhizomes, roots); morphological structures may vary in size and shape, probabilities of dying off or rejuvenate during ontogenesis.

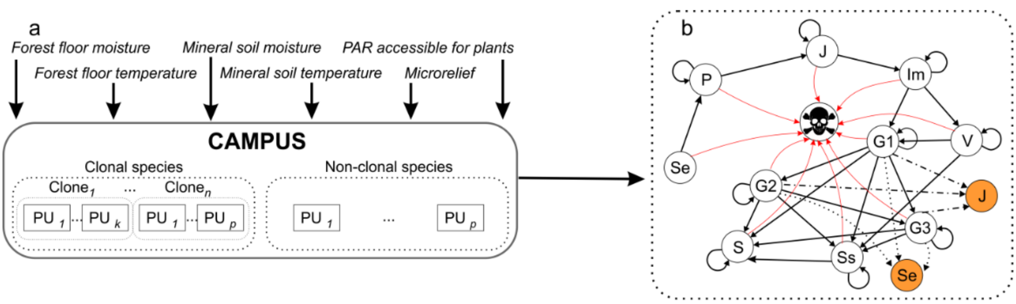

Fig. 1. CAMPUS model organization diagram (*a*) and the flowchart of the CAMUS-S model individual step (*b*). Se, P, J, Im, V, G1, G2, G3, Ss, and S are PU development stages which in the model are based on ontogeny theory. Solid lines show possible transitions between ontogenetic stages, dotted lines show seed reproduction, dotted-dashed lines show vegetative reproduction

Results: The parameterization of the model has been carried out for eight perennial species that dominate coniferous and coniferous-deciduous forests. The species belong to different life-form: deciduous dwarf shrub *Vaccinium myrtillus* L., evergreen dwarf shrub *Vaccinium vitis-idaea* L., Wintergreen rhizomatous rhizomatous summer green plant *Convallaria majalis* L.; rhizomatous winter green plants: *Aegopodium podagraria* L., *Carex pilosa* Scop., *Oxalis acetosella* L.; rhizomatous fern *Pteridium aquilinum* (L.) Kuhn ex Decken; bunch grass *Calamagrostis arundinacea* (L.) Roth. Data about primroses: *Anemone ranunculoides* L., *Corydalis solida* (L.) Clairv. and other plants were collected.
Conclusion: The CAMPUS-S computer program allows to represent detailed information about the morphology of plants (height of shoots, diameter of the aboveground part, length of rhizomes, number and frequency of their branching), time indicators of ontogenetic development (duration of stages), flexibility of growth patterns. Such data make it possible to model the spatial development of plants and predict competition for the space of cenopopulations of different species.
Acknowledgements: This study was carried out within the state assignment of Ministry of Science and Higher Education of the Russian Federation (theme No. 122040.500037-6). The research on determination of heterogeneity of soil conditions was supported by RSF (project No. 18-14-00362-P).

References

1. Rabotnov T.A. The life cycle of perennial herbaceous plants in meadow cenosis. In: Tr. Bin. USSR Academy of Sciences, Geobotany. M.-L., 1950;3(6):3-204. (In Russian)
2. Uranov A.A. Age spectrum of phytocenopopulation as a function of time and energy wave processes. *Biol Sci.* 1975;2:7-34. (In Russian)
3. Zaugolnova L.B., Zhukova L.A., Komarov A.S., Smirnova O.V. Cenopopulations of plants: article of population biology. M.: Nauka, 1988. (In Russian)
4. Frolov P.V., Shanin V.N., Zubkova E.V., Bykhovets S.S., Grabarnik P.Ya. CAMPUS-S – The model of ground layer vegetation populations in forest ecosystems and their contribution to the dynamics of carbon and nitrogen. I. Problem formulation and description of the model. *Ecoll Modell*. 2020;431:109184. doi: 10.1016/j.ecolmodel.2020.109184.
5. Frolov P.V., Zubkova E.V., Shanin V.N., Bykhovets S.S., Mäkipää R., Salemaa M. CAMPUS-S – The model of ground layer vegetation populations in forest ecosystems and their contribution to the dynamics of carbon and nitrogen. II. Parameterization, validation and simulation experiments. *Ecoll Modell*. 2020;431:109183. doi: 10.1016/j.ecolmodel.2020.109183.
6. Harper J.L. Population biology by plants. Acad. Press., 1977.